SUSTAINABLE GROUNDWATER MONITORING SYSTEM OF EAST-VIRU COUNTY, ESTONIA

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Inventory of the existing monitoring system in Ida-Viru county

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1. Current monitoring strategy

The first groundwater monitoring programme was established in 1959. The main objective of groundwater monitoring is to produce reliable and comprehensive information on groundwater resources and their quality. This information can be used as a basis for decisions on environmental issues with the following additional goals:

1) estimation of temporal and spatial fluxes in the quantity and quality of groundwater under various hydrogeological and climatic conditions;

2) estimation of the effect of human activities on the quantity and quality of groundwater;

3) long-time estimation and predictions of the changes in groundwater to obtain information necessary for decision-making on national level and for international co-operation.

According to set objectives and hydrogeological conditions, groundwater monitoring is divided into state (national), local and enterprise monitoring.

In Ida-Viru county exists 2 state-financed monitoring sub-programmes belonging to "The national monitoring programme of the groundwater in Estonia":

- Monitoring of the groundwater basic network;
- Monitoring of groundwater organic compounds in the industrial region of North-East Estonia.

The objective of enterprise groundwater monitoring is to observe changes in the state of groundwater caused by the operation of some production enterprise. The last monitoring is launched as a response to the application of the local environmental departments or at the request of the particular enterprise. There are in addition some groundwater monitoring programmes implemented pursuant to the terms and conditions of the permits for the special use of water to the issuer of the permit.

2. Monitoring of the groundwater basic network

2.1. Characterization of monitoring network

The most important part of the monitoring programme – the monitoring of the groundwater basic network is implemented by the Geological Survey of Estonia. The basic monitoring network consists today of 100 wells, which include both manholes constructed specially for monitoring and operating water-abstraction wells (Figure 1; Table 1). Usually the monitoring wells have measurement screens at several depths and in different aquifers. The main monitoring procedures are water level measurements and water quality sampling. Water level of shallow groundwater is measured 1–5 times per month, the level of deep confined aquifers is measured once per month.

Water sampling for analysis of basic chemical composition is performed in 34 wells once per year. List of monitoring wells by Regulation of Minister of the Environment No 50 at 30 July 2002 is presented in table 1.

Table 1. List of monitoring wells of the basic monitoring network

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year	Parish, town	Chemical composition	Groundwater level (frequency measurements)
3269	7305	7305	O	24	1971	Jõhvi	-	2002*
3270	7304	7304	Q	8	1971	Jõhvi	-	2002
13704	3187	3187	O	20,6	1951	Jõhvi	-	2002
5070	0750g	115	Q	11	1989	Illuka	2006*	1
5069	0751g	116	O	32	1989	Illuka	2006	1
5166	0775g	131	O-C	101,4	1987	Illuka	-	1
13733	132	132	Q	28,5	1987	Illuka	-	1
3281	7319	7319	O	76,2	1971	Illuka	2003	1
3282	7318	7318	Q	39,7	1971	Illuka	-	1
5077	0767g	127	Q	35,5	1987	Illuka	-	1
5078	0770g	128	Q	58,5	1988	Illuka	-	2005
3278	7312	7312	Q	16,8	1971	Illuka	1995	1
3277	7313	7313	O	39,9	1971	Illuka	-	1
3279	7314	7314	Q	13,4	1971	Illuka	1997	1
3280	7315	7315	O	38,9	1971	Illuka	1996	1
3398	8118	8118	O	28	1974	Illuka	-	5
3396	8123	8123	O	61,7	1974	Illuka	-	5
3873	218	218	Q	20	1977	Illuka	+	5
3875	220	220	O	36	1977	Illuka	+	5
3263	4870/1	160	Q	17	1980	Illuka	+	1
3264	4870/2	162	Q	15,5	1980	Illuka	2006	1
3266	4870/4	164	Q	16	1980	Illuka	2006	1
3289	6887	6887	O	72,5	1967	Illuka	-	5
13701	6895	6895	O	44,2	1967	Illuka	-	5
19016	519	246	O-C	50	1986	Lüganuse	+	5
3647	267-a	267-A	Q	6	1980	Lüganuse	2004	5
3648	267	267	O	23	1980	Lüganuse	+	5
3643	269	269	O	19	1980	Lüganuse	1991	5
3644	269-a	269-A	Q	4,5	1980	Lüganuse	-	5
3645	268-a	268-A	Q	4,4	1980	Lüganuse	-	
3646	268	268	O	15	1980	Lüganuse	-	5
4016	35	335	O	19,3	1975	Iisaku	+	1
4017	34	335-A	O	56,7	1975	Iisaku	+	1
4018	885-A	885-A	C-V	216,3	1982	Iisaku	-	1
4019	885-B	885-B	O-C	125,4	1982	Iisaku	+	1
4009	5119	5119	O	38	1972	Sonda	-	1
4010	5120	5120	O	68,6	1972	Sonda	-	1
2438	1-g	881	C-V	260	1964	Jõhvi	-	episoodil.
3439	330	330	O	17,2	1963	Vaivara	-	2004
19571	8112	8112	Q	48,8	1974	Illuka	-	1
3536	6875	6875	D2nr	37	1968	Illuka	+	1
3537	6876	6876	O	57,6	1968	Illuka	+	1
3538	6877	6877	O	86,9	1968	Illuka	1996	1
3980	5745	5745	O	94,5	1982	Illuka	+	1
3981	5742	5742	O	43,8	1982	Illuka	2006	1
3985	5738	5738	Q	8,3	1982	Illuka	2004	1
3979	5748	5748	O	128	1982	Illuka	-	1
3988	5707	5707	O	77,4	1982	Illuka	2006	1
4014	5705	5705	O	25,2	1982	Illuka	2006	1
2088	4562(10A)	912	C-V	120	1978	Narva-Jõesuu town	+	1

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year	Parish, town	Chemical composition	Groundwater level (frequency measurements)
3974	8417	8417	O	38,5	1977	Iisaku	2006	1
3368	101	101	Q	8	1959	Illuka	-	2000
3372	110-g	110	Q	11	1959	Illuka	-	5
5067	0753g	117	O	55	1989	Illuka	-	1995
3876	211	211	Q	4	1960	Illuka	-	5
3870	215	215	Q	23	1977	Illuka	-	5
3872	217	217	O	45,4	1977	Illuka	-	5
3385	8074	8074	Q	20,3	1974	Illuka	-	5
2360	A-558-M	860	O-C	95	1960	Illuka	-	1994
3861	8653g	8653	Q	18,5	1982	Illuka	-	5
3862	8658g	8658	O	37,8	1982	Illuka	-	5
3367	98	98	Q	7,23	1959	Illuka	-	5
3960	241	241	O	52,6	1975	Mäetaguse	1997	1998
3963	244	244	O	38	1975	Illuka	-	3
3649	272-a	272-A	Q	4,5	1980	Lohusuu	1994	1
3650	272	272	O	24	1980	Lohusuu	1994	1
3651	271	271	O	22	1980	Lohusuu	1999	1
3652	271-a	271-A	Q	4,5	1980	Lohusuu	1996	1
3653	270	270	O	21,2	1980	Lohusuu	1994	-
3973	270-a	270-A	Q	3,5		Lohusuu	1994	1
19026	273	273	O	19,5	1980	Lohusuu	-	1
19027	273-A	273-A	Q	4,4	1980	Lohusuu	-	1
3448	311	311	C-V	378,6	1963	Vaivara	-	2004
19403	311-A	311-A	C-V	169,45	1963	Vaivara	-	2004
3966	346	346	O	57,4	1975	Illuka	-	1
3005	5500	5500	O	18,5	1971	Mäetaguse	-	2003
4003	5502	5502	O	15	1971	Mäetaguse	1997	2003
4004	5503	5503	O	64,3	1971	Mäetaguse	-	2003
4005	5504	5504	O	18,9	1971	Mäetaguse	-	2003
4015	5508	5508	O	15,8	1971	Mäetaguse	1997	3
4012	5511	5511	O	18,8	1971	Illuka	-	1
3008	5510	5510	O	71,6	1971	Illuka	-	1
2585	6091	6091	O	104	1965	Mäetaguse	-	2003
2586	6091-A	6091-A	O	71,7		Mäetaguse	-	2003
2587	6091-B	6091-B	O	25,2	1966	Mäetaguse	-	2003
3951	247	247	Q	10,3	1980	Vaivara	-	1999
3952	249	249	O	31	1980	Vaivara	-	1999
3953	250	250	O-C	67,5	1980	Vaivara	-	1999
3955	253	253	O	34,6	1980	Vaivara	-	1999
3957	255	255	O	38	1980	Vaivara	-	1999
3477	6218	6218	O	78,7	1965	Illuka	-	2001
3478	6218-B	6218-B	O	28,7	1965	Illuka	-	2001
3479	6218-A	6218-A	O	112	1965	Illuka	-	2001
3525	6798	6798	O	62,9	1968	Illuka	-	1
3487	6864	6864	O	65,5	1969	Illuka	-	1992
3488	6917	6917	O	94,8	1969	Illuka	-	1992
3287	3287	6863	Q	22,2	1969	Illuka	-	1992
3458	73-G	73	O	29,85	1958	Vaivara	2004	2004
3992	75	75	O	31,4	1958	Vaivara	-	2004
4021	7501	7501	O	37,6	1971	Maidla	-	1
4022	7502	7502	O	109,9	1971	Maidla	-	1
4023	7503	7503	O	78,4	1971	Maidla	-	1
3400	8115	8115	Q	16,3	1974	Illuka	-	5
3401	8134	8134	Q	67,8	1974	Jõhvi	-	2002
3402	8032	8032	O-C	63,5	1975	Jõhvi	-	2002
3403	8138	8138	C-V	154,2	1974	Jõhvi	-	2002
3404	8139	8139	Q	33	1975	Jõhvi	-	2002

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year	Parish, town	Chemical composition	Groundwater level (frequency measurements)
2581	7878	7878	O	40	1970	Maidla	-	3
2582	7876	7876	O	75	1970	Maidla	-	3
2583	7877	7877	Q	23,7	1970	Maidla	-	3
2593	948	948	O	55	1966	Maidla	1997	3
2594	947	947	O	8,4	1966	Maidla	1997	3
2595	949	949	O	91,8	1966	Maidla	1997	3
2262	31	864	C-V	180	1957	Jõhvi town	1979	1
2400	A-3-B	906	C-V	160,5	1956	Lüganuse	2002	2002
2464	A-175-M	897	C-V	201	1956	Toila	+	-
2470	A-8389	879	C-V	180	1955	Vaivara	1997	1999
2632	A-275-M	865	C-V	270	1957	Kohtla-Järve town	2002	-
2182	4702	907	C-V	260	1979	Kohtla-Järve town	-	1
3971	8423	8423	O	117	1977	Iisaku	2006	1
3972	8420	8420	O	89,1	1977	Iisaku	+	1
12301	8415	8415	O	101,4	1977	Mäetaguse	-	2003
3196	959	959	O	18	1964	Iisaku	-	1
3197	960	960	O	64	1964	Iisaku	-	1
3198	961	961	O	100,38		Iisaku	-	1
2207	4051	922	C-V	220	1975	Sillamäe town	-	1
3579	258	258	O-C	71,5	1987	Sõmeru	2007	episoodil.
3580	259	259	O	53	1987	Sõmeru	2000	2003
3581	266	266	O	38	1980	Sõmeru	-	-
3582	266-A	266-A	Q	3,6		Sõmeru	-	-
3583	265	265	O	24	1980	Sõmeru	-	-
3584	265-A	265-A	Q	3,5	1980	Sõmeru	-	-
3585	263	263	O	15	1980	Sõmeru	-	-
13702	8637	8637	C-V	116	1982	Toila	-	-
2473	8395	934	C-V	140	1955	Toila	-	-
2198	7619	580-A	C-V	150	1953	Sillamäe town	+	1
2478	362	362	C-V	160	1960	Toila	+	-
19028	23	23	O	3,4	1946	Aseri	+	5
3964	245	245	O	18,2	1975	Illuka	-	1
2477	1486	940-B	C-V	240	1963	Toila	-	1995
2179	1035	358-A	C-V	165	1958	Toila	2006	-
3265	4870/3	163	Q	15	1980	Illuka	-	1
9026	6644	9026	C-V	270,5	1993	Ahtme	+	-
2387		2387	C-V	197	1973	Aseri	+	-
2657		2657	C-V	290	1972	Mäetaguse	+	-
2119		2119	C-V	135	1980	Narva town	+	-
3435		3435	C-V	191,5	1963/2004	Vaivara	+	episoodil.
13494		13494	O-C	66	1996	Vaivara	+	episoodil.
5436		5436	O	100	1962	Avinurme	+	episoodil.
3969		8414	O	102	1977	Illuka	-	1
3662		5028	O	49,7	1984	Jõhvi	+	episoodil.
19498		8214-A	O	28	1974	Kohtla	+	episoodil.
19560		19560	O	38	1991	Kohtla	+	episoodil.
19532		19532	O	26,5	2000	Narva	+	episoodil.
19606		19606	O	40,1	2002	Sonda	+	episoodil.
19499		19499	O	50	2000	Vaivara	+	episoodil.
19522		19522	O	37,5	1989	Vaivara	+	episoodil.
3245		3245	Q	61	1987	Illuka	+	

* - end of monitoring

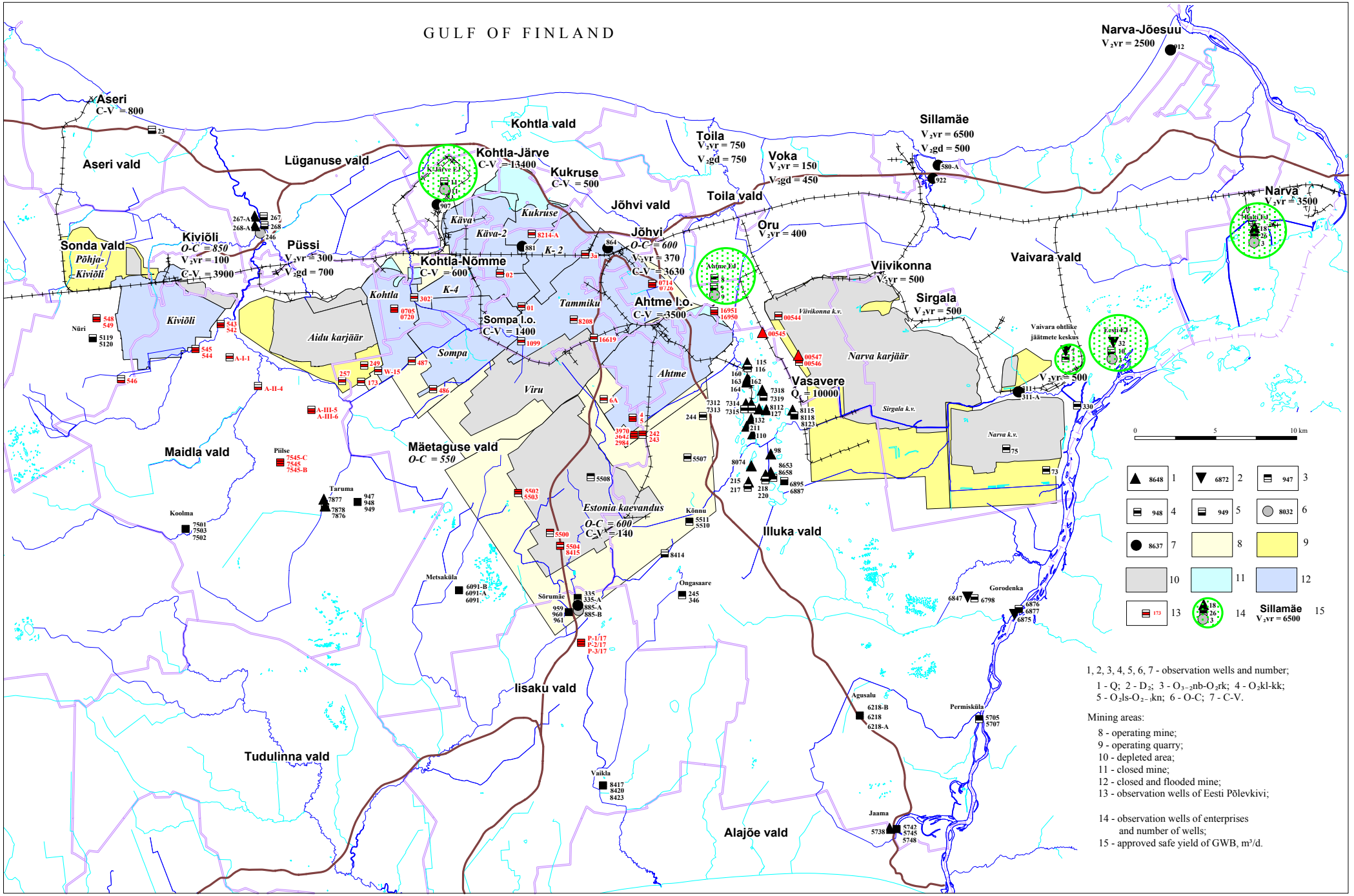

Figure 1. Location of monitoring wells of Ida-Viru county.

The monitoring stations are established on regions with different geological and hydrogeological conditions and different amount of groundwater consumption and discharge of groundwater because of mining activities.

Groundwater level monitoring is a part of national monitoring to evaluate the response of the groundwater bodies to abstraction. Over 20 thousand m^3/d of groundwater is abstracted at present time in Ida-Viru county for domestic use. From this amount an average 75% is extracted from the deep confined Cambrian–Vendian groundwater bodies. The most serious consequences of the intensive groundwater use include the formation of regional depressions of potentiometric level which has caused changes in the direction and velocity of filtration flows in the Cambrian–Vendian groundwater bodies. As the groundwater bodies crops out in the Baltic Sea, not very far from the shoreline, the drawdown contours show that there exists the risk of recent seawater intrusion. The most important result of decreasing groundwater abstraction is that potentiometric levels are rising and the quantitative and chemical status of Cambrian–Vendian groundwater bodies is improved and the risk of seawater intrusion is decreased. For evaluation of groundwater resources and groundwater–seawater interactions, the groundwater modelling is needed.

The groundwater observation stations are divided by the aims into monitoring areas (Figure 2).

1. Area, within which groundwater flows and water intakes influence across Estonian–Russian border.

2. Areas of potential seawater intrusion into Cambrian-Vendian aquifer system.

3. Area of mining affecting the natural groundwater regime.

    3.1. Influence of quarries dewatering to status of groundwater.

    3.2. Influence of mines dewatering to status of groundwater.

    3.3. Influence of exhausted and flooded mines to status of groundwater.

4. Influence of groundwater consumption of Vasavere water intake and drainage of mines and quarries to groundwater and to Kurtna lakes.

2.1.1. Area, within which groundwater flows and water intakes influence across Estonian–Russian border.

As the groundwater has transboundary character of flow, groundwater vulnerability and protection are the issues of serious concern at the Narva River watershed, which is the border area between Estonia and Russia. Any human activity, which may threat the groundwater quality, on the one side can do the same on the other one as well.

There are three main activities able to threaten the quality and quantity of groundwater and what need the groundwater monitoring:

1. Quarries and mines dewatering to status of groundwater influence across Estonian-Russian border.

2. Intensive groundwater consumption from Cambrian-Vendian groundwater bodies in Sillamäe, Narva-Jõesuu and Narva.

3. The sources of groundwater industrial contamination (Baltic and Estonian Power Plants).

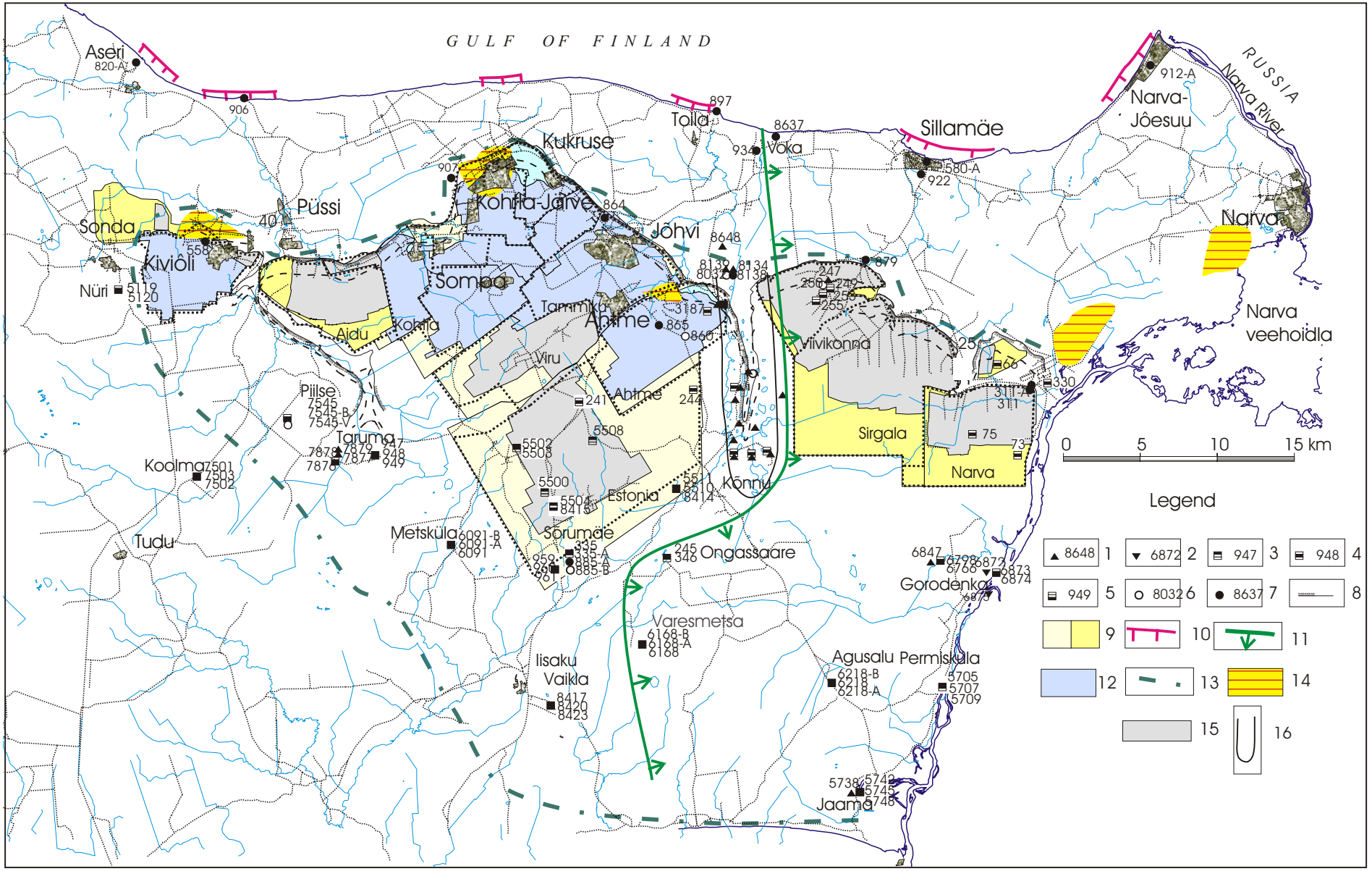

Figure 2. Location map of monitoring areas.

1,2,3,4,5,6,7 - observation well and number (1 - Q; 2 - D_2; 3 - O_{3-2}nb-O_2rk; 4 - O_2kl-kk; 5 - O_2ls-O_2-1kn; 6 - O-Ca; 7 - Ca-V); 8 - the northern border of oil-shale distribution area; 9 - border of mines and quarries; 10 - areas of potential seawater intrusion; 11- area, within which groundwater flows and water intakes influence across Estonian -Russian border; 12 - area of closed mines; 13 - area of mining affecting the natural groundwater regime; 14 - sources of groundwater industrial contamination; 15 - exhausted area; 16 - influence of groundwater consumption of Vasavere water intake and drainage of mines and quarries to groundwater and to Kurtna lakes.

2.1.2. Areas of potential seawater intrusion

The Cambrian-Vendian aquifer system consists of Voronka and Gdov groundwater bodies. The aquifer system is the most important source of public water supply in North-Estonia and Ida-Viru county. Because of intensive water consumption extensive depressions of potentiometric level has been formed and there is potential danger of seawater intrusion.

2.1.3. Area of mining affecting the natural groundwater regime

Serious environmental problems are connected with the excavation of oil shale, which is accompanied by dewatering of aquifers and degradation of the groundwater quality. In case of open cast mining the depth of the depressions reaches 20 m with an impact radius measured from the mines up to 2 km.

2.1.4. Influence of groundwater consumption of Vasavere water intake and drainage of mines and quarries to groundwater and to Kurtna lakes

Approved groundwater safe yield of Vasavere groundwater body is 8000 m^3/d. Groundwater level depends largely on weather conditions which can cause the amplitude of fluctuation of groundwater level up to 1 m. Groundwater consumption of Vasavere water intake is also influenced by oil shale mining. Therefore, the future of Vasavere water intake depends on oil shale mining and its influence on the groundwater safe yield and to water levels of Kurtna lakes.

The list of groundwater observation stations and frequency of optimal and minimal observations is added in appendix. Zone of groundwater monitoring areas is described on figure.

2.2. Tasks of groundwater policy

The main tasks of groundwater policy are summarized in Water Act approved on May 11, 1994. The objectives for assessment of quantitative and chemical status of Estonian groundwater bodies in accordance with WFD are listed in the Regulation of the Minister of the Environment No 47 of 10 May 2004 “Water classes of groundwater bodies, values of the quantity indicators complying with the water classes of groundwater bodies and the procedure for defining water classes”. The criteria established by this Regulation were used upon the assessment of the threat to groundwater bodies due to pressures.

In the oil shale basin area and in the immediate vicinity of the sources of pollution have been observed hazardous substances. The content of hazardous substances should not exceed the maximum limits established by the Regulation of the Minister of the Environment “Maximum Limits for Dangerous Substances in Soil and Groundwater”.

By Regulation of the Minister of Social Affairs “Quality and inspection requirements to the surface and groundwater used or intended to be used for the production of drinking water” there is an additional surveillance requirement of a drinking water source upon the use of groundwater for the production of drinking water (>10 m^3/d).

The data collected by the national groundwater monitoring as well as the data collected by the water intakes are stored in the Estonian Environment Information Centre. The data of national monitoring is for free. The annual reports provide information on main results. Everybody can download the report from web-site. The data is used by all parties involved in water management. Some data are accessible via INTERNET (database EIONET WATER).

2.3. Monitoring of pressures in relation to WFD

All the pressures which alone or together may change the groundwater status into the poor water class have been considered as significant. Significant diffuse source pollution is connected with agriculture, transport and industrial territories including mines and quarries. At present there are insufficient data for the assessment of the impact of oil shale mining to chemical composition of groundwater. The sources of pollution, which alone or together with some other diffuse source may cause the exceeding of the quality threshold values on more than 10% of the area of a groundwater body or in more than 10% of wells or springs, have been identified as significant pressures of diffuse pollution.

According to the values of physico-chemical quality indicators, the water class of a groundwater body is poor, if less than 90% of the values of quality indicators obtained from the observation points of the monitoring network of the groundwater body comply with the values of the quality indicators of the good groundwater body water class.

Quality indicators of the good water class:

- Human activity or saltwater intrusion has not caused the elevation of the concentration of solutes (as measured by conductivity);
- Human activity or saltwater intrusion has not caused elevated of chloride ion content;
- Nitrate ion content does not exceed 50 mg/l and the elevation tendency of the content of nitrates does not cause significant deterioration of the ecosystems dependent on groundwater;
- Ammonium ion content in naturally aerobic groundwater does not exceed 0.5 mg/l or in naturally anaerobic aquatic environment does not exceed 1.5 mg/l or if, in case of exceeding the value of the quality indicator the natural origin of ammonium ion in groundwater has been proved;
- The content of plant protection products does not exceed 0.1 μg/l;
- pH is between 6–9;
- Dissolved oxygen content does not indicate decreasing tendency caused by human activity or the oxidizability of water is <= 5 mg/l O_2;
- There are no hazardous substances to the aquatic environment or their content does not exceed the limit values of hazardous substances to the aquatic environment established by the Regulation of the Minister of the Environment No 12 of 2 April 2004 "Maximum Limits for Hazardous Substances in Soil and Groundwater" (RTL 2004, 40, 662) or, if in case of the occurrence of the hazardous substances to the aquatic environment mentioned in this Regulation the natural origin of these substances has been proved.

The quantitative status of a groundwater body belongs to the good water class of groundwater bodies by the values of quantity indicators, if a groundwater complies with all the following values of quantity indicators:

- The use of groundwater is smaller than the confirmed groundwater resources or the natural resources of groundwater identified in the course of the preparation of the management plan of a river basin district;
- Alterations of the direction of the flow of groundwater caused by alternations in groundwater levels do not cause saltwater intrusion into a groundwater body;

- There is no long-term lowering tendency of groundwater level and the lowering of groundwater level does not cause significant deterioration of the ecosystems dependent on groundwater;
- The lowering of groundwater level caused by human activity occurred in less than 10% of the observation points of the monitoring network of groundwater bodies.

In the cause of the identification of groundwater bodies at risk only one groundwater body in Ida-Viru county has been identified as being at risk. The qualitative and quantitative status of this groundwater body has become poor as result of mining activity and achievement of its good status is not feasible in the course of the first stages of the water management plan, as oil shale will be mined. In more detail and automatic monitoring network will be necessary to avoid deterioration of status of this groundwater body. The risk of failing to achieve the good status of the rest of the groundwater bodies shall be investigated further.

3. Problems, risks, uncertainties and gaps in existing monitoring system

3.1. Monitoring on Quantitative status

This monitoring includes parameters for the classification of the quantitative status, which mainly consist of measuring the groundwater level regime. WFD requirement for good quantitative status are:

- to ensure that the available groundwater resource for the groundwater bodies as a whole is not exceeded by the long-term annual average rate of abstraction;
- abstraction and other anthropogenic alterations to groundwater levels should not adversely affect associated surface water bodies and terrestrial ecosystems that depend directly for their water needs on the groundwater bodies;
- anthropogenic alterations to flow direction must not have caused, or be likely to cause, saltwater or other intrusion.

The amount of monitoring required depends on the extent of existing information on water levels and the groundwater flow system. In principle, the more spatially variable the groundwater flow system or the pressures on it, the greater the density of monitoring points that will be required to provide the data needed to make suitable confident assessments of the status of a groundwater body or group of bodies.

The maximum amount of monitoring wells has been counted in 1985. After that, due to financial reasons, lots of monitoring wells were closed. The list of monitoring wells from different previous periods is presented in Appendix 1. The list of monitoring wells of basic groundwater monitoring networks has been confirmed by Minister of the Environment in 30. July 2002. After that some changes have been made into this programme.

In 2008 the basic quantitative groundwater monitoring network consists of 100 monitoring wells (Table 1). The distribution of monitoring wells between different groundwater bodies are presented in table 2.

Table 2. Distribution of monitoring wells in groundwater bodies

Groundwater body (GWB)	Number of monitoring wells		Area of GWB (km^2)	Density of monitoring wells, km^2/point	
	quantitative	chemical		quantitative	chemical
01 Cambrian–Vendian Gdov GWB	2	4	1130	565	283
02 Cambrian–Vendian Voronka GWB	4	7	3371	843	482
04 Ordovician–Cambrian GWB	4	4	3318	830	830
05 Ordovician Ida-Viru GWB	35	7	1867	53	267
06 Ordovician Ida-Viru Oil Shale basin GWB	23	8	1014	44	127
10 Middle-Lower Devonian GWB	1	1	255	255	255
13 Vasavere GWB	18	3	75,1	4	25

Ordovician and Vasavere groundwater bodies, in which the natural temporal variability of groundwater level is high, more frequency of measurements will be required, than will be for deep confined Cambrian–Vendian and Ordovician–Cambrian groundwater bodies. This is because C-V and O-C groundwater bodies are relatively unresponsive to short-term variations in precipitation or pressure changes in groundwater.

In monitoring wells of shallow aquifers the groundwater level has been measured 1–5 times per month, the level of confined aquifers – once per month. The frequency of measurements in wells is presented in table 1.

The general monthly monitoring will be sufficient for quantity monitoring where variability is low, but in Ida-Viru county where all groundwater bodies are at risk daily monitoring would be necessary. It will need installation of divers into monitoring wells.

3.2. Monitoring on Qualitative status

Existing monitoring network

The principal purposes of groundwater quality monitoring are to:

- Provide information for use in the classification of the chemical status of groundwater bodies;
- Establish the presence of any significant upward trend in pollutant concentrations in groundwater bodies and the reversal of such trends.

Water sampling on qualitative status is currently performed in 34 monitoring wells (main ions and other parameters). Sampling is performed once per year, usually in summer. All data are stored in the centralized databases of Geological Survey and Info-Techno Centre of Ministry of Environment. The annual report provides information on main results. The data of basic monitoring is for free.

The monitoring network consists from existing monitoring wells of basic and enterprises network and can be extended with abstraction wells. The distribution of monitoring wells by task of monitoring is presented on figure 3.

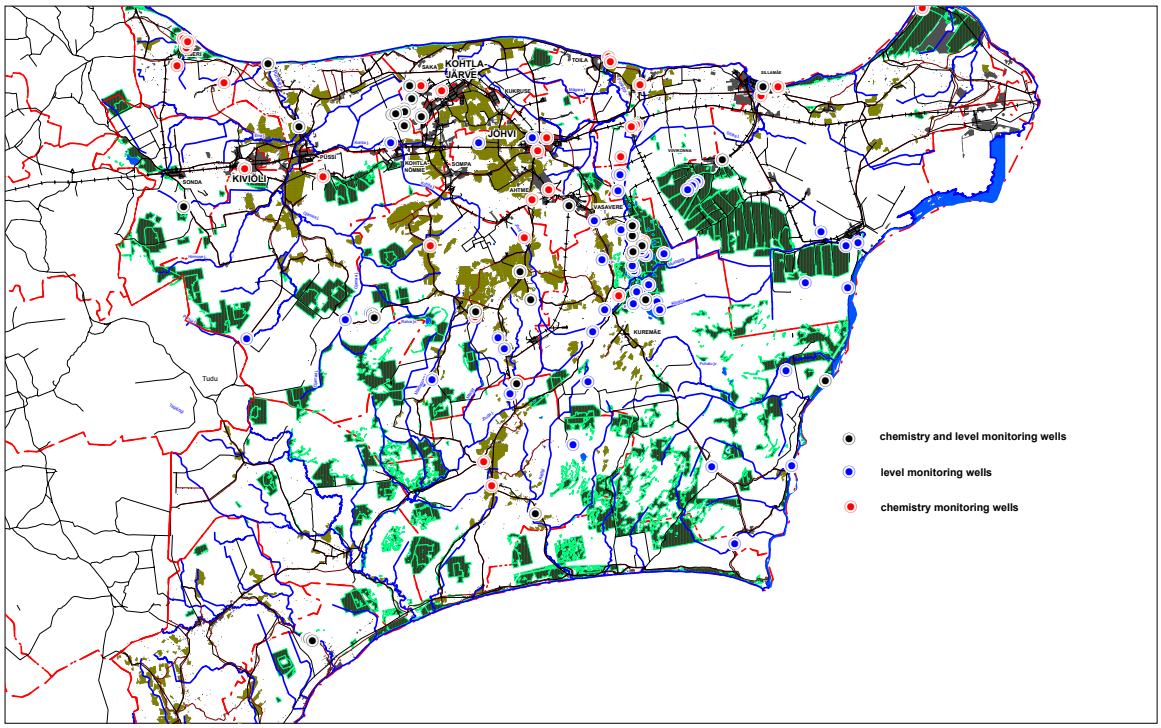

Figure 3. Distribution of monitoring wells.

It would be necessary to revise the current technical situation of monitoring wells and to establish the new monitoring network.

The density of monitoring points depends from aquifer properties (porous or karstic, confined or unconfined), from hydrodynamic conditions (recharge, transitional or discharge area) and from vulnerability of groundwater bodies. The density of monitoring wells is presented in the table 2.

Minimum monitoring parameters concern O_2, pH, NO_3, NH_4 and conductivity have been monitored. These parameters will be needed for all groundwater bodies.

The reference values of the characteristics of the chemical composition of groundwater bodies are presented in the report on groundwater status.

In deep Cambrian–Vendian groundwater bodies the problematic quality parameters are Na, Cl and radionuclides.

Around point source pollution sites there will necessary to continue monitoring of heavy metals, hydrocarbons, phenols and other specific indicators.

The indicators of diffuse pollution are NO_3, NH_4, dissolved oxygen or COD, conductivity, Na, Cl and SO_4. It will necessary to investigate also the distribution of pesticides and determining the reason of high content of NH4 in groundwater of Vasavere and Ordovician GWB's.

By directive 2006/118/EC the indicators of pollution are: pH, Cl, SO_4, NO_3, NH_4, NO_2, COD (oxidizability) O_2, conductivity, phenols, pesticides, trichloroethylene, tetrachloroethylene, As, Cd, Pb, Hg. Unfortunately today only part of these substances has been monitored.

All together the present density of quantitative monitoring wells is sufficient. Unfortunately the most amount of wells has been drilled 20–30 years ago and would be needed some renovation works (redrilling, cleaning etc). From different previous periods are about 300 monitoring wells. It would be necessary to inventory the status of the existing wells and identification of the needs for rehabilitation, replacement, liquidation or drilling new monitoring wells.

Also it would be necessary to start with continuous observations particularly in karstic Ordovician groundwater bodies, where changes of groundwater level are highly fluctuating. With the additional information it will be possible to calculate the water balance of groundwater replenishment for each year.

For this aim it would be needed to install automatic level loggers (divers) into the monitoring wells. Preferably divers need to be installed in all other quantitative monitoring wells as well (almost 100 in total).

4. Enterprise monitoring

4.1. Groundwater monitoring in Narva Power Plants areas

The groundwater monitoring has been carried out in two areas: Balti Power Plant and Eesti Power Plant. Energy plants situated near Narva seem to be one of the biggest sources of environmental pollution in the Baltic region. The alkaline water originating from the hydro eliminating system of ash that must be periodically let into the Narva water reservoir, have been a serious problem.

In surroundings of Power Plants the shallow groundwater is practically everywhere polluted. Intensity of pollution depends primarily from location of monitoring wells concerning source of pollution. Sources of pollution are water in sedimentary ponds of ash fields. Therefore, the ash-ponds water is enriched by potassium. As result of infiltration of surface water in shallow groundwater of Quaternary deposits and Ordovician aquifer system the concentration of K^+, Cl^- and SO_4^{2-} is high. The groundwater monitoring was established in 1989 since, that time the monitoring has been ordered by contract from Geological Survey of Estonia. The groundwater quality of Ordovician–Cambrian GWB is good although. In some monitoring wells the impact of ash pollution has been monitored (elevated concentration of K^+ reaches to 250 mg/l). The list of monitoring wells is presented in table 3, the location of monitoring wells is shown on figure 4. The changes of chemical composition in groundwater of Quaternary deposits are presented on figure 5.

4.2. Groundwater monitoring of Viru Keemia Grupp VKG Kaevandused OÜ

Viru Keemia Grupp (VKG) is the biggest oil shale processing company in Estonia and one of the leading shale oil producers in the world. In 2006 VKG processed about 1.47 million tones of oil shale and sold 200 000 tones of shale oil. In the nearest future there is planned to open new mine – Ojamaa. In 2005 were in surroundings of Muraka bog and Arvila Natura Reserve established 6 groundwater monitoring wells. The monitoring has been ordered from Geological Survey of Estonia. In 2008 the monitoring wells were automatized. Into all wells were installed automatic monitoring divers. The list of monitoring wells is presented in table 4.

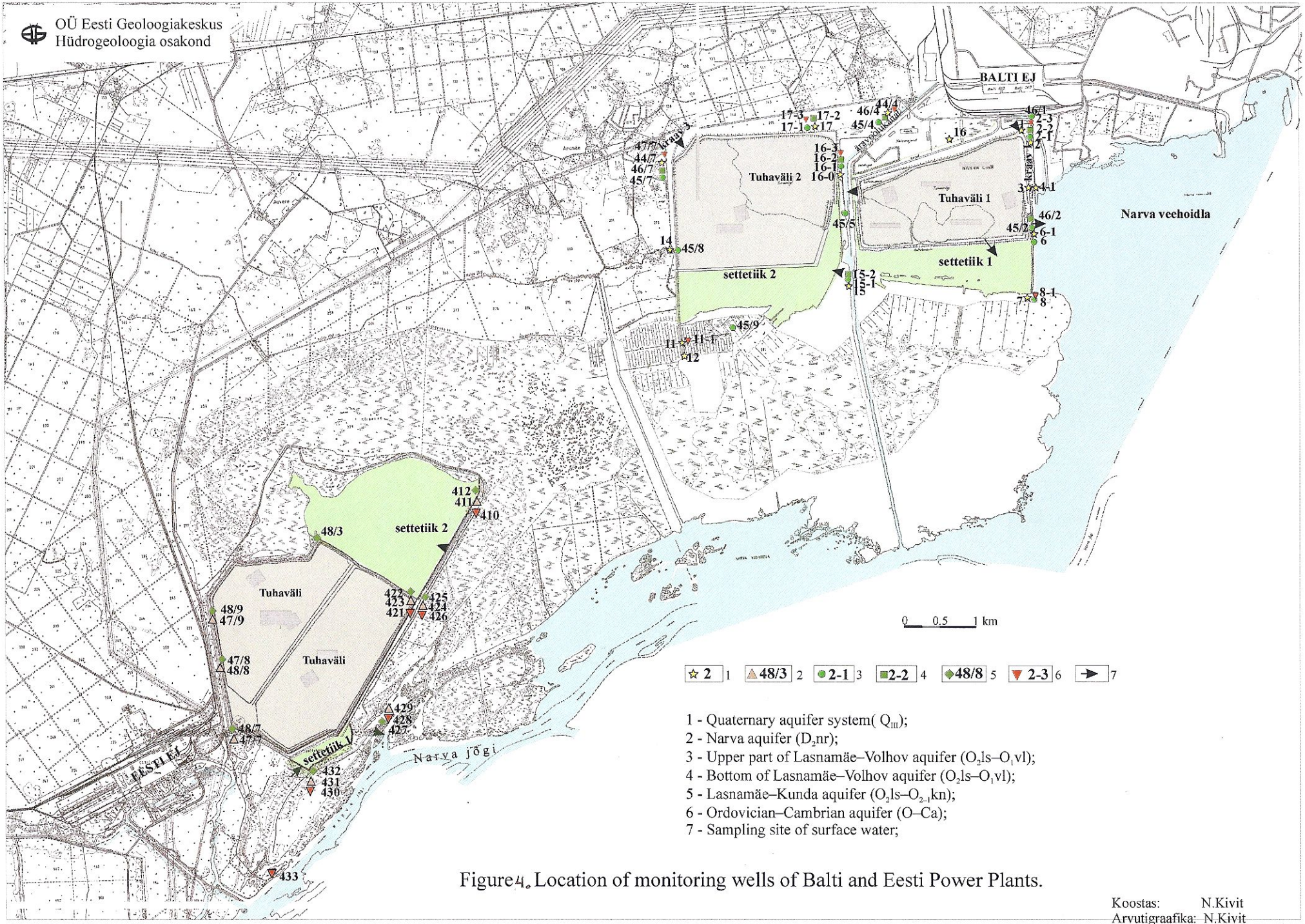

Figure 4. Location of monitoring wells of Balti and Eesti Power Plants.

Koostas: N.Kivit
Arvutigraafika: N.Kivit

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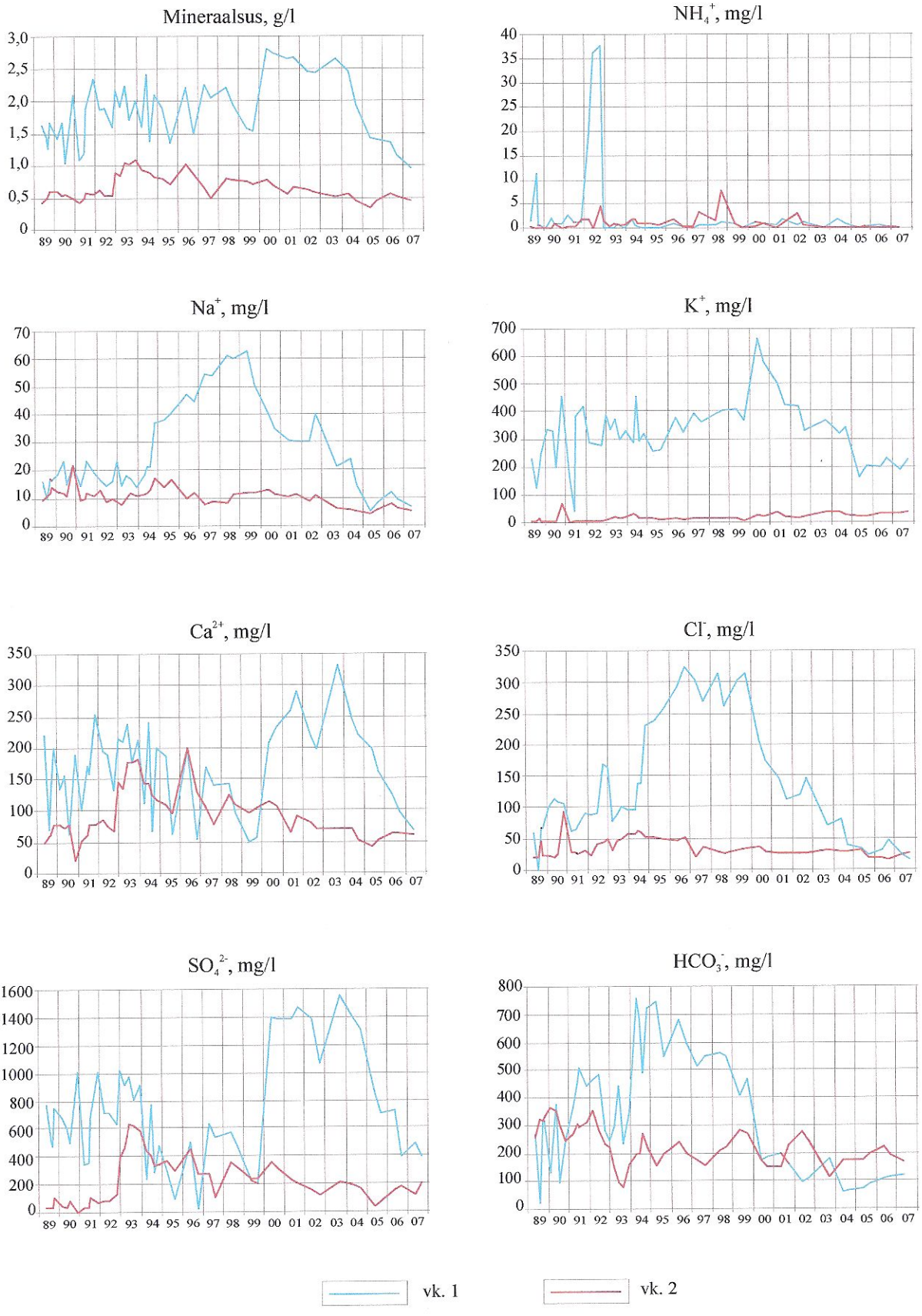

Figure 5 Changes of chemical composition of groundwater of Quaternary deposits in monitoring wells 1 and 2 (Q_{III}).

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Koostas: N. Kivit
Arvutigraafika: N.Kivit

Table 3. List of monitoring wells of Balti and Eesti Power Plants

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year
Balti Power Plant					
19933	1	1	Q	5,2	1985
19934	2	2	Q	5,2	1985
13056	2-1	2-1	O	9,3	1998
13055	2-2	2-2	O	24,5	1998
13054	2-3	2-3	O-C	28,3	1998
19935	3	3	Q	6	1985
13057	4-1	4-1	Q	6,7	1998
19936	6	6	O	16,3	1985
13058	6-1	6-1	Q	7,6	1998
13064	7	7	Q	8	1998
13063	8	8	O	13	1998
13062	8-1	8-1	O-C	32,2	1998
19937	11	11	Q	8,6	1985
13053	11-1	11-1	O-C	39,3	1998
19938	12	12	Q	8,4	1985
19939	14	14	Q	8,4	1985
13061	15	15	Q	7,7	1998
13060	15-1	15-1	O	13,1	1998
13059	15-2	15-2	O	26,3	1998
19940	16	16	Q	7,7	1985
19809	MW-16	16-0	Q	5	2006
19810	MW-16-1	16-1	O	10	2006
19811	MW-16-2	16-2	O	29	2006
19812	MW-16-3	16-3	O-C	32	2006
19805	MW-17	17	Q	4,5	2006
19806	MW-17-1	17-1	O	10	2006
19807	MW-17-2	17-2	O	27,5	2006
19808	MW-17-3	17-3	O-C	31	2006
19804	MW-44-4	44/4	Q	4,5	2006
19802	MW-44-7	44/7	Q	4,7	2006
19533	45/2	45/2	O	14,7	2000
19534	45/4	45/4	O	10	2000
19535	45/5	45/5	O	15	2000
19536	45/7	45/7	O	9,9	2000
19537	45/8	45/8	C-V	13,5	2000
19538	45/9	45/9	O-C	15	2000
19529	46/1	46/1	O	24	2000
19530	46/2	46/2	O	26	2000
19532	46/4	46/4	O	26,5	2000
19531	46/7	46/7	O	29,2	2000
19803	MW-47-4	47/4	O-C	30	2006
19801	MW-47-7	47/7	O-C	33	2006

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year
Eesti Power Plant					
19521	00410	410	O-C	64	1989
19522	00411	411	O	37,5	1989
19523	00412	412	D	19	1989
19518	00421	421	O-C	64	1989
19519	00422	422	O	43,2	1989
19520	00423	423	D	21	1989
19506	00424	424	O	42	1989
19507	00425	425	D	20	1989
19508	00426	426	O-C	61	1989
19509	00427	427	O-C	65	1989
19510	00428	428	O	44,5	1989
19511	00429	429	D	20,5	1989
19515	00430	430	O-C	59,3	1989
19516	00431	431	O	45	1989
19517	00432	432	D	17,5	1989
19512	00433	433	O-C	70	1989
19502	47/7	47/7	D	13,5	1989
19503	47/8	47/8	D	15,7	1989
19504	47/9	47/9	D	15,5	1989
19500	48/3	48/3	O	44	1989
19499	48/7	48/7	O	50	1989
19505	48/8	48/8	O	47	1989
19501	48/9	48/9	O	48,5	1989
18121	1	P-1	D	8	1970
18122	2	P-2	D	8,1	1970
18123	3	P-3	D	8,4	1970
18124	6	P-6	D	8,85	1976
18125	7	P-7	D	7,4	1970
18126	9	P-9	D	8,6	1976
18127	10	P-10	D	8,75	1976
18128	11	P-11	D	8,75	1976
18129	13	P-13	D	8	1971
18130	14	P-14	D	8,2	1970
18131	15	P-15	D	8,5	1970
18132	16	P-16	D	8,1	1970
18133	18	P-18	D	8,2	1970
18134	21	P-21	D	9,1	1976
18135	22	P-22	D	8,45	1976
18136	23	P-23	D	10	1981
18137	24	P-24	D	10	1981
18138	25	P-25	D	10	1981
18139	26	P-26	D	10	1981
18140	27	P-27	D	10	1981
18141	28	P-28	D	10	1981
18142	29	P-29	D	10	1981
18142	30	P-30	D	10	1981
	3-A	3-A	O	6,6	1966
	6-A	6A	O	6,3	1966
	9-A	9-A	O	8,9	1966
	10-A	10-A	O	7,8	1966
	15-A	15-A	O	8,1	1966

No of well in cadastre	No of passport	No of monito-ring well	Geological index of aquifer	Depth to aquifer, m	Drilling year
	16-A	16-A	O	8,1	1966
	18-A	18-A	O	8,1	1966
	20-A	20-A	O	8,3	1966
	21-A	21-A	O	8,6	1966
	24-A	24-A	O	8,3	1966
	25-A	25-A	O	8,2	1966
19943	6/1	6/1	Q	3,9	2000
19944	6/2	6/2	Q	3,9	2000
19945	6/3	6/3	Q	3,4	2000
19946	6/4	6/4	Q	3	2000
19941	1	1(1/1)	Q	3,5	2000
19942	2	2(1/2)	Q	3	2000

Table 4. List of monitoring wells of VKG Kaevandused OÜ Ojamaa mine field

№ of well in cadastre	№ of passport	№ of monitoring well	Geological index of aquifer	Depth to aquifer, m	Drilling year
Arvila site					
20975	1-0-I	I-1	Q	0,0	2005
20976	2-0-I	I-2	O_3kl–kk	6,6	2005
20977	3-0-I	I-3	O_2ls–kn	51,0	2005
Muraka site					
20978	1-0-II	II-1	Q	0,0	2005
20979	2-0-II	II-2	O_3rk	2,9	2005
20980	3-0-II	II-3	O_3kl–kk	10,5	2005

Appendix 1 List of monitoring wells of basic monitoring network in period 1947-2008

Vasavere GWB (13)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
3209	133	1961-1994		
3228	212		1972-1998	
3231	213		1972-2002	
3245	3245		2007-2007	
3263	160	1981-2008	1994-2006	
3264	162	1981-2008	1994-2006	
3265	163	1981-2008		
3266	164	1981-2008	1994-2006	
3270	7304	1973-2002		
3273	7308	1973-1976		
3278	7312	1973-2008	1995-1995	
3279	7314	1973-2008	1996-1997	
3282	7318	1973-2008		
3287	6863	1970-1992		
3366	89	1963-1994		
3367	98	1960-2008		
3368	101	1960-2000		
3369	103	1961-1991		
3371	109			
3372	110	1959-2008		
3374	151		1993-1993	
3375	152	1968-1981	1961-1972	
3376	153	1968-1975		
3377	155	1968-1973		
3378	157			
3384	8035			
3385	8074	1976-2008		
3400	8115	1976-2008		
3401	8134	1976-2002		1978-1978
3404	8139	1976-2002		
3657	5022			
3860	7306	1973-1983		
3861	8653	1984-2008		
3864	111			
3868	105			
3870	215	1978-2008		
3873	218	1979-2008	1995-2008	
3876	211	1961-2008		
4713	8648		1994-1994	
5070	115	1994-2008	1995-2006	
5075	124			
5077	127	1991-2008		
5078	128	1995-2005		
5080	129			
5082	130			
13733	132	1991-2008		

19243	135		1961-1963	
19255	224	1978-1991		
19571	8112	1998-2008		

Middle-Lower Devonian GWB (10)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
3462	323		1965-1989	
3524	6847	1969-2008		
3533	6872	1970-1998	1970-1995	
3536	6875	1969-2008	1996-2006	
3674	5029			
19231	57		1960-1962	
19511	19511		2007-2007	

Ordovician East-Viru Oil-Shale Basin GWB (6)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2585	6091	1968-2003		
2586	6091-A	1968-2003		
2587	6091-B	1968-2005		
2588	6091-C	1968-2003		
2589	6258	1969-1994	1969-1994	
2590	6258-A	1967-1994	1968-1974	
2591	6258-B	1967-1994	1970-1994	
2592	6258-C	1967-1994	1968-1991	
2593	948	1967-2008	1968-1997	
2594	947	1967-2008	1968-1997	
2595	949	1967-2008	1968-1997	1978-1978
2598	950	1967-1994		
2984	1-G	1961-1992		
2985	64-G	1968-1978	1966-1969	
2986	84	1959-1972	1961-1971	
2987	85	1959-1972		
2988	232	1968-1982	1967-1993	
2989	233	1968-1982		
2990	234	1968-1978	1966-1991	
2991	235	1968-1982		
2994	392	1968-1989		
2995	393	1968-1988		
2996	394	1968-1981		
2998	952	1967-1975		
3001	809	1968-1974		
3002	976	1969-1994		
3003	3746	1962-1972		
3004	3888	1962-1977		
3005	5500	1972-2003		
3006	5501	1972-1986		
3007	5065	1968-1974		
3008	5510	1972-2008		
3009	7158	1970-1980		
3018	8206	1974-1983		
3020	8210	1974-1983		

3022	8208	1974-1983		
3023	8207	1974-1983		
3196	959	1969-2008		
3197	960	1965-2008		
3198	961	1969-2008		
3215	142	1968-1973		
3260	3743	1968-1981		
3293	6889	1970-1993		
3294	6890	1970-1993		
3295	6891	1970-1993		
3439	330	1964-2004		
3440	334	1968-1981		
3441	332	1968-1981		
3452	58	1967-1994		
3452	58-A	1962-1994		
3452	58-B	1968-1994		
3452	58-G	1962-1994		
3455	72	1963-1992		
3456	70	1968-1978	1960-1976	
3457	71	1968-1984	1960-1984	
3458	73	1960-2005	2004-2004	
3463	66	1962-1997		
3642	1-B	1980-1992		
3654	5001			
3655	5002	1987-1999		
3656	5003	1987-1999		
3659	5005	1987-1999		
3660	5004	1987-1999		
3661	5014			
3662	5028		2007-2007	
3663	5017	1995-1995		
3664	5018	1995-1995		
3665	5013			
3666	5012			
3667	5027			
3668	5019			
3669	5021			
3670	5020			
3671	5032			
3672	5030			
3715	5007			
3716	5006			
3717	5008			
3718	5009			
3719	5010			
3720	5011			
3723	5026			
3724	5024			
3725	5025			
3727	5034			
3728	5035			
3729	5037			
3730	5038			
3732	542	1988-1991	1989-1993	
3733	543	1988-1991	1989-1993	
3734	544	1988-1991	1989-1991	

3735	545	1988-1991	1989-1991	
3736	546	1988-1991		
3737	547	1988-1993		
3738	548	1988-1991	1989-1991	
3739	549	1988-1991	1989-1991	
3952	249	1980-1999		
3955	253	1980-1999		
3957	255	1980-1999		
3958	238	1975-1992		
3959	239	1975-1990		
3960	241	1975-1998	1996-1997	
3961	242	1975-1992		
3962	243	1975-1992		
3963	244	1975-2008		
3964	245	1975-2008		
3965	340	1975-1991		
3966	346	1975-2008		
3969	8414	1978-2008		
3970	1-A	1980-1992		
3992	75	1960-2004		
3993	274	1981-1982	1983-1983	
3994	274-A	1981-1982		
3996	275	1981-1984	1983-1983	
3997	275-A	1981-1984		
3999	276	1981-1984		
4000	276-A	1981-1984		
4003	5502	1972-2003	1984-1997	
4004	5503	1972-2003		
4005	5504	1974-2003		
4006	5506	1972-1986		
4007	5507	1972-2003		
4008	5118	1975-1999		
4009	5119	1975-2008	1995-1995	
4010	5120	1975-2008	1995-1995	1978-1978
4011	5121	1975-1999	2007-2007	
4012	5511	1972-2008		
4013	5512	1995-1995		
4015	5508	1972-2008	1995-1997	
4016	335	1975-2008	1977-2006	1978-1978
4017	335-A	1975-2008	1977-2006	
4030	228	1989-1994		
4032	74	1963-1992		
5066	118	1995-1995		
5067	117	1995-1995		
5072	120		1995-1997	
12301	8415	1978-2003		
13703	61	1962-1994		
19232	62			
19233	63	1963-1963		
19234	67	1968-1974		
19239	76	1968-1992		
19240	87		1960-1964	
19241	88		1960-1965	
19242	110-2		1963-1966	
19250	168	1968-1972		
19251	201	1968-1974		

19252	202		1965-1966	
19253	284-2	1968-1974	1960-1966	
19263	5509	1972-1980		
19264	5065-C	1968-1974		
19265	5065-B	1968-1974		
19266	7173	1970-1975		
19278	8416	1978-1986		
19498	8214-A	1975-1995	1983-2003	
19499	19499		2007-2007	
19522	19522		2007-2007	
19532	19532		2007-2007	
19560	19560		2007-2007	
19606	19606		2007-2007	
132007	123-P		1972-2002	
132009	102-P		1972-1994	
132011	104-P		1972-1994	
132012	107-P		1973-2002	
132013	138-P		1985-1994	
132014	118-P		1985-1994	
132015	119-P		1985-1994	
132016	120-P		1985-2002	

Ordovician East-Viru GWB (5)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2425	240		1962-1975	
2581	7878	1972-2008		
2582	7876	1972-2008		
3199	6168	1968-1996		
3200	6168-A	1968-1996		
3201	6168-B	1967-1996		
3216	143	1961-1978	1961-1972	
3269	7305	1973-2002		
3271	7307	1973-1984		
3274	7309			
3275	7311	1973-1979		
3277	7313	1973-2008		
3280	7315	1973-2008	1981-1996	
3281	7319	1973-2008	1981-2003	
3289	6887	1969-2008		
3370	108			
3396	8123	1977-2008		
3398	8118	1976-2008		
3477	6218	1967-2001		
3478	6218-B	1967-2001		
3479	6218-A	1967-2001		
3487	6864	1969-1992		
3488	6917	1970-1992		
3491	6886-D	1969-1982		
3525	6798	1969-2008		
3526	6766	1969-1995		
3534	6873	1969-1997	1970-1994	
3535	6874	1969-1996	1970-1994	
3537	6876	1969-2008	1995-2006	
3538	6877	1969-2008	1996-1996	

3641	6168-C	1967-1997		
3643	269	1981-2008	1981-1991	
3646	268	1981-2008		
3648	267	1981-2008	1983-2006	
3650	272	1980-2008	1981-1994	
3651	271	1984-2008	1984-1999	
3653	270	1998-1998	1981-1994	
3658	5023			
3862	8658	1986-2008		
3867	104		1961-1963	
3871	216	1978-1999		
3872	217	1978-2008		
3874	219	1978-1994		
3875	220	1978-2008	1995-2008	
3968	8970			
3971	8423	1978-2008	1988-2006	
3972	8420	1978-2008	1988-2006	
3974	8417	1978-2008	1988-2006	
3976	5769			
3977	5766			
3978	5760			
3979	5748	1986-2008	2003-2006	
3980	5745	1986-2008	2003-2006	
3981	5742	1986-2008	2003-2006	
3982	5731			
3983	5709	1986-1997	2004-2004	
3984	5733			
3986	5729			
3987	5724			
3988	5707	1986-2008	2003-2006	
4014	5705	1986-2008	2003-2006	
4021	7501	1972-2008		
4022	7502	1972-2008		
4023	7503	1972-2008		
4024	7505	1972-1997		
4025	7545-B	1995-1995		
4026	7545	1995-1995		
4028	230			
4031	6218-C	1967-1998		
4033	112			
4715	8651	1984-1991		
4720	8641	1995-1995		
5069	116	1996-2008	1995-2006	
5073	122			
5074	123			
5076	126			
5436	5436		2007-2007	
13701	6895	1969-2008		
13704	3187	1961-2002		
19026	273	1981-2008		
19028	23	1947-2008	1961-2006	
19235	68	1968-1974		
19244	140		1961-1963	
19256	225	1978-1991		
19257	226	1978-1991		
19305	22	1964-1992		

Ordovician-Cambrian GWB (4)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2254	557	1962-1982	1961-1992	
2360	860	1962-1994		
2997	395	1973-1982		
3248	210		1982-1991	
3253	8032-A		1979-1991	
3254	312	1966-1992		
3402	8032	1977-2002		1978-1978
3445	316	1968-1999		
3953	250	1980-1999		
3975	5770			
3989	39	1963-1994		
3990	236	1968-1982		
4002	7545-C	1995-1995		
4019	885-B	1983-2008	1994-2006	
4027	231			
4029	229	1989-1994		
4719	8642	1995-1995		
5166	131	1992-2008		
13494	13494		2007-2007	
19016	246	1989-2008	1995-2007	
19228	24	1963-1998		
19230	26	1960-1967		
19245	859	1968-1976		
19254	223	1978-1991		
19304	854-2		1961-1967	

Cambrian-Vendian GWB (1+2)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2145	852	2002-2002	1961-1977	
2149	858		1961-1991	
2190	852-A	1968-1978		
2281	866		1961-1964	
2291	558	2000-2000	1965-1997	
2315	556	1989-2000		
2476	897-B		1982-1991	

Cambrian-Vendian Voronka GWB (2)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2079	913-A	1979-1979	1973-1997	
2083	912-A	2003-2003	1980-2003	
2088	912	1979-2008	1996-2007	
2090	913	1958-1982	1961-1995	
2100	2100		2007-2007	
2110	981	1973-1992	1973-1990	
2119	2119		2007-2007	
2179	358-A		1965-2006	

2198	580-A	1973-2008	1972-2007	
2262	864	1965-2008	1965-1979	
2333	933		1973-1988	
2470	879	1961-1999	1961-1997	
2473	934	1973-1993	1973-1996	
2478	362		1973-2006	
2657	2657		2007-2007	
2993	319		1989-1989	
3195	885	1967-1978		
3403	8138	1976-2002		1978-1978
3435	3435		2007-2007	
4018	885-A	1983-2008		
4225	4225		2007-2007	
13702	8637	1986-2000		
19403	311-A	1965-2004		

Cambrian-Vendian GWB (1)

No of well in cadastre	No of monitoring well	Groundwater level	Chemical composition	Temperature of groundwater
2084	913-B		1981-1989	
2138	918		1978-1991	
2141	916		1978-1993	
2142	917		1979-2007	
2182	907	1982-2008		
2207	922	2000-2008	1979-2002	
2282	919		1977-1992	
2383	820-A	1963-1994	1963-1995	
2387	2387		2007-2007	
2400	906	1957-2002	1961-2002	
2438	881	1965-2006		
2464	897	1956-1994	1962-2006	
2477	940-B		1975-1995	
2632	865	1967-1995	1963-2002	
3448	311	1965-2004		
9026	9026		2007-2007	