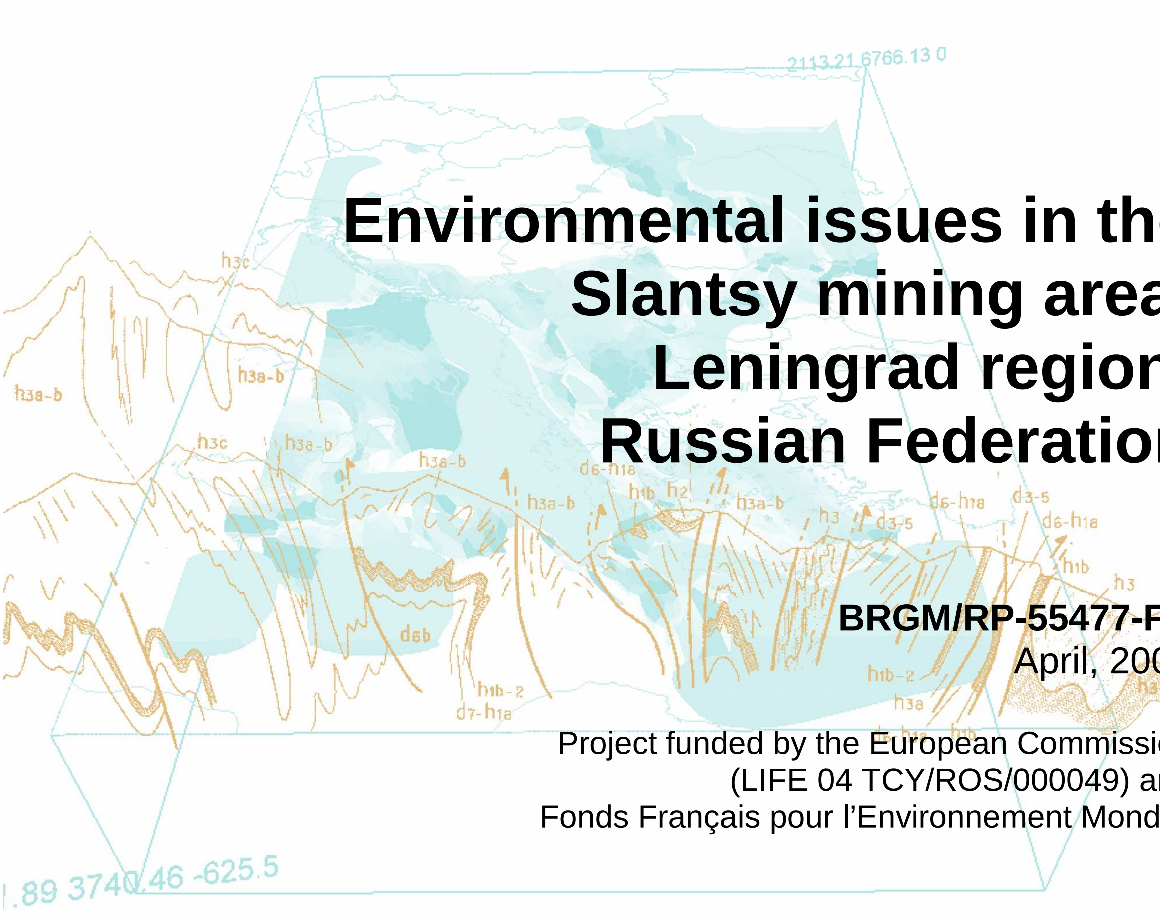

Environmental issues in the Slantsy mining area, Leningrad region, Russian Federation

BRGM/RP-55477-FR

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Geoscience for a sustainable Earth

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Checked by:	**Approved by:**
Name:	Name:
Date:	Date:
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Glossary

MPC	Maximum Permissible Concentration
EU	European Union
WWTP	Waste Water Treatment Plant
WFD	Water Framework Directive

1. Introduction

1.1. A BRIEF HISTORICAL PERSPECTIVE OF OILSHALE MINING IN THE STANTSY (RUSSIA) AND IDA VIRU (ESTONIA) REGIONS

Discovered at the beginning of the century and exploited since the early 1930, the oilshale mining fields located between the Leningrad's region in Russia and the Ida Viru region in Estonia have been the main source of economic wealth of this large region for decades. Oilshales were mainly used for producing electricity with two very large power plants constructed close to Narva, located in today's Estonia. A number of small capacity power plants were also constructed for supplying small cities (for instance a 75 MW capacity plant constructed in 1953 was operated at Slantsy until the 1980s). Oilshales were also used for producing (shale) oil, with some processing plants located in Estonia (Kivioli, Kothla Jarve) and Russia (Slantsy), the oil being used by chemical industries or for collective heating systems. Several industrial complexes (heavy industry, military and nuclear activities) were developed on both sides of what would become an international border in 1991, with a particularly dense concentration in the region of Silamaë, Khotla Järve, Narva and Kivioli in Estonia. A very significant Russian population settled down in Ida Viru region (Estonia) where it still remains more numerous than the native population.

The independence of the Baltic States provoked a drastic disruption of the economy in this region suddenly split into two parts. *On the Estonian side*, the inevitable decline of soviet time industrial complexes led to a drastic increase of unemployment and poverty in the Russian population living in Ida Viru – a situation which still prevails today. The socio-economic situation was aggravated by the sharp decline of electricity demand which compelled the Mining Company to reduce its activity, closing down certain mines and reducing its staff. Interviews carried out by BRGM team as part of the LIFE Pepsi Camp project (See Rinaudo and Houix, 2005) highlighted that the economic decline of this region also resulted in an increasing number of environmental problems, part of them being related to oilshale mining industry. Oilshales mines were progressively flooded, resulting in large scale groundwater contamination (sulfates, heavy metals, BTEX and PAH), sometimes putting at risk aquifers exploited for drinking water (for instance *Vasavere* quaternary aquifer in the region of Khotla Järve). Ashes and other industrial waste produced by the two Narva power plants and oilshale processing industries caused contamination of rivers, lakes and groundwater with phenols and hydrocarbons. And pollutions generated by military complexes have lead to large scale soil and water contamination with kerosene, other hydrocarbons and, in one case at Silamaë, with nuclear material.

On the Russian side, the economy, which was heavily depending on electricity produced on the Estonian side, did not suffered too intensively in the early years following the partition of the region. Oilshales produced in the region of Slantsy continued being exported to Narva power plants, and although a quota of 3 millions tons per year was imposed by Estonia, the mining activity continued in Slantsy area. Electricity produced in Estonia with Russian shales was returned to Russia, the service being charged per ton of oilshales burnt. Gaz was increasingly used as a substitute to oilshale in St Petersburg and the Leningrad's region, ensuring energetic supplies. Estonia however put an end to this agreement and stopped importing Russian oilshales soon after its accession to the European Union. As a European Member State, Estonia was allocated a CO2 emission quota above which emissions would be charged at a rate 40 € per ton of CO2. Estonia therefore decided to charge this indirect cost of oilshale burning to the Russian party[1]. The long negotiation that followed did not led to an agreement and Estonia totally ceased importing oilshale at the end of 2005. This situation compelled the *Leningradslanets* mining company to stop operating as it did not have any other market where to sell oilshales. And since the mining company is the main employer of the region, poverty has drastically increased in the region. Preliminary interviews carried out in the Slantsy region indicate that many inhabitants have been forced to migrate to St Petersburg in search of a job; financial resources available for maintaining public infrastructures and operating public services have also shrunk, resulting in a deterioration of almost all public services.

1.2. OVERVIEW OF SLANTSY ENVIRONMENTAL CONTEXT

The general economic decline described above has *aggravated all existing environmental problems* which in turns results in a deterioration of the living conditions of the population. Unlike the Ida Viru mining region of Estonia, where environment protection has benefited from a significant financial support from the EU and other bilateral funding agencies, environmental problems inherited from past industrial activities have not been addressed in the Slantsy region. Huge quantities of ash deposits generated by the ancient oilshale power plants (constructed in 1953), semi-coke heaps generated by an ancient oilshale processing plant and mining waste generated by the mining activity itself are still in place, probably contaminating surface and groundwater bodies. Large scale groundwater pollution with sulfate and heavy metals could also take place if mine dewatering would stop, with possible impacts on surface waters. Also, the deterioration of the municipal and the industrial waste water treatment plants is probably leading to intense contamination of rivers, with a possible impact on ecosystems and human health.

A series of interviews conducted with 29 actors in the region of Slantsy confirmed that mining and industrial problems are far from being the main sources of environmental concern of the population in that area (Annex 1). For instance people consulted are increasingly concerned by the following environmental issues:

- ***Wastewater treatment***. Due to lack of maintenance and obsolescent technologies, waste water treatment plants of Slansty town and neighboring villages do not function properly. In some villages, effluents are directly discharged in the rivers. The sewage collection system can also occasionally break down. Several consulted experts and stakeholders fear that this may result in the breakout of infectious diseases. Rivers receiving untreated effluents are also considered as running a very serious pollution risk. The reconstruction of WWTP is considered as too costly for being conducted by the municipality of Slantsy without the (very unlikely) financial support from the Region.
- ***Municipal solid waste*** is another major source of water contamination in the study area. Slantsy municipal urban waste dump is probably contaminating soil

[1] 2005 values, provided by the Leningradslanets company – not cross checked yet with other sources

and groundwater with heavy metals (mercury and lead quoted by respondents). Moreover, in small settlements around Slantsy, urban waste collection has almost stopped for economic reasons. As a result, urban waste are increasingly discharged in uncontrolled dumps around villages (25 to 30 sites), diffuse waste deposits along roads and in even just around houses in the villages. This trend represents new polluting threats for soils, surface and ground water.

- ***Industrial air pollution*** is considered as declining by most of the experts consulted. Air pollution by the cement factory and the oilshale processing plants were the two main problems. The cement factory has been reconstructed (Tsesla, German investor) and the oilshale processing plant changed activity. Estonian power plants at Narva still continue polluting the air (as proved by the presence of black deposit on snow in winter). Although reduced, air pollution however still generates asthma problems in the population.
- ***Industrial water pollution*** generated by local industries (cement factory oilshale / chemical industry, rubber product production plant) has also decreased and the general ecological status of the *Pjlussa* river is improving (presence of certain species quoted). Discharge of phenolated waters through the "phenol channel" into the *Pjlussa* river was reduced after the industry changed activity, resulting in an improvement of ecological quality. In the past, fished caught in *Pjlussa* had a smell of phenol. Industrial waste dumps (mainly ashes and semi coke heaps from the shale processing plant) are however quoted as sources of water pollution.
- ***Environmental impact of mining activity***. Waste heaps ("terrikoniki") of Mine No. 1, No.3 and Kirova mine are considered as sources of pollution. In the past, one of these mining waste dump burnt (self combustion process) for one month, creating intensive air pollution, with severe impacts of the nearest part of the city (impact on children quoted, allergic diseases). There is a risk that other waste dumps could too burn in the future. Mining dumps may also generate harmful dust during windy periods. More important, mining waste dumps are leached by rainfall which results in a contamination of *Pjlussa* river (and the Baltic sea) by sulfates and phenols, considered as harmful to health (and ecosystems).
- ***Drinking water quality***. Drinking water supply comes from groundwater (artesian wells) in certain villages of Slantsevski district and from *Pjlussa* river in Slantsy town. In Slantsy: although water quality is acceptable at the source, it deteriorates during the distribution due to the poor condition of the distribution network. According to several respondents, water shows high iron content (rust in pipes), poor organoleptic characteristics and occasional bacteriological contamination (coliform bacteria, hepatite virus). Most households have installed a filter and boil water. The rehabilitation of the network could only be undertaken if government budget was made available for this. The use of groundwater pumped at Kirova mine (treatment plant) is a controversial issues as some stakeholders do not trust the quality of this water (some mentioned results of scientific studies showing high radionucleide concentrations in mine water; others mention heavy metals). In villages, drinking water comes from

wells which are not systematically well protected and groundwater may be contaminated by ancient abandoned wells.

- ***Mine dewatering.*** Mine water pumped in the mine is discharged in *Pjlussa* river, with no significant impacts noted by respondents. Mine dewatering still takes place although the oilshale extraction has stopped. The pumping costs are tremendously high and they could be stopped at any time, if new markets are not found for the shale. The redevelopment of an oilshale processing activity at Slantsy remains an option; a Korean investor could be interested. In case dewatering is stopped, some stakeholders fear that an ecological catastrophy would occur: contaminated groundwater would contaminate rivers and soils, with heavy metals and sulfates. This is a very controversial issue where wcientific evidence is lacking. People refer to a period when, during the 2nd World War, pumping stopped, leading to large scale contamination for some respondents, no consequences for others. Several studies, conducted at the time of closing Kirova Mine (1998), have shown that the impact of mine flooding could be significant and recommended to continue pumping. The same conclusion should therefore apply to today's situation.

1.3. OBJECTIVES OF THE REPORT AND ANALYTICAL FRAMEWORK

1.3.1. A three step planning process

The overall objective of the environmental and socio-economic analysis carried out as part of tasks 3 and 4 of the project is to design a technically and economically sound programme of action to mitigate water related problems in the Slantsy region. The methodological approach implemented is inspired from planning procedure proposed by the European Water Framework Directive:

- ***The first step of this planning procedure consists in characterising the river basin***. This initial characterisation is intended to make a snapshot of water management problems at the beginning of the process, by (i) identifying all major sources of pressures due to human activities (pollution sources, abstraction, other modifications of aquatic ecosystems), (ii) assessing the nature and extent of degradation of water resources and (iii) assessing the impacts of the observed water resources degradation on human activities (health impacts, costs incurred by certain activities due to pollution, etc.). According to the WFD, the initial characterisation of river basin should also include a description of expected future changes in human activities which could result in increased or reduced pressures on water resources. The two types of information combined are then used to assess the risk that the different water bodies included in the basin do not reach the environmental objective (good water status) of the directive by the prescribed date (2015). This leads to the definition of significant water management issues in the basin. An active involvement of stakeholders is recommended to perform this river basin characterisation and in particular to identify significant water management issues.

- ***The second step of the planning procedure consists in identifying alternative possible actions*** that can be implemented to solve the water management problems previously identified. Such actions may consist of technical measures such as pollution reduction measures in agriculture, contaminated sites clean-up, water saving programmes to reduce water abstraction, etc. They may also consist of economic measures, such as providing water saving incentives through water tariffs and rates or pollution reduction through environmental taxes. Regulatory and organisational instruments can also be included in the programme of measures. One of the key innovations of the WFD is to require that an economic analysis be performed to identify the cheapest way to achieve the environmental objective. This analysis, referred to as "cost-effectiveness analysis", is supposed to ensure that authorities in charge of the planning process report on economic implications of the choices they make to stakeholders and the public at large, as imposed in article 14 of the directive.

- ***The third step consists in assessing if costs are disproportionate and in justifying derogation if it is required.*** The European legislator has however anticipated that achieving the environmental objective of the directive might entails very high costs for intensively deteriorated water bodies. In such cases, the WFD allows Member States to target less stringent environmental objectives, provided they can prove that the costs of restoring good ecological status are disproportionate with the benefits they would generate for the society as a whole. Justifying such derogation requires conducting a second type of economic analysis, referred to as cost-benefit analysis. This should however only be conducted in a limited number of cases.

1.3.2. Initial characterisation in Slantsy region

The analysis proposed in tasks 3 and 4 of the LIFE Narva groundwater management plan project is following this general framework. This report presents the results of the first of the three steps described above, namely the river basin characterisation. Data and information gathered in this report are mainly issued from a series of interviews conducted with local stakeholders (Annex 1) and on several reports and data collect commissioned by SGE as part of this project (Podsevalov, 2006; NARVA Progress report n°1, 2005; Sammet *et al.*, 2006; Tsepilova *et al.*, 2006; data from Slantsy municipality, 2006).

It first focuses on the description of human activities generating pressures on water resources in the Slantsy region (***Chapter 2***). The main sources of pressures identified (Figure 1) are waste landfills (municipal and unauthorised), municipal waste water treatment plants, industrial liquid effluent discharges and industrial waste dumps, mining waste deposits, mine water discharge and agriculture activities (storage of farm manure and cattle graves). The analysis also reports on the impacts of environmental degradation, mainly based on information collected through interviews with stakeholders.

The report then focuses on the description of water resources impacted by human activities (***Chapter 3***). Several sources of information are cross-checked to understand the local hydrogeological conditions and assess the vulnerability of the different aquifer layers. The quality of surface and groundwater resources is also assessed and some information is also compiled to assess soil degradation (which may represent a source of pollution for water resources).

Chapter 4 briefly describes qualitatively potential impacts due to environmental degradation in the area. Drinking water contamination, human health damage, agricultural and gardening land contamination, fish contamination and absence of recreational areas were the most quoted damage during interviews. Nevertheless links between water quality degradation and these potential impacts are not well established nor understood and stakeholders often refer to the poverty and unemployment as the main cause of damage to health.

Finally, the report analyses possible future evolution of the situation (***Chapter 5***). It identifies possible future changes in level of pressures, describes resulting modifications of water quality levels and anticipates what would be the expected socio-economic impacts. Major changes are expected to take place if mine dewatering ceases. This would result in drastic modifications of the aquifers. The rise of water table and changes of water flows direction would probably lead to large scale groundwater contamination – the extent of which can only be assessed using a groundwater model developed and calibrated at the local level. The third section explores the possible consequences of this change.

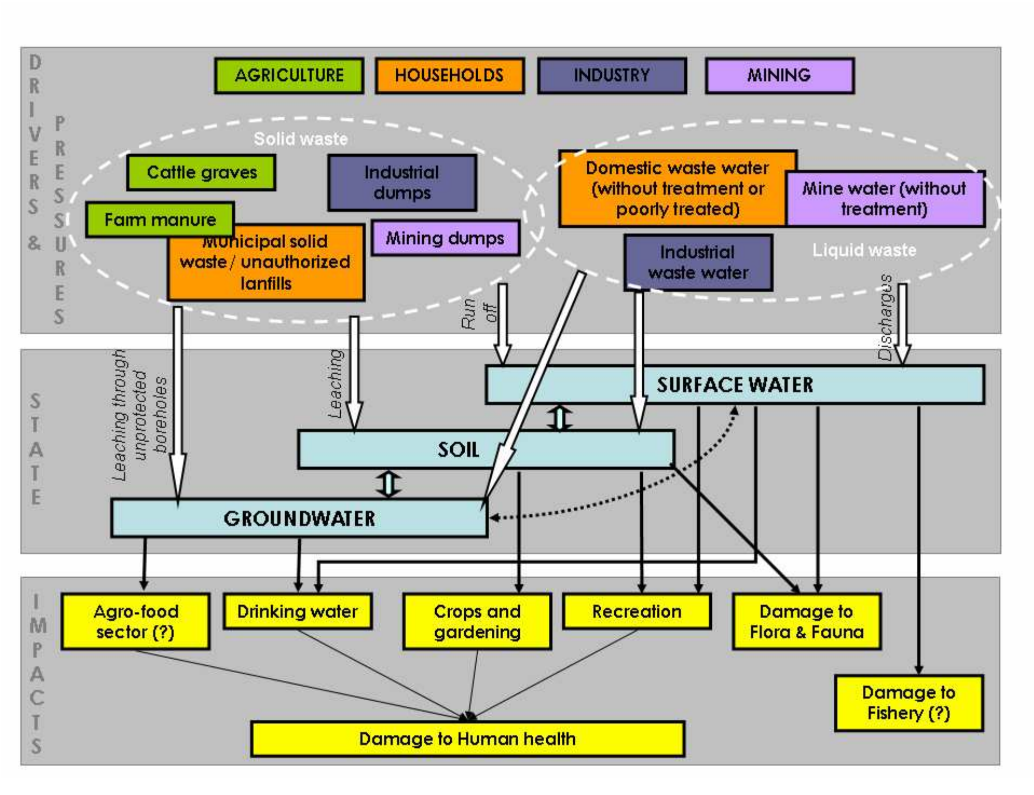

Figure 1. Drivers & Pressures leading to environmental degradation (State) and related Impacts in Slantsy mining area

2. Socio-economic drivers and resulting pressures on water resources

The district of Slantsy belongs to in the North West Federal district of the Russian Federation, Leningrad Region. Its territory is located both in the Pjlussa and Narva river basins. Its area (2,191 km²) is mainly covered by forests (53%) and agricultural lands (35%). The remaining area is divided between water bodies (6%), settlements (3%), reserved areas (2%) and industrial lands (1%).

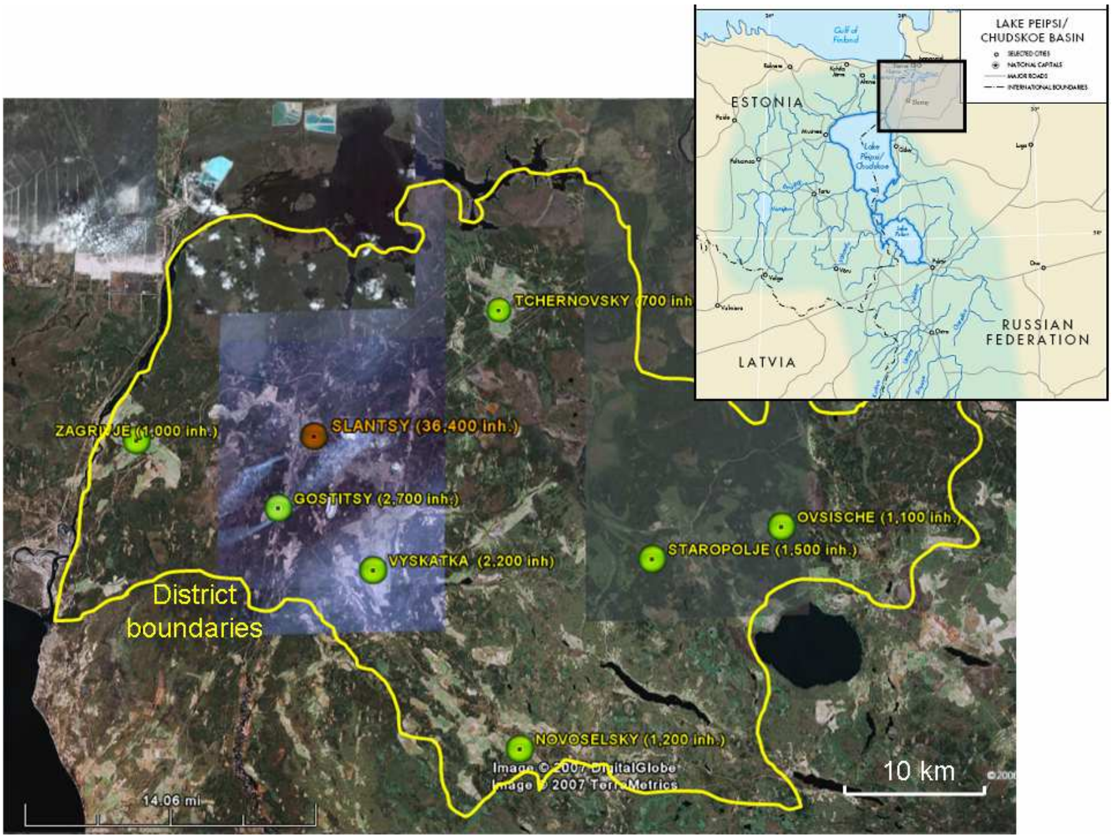

Figure 2. Location of Slantsy district (use of Google Earth map 2007)

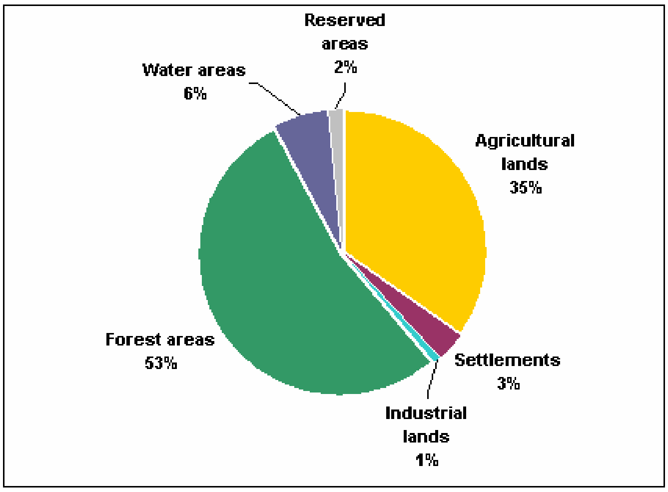

Figure 3. Land use in Slantsy district in January 2005 (Data source: Slantsy municipality, 2006)

2.1. POPULATION

46,800 inhabitants lived in the Slantsy district on January 2006 (49,800 in 2005), distributed between Slantsy town (78%) and rural settlements (Vyskatka, Gostitsy, Zagrivje, Tchernovsky, Novoselje, Staropolje and Ovsische) (Figure 4). The average density of population is around 21 inhabitants per square kilometre.

Location	**Population (01.01.2006)**
Slantsy town	36,400
Gostitsy village	2,700
Vyskatka village	2,200
Staropolje village	1,500
Novoselje village	1,200
Ovsische village	1,100
Zagrivje village	1,000
Tchernovsky village	700
Slantsy district	46,800

Figure 4. Population in Slantsy district (Source: Slantsy municipality, 2006)

- ***Domestic waste water discharge***

According to Slantsy municipality and the results of interviews[2], nine waste water treatment plants exist in the Slantsy district (Figure 5). Three of them still function. The

[2] 29 interviews have been carried out from April to July 2006 by the Sociological Institute of Saint Petersburg. During these interviews stakeholders (representatives of district-, city and rural administrations, of the main industrial units, of the water services, of hospitals, of schools and journalism) were met and asked about the environmental situation of the Slantsy mining area.

theoretical total treatment capacity is 29,500 m^3/day (real capacity: 26,000 m^3/day). A crisis situation has been noted in the waste water treatment system, especially in rural settlements. Most treatment plants have been in operation for 25 to 30 years and need to be reconstructed. Waste water collection network is also in a poor quality and has seriously deteriorated due to lack of repair and maintenance over a large span of years. Leaking sewers pose a big threat to surface and groundwater bodies and endangers drinking water supply.

Location	**Construction date**	**Capacity (m^3/day)**	**Discharge point**	**State**
Slantsy town	1965	25,000	*Pjlussa* river	Satisfactory
Bolshiye Polja	1979	200 (fact 80)	*Pjlussa* river	Operating but requires renewal
Gostitsy village	1980	600	*Pjlussa* river	Does not function
Vyskatka village	1984	700 (fact 400)	Kushelka river	Operating but requires renewal
Staropolje village	1980	700	Dolgaya river	Does not function
Novoselje village	1980	600	Belka river	Does not function
Ovsische village	1980	600	Samro river	Does not function
Zagrivje village	1980	400	B.Cherjomukha river	Does not function
Monastyrek	1980	700	Tchernovka river	Does not function
Slantsy district: theoretical capacity		29,500		
Slantsy district: capacity of functioning plants		26,000		

Figure 5. Waste water treatment plants located in Slantsy district (Source : Slantsy municipality, 2006)

Slantsy town

The biggest waste water treatment plant is located near the *Pjlussa* river downstream Slantsy town. It belongs to *AO Slantsy* industrial unit (oil shale processing plant) but treat both industrial and domestic waste water discharge from the city. The treatment capacity is 25,000m^3/day. According to the Slantsy municipality, the plant treats 16,500 m^3 of waste water per day, including 12,600m^3 coming from domestic discharges. Both domestic and industrial waste water are treated (biological treatment) and discharged into the *Pjlussa* river. Even if the general state of the waste water treatment system of Slantsy town has been noted as satisfactory by the municipality, interviews mentioned several breakthroughs of the waste water network during 2005 which led to the discharge of waste without treatment into the river. It has been estimated by stakeholders that 3.8 km of pipes need to be urgently reconstructed (total length of the municipal sewerage network: 27 km).

Rural settlements

Eight waste water treatment plants are located in the rural areas. Only two of them function partially today (mechanical treatment only) and are generally overloaded. Waste waters from approximately 8,000 people are directly discharged into surface water without any treatment. For example the waste water treatment plant of Gostitsy village stopped ten years ago (lack of means for maintenance and/or reconstruction).

Waste waters are still accumulated in the station and discharged without treatment in the *Pjlussa* river (Figure 6). The situation is quite the same in the other rural settlements. In Zagrivje waste waters are directly discharged into *B.Cherjomukha* river (and then into *Narva* river located in the boundaries with Estonia).

Figure 6. Unoperated waste water treatment plant in Gostitsy village.

- ***Domestic waste dumps***

There is no official authorized landfill in Slantsy area. According to the interviews, more than 40 unauthorized waste dumps are located within the limits of the district, especially along the roads (Figure 8) or in gardening areas. The table below gives the characteristics of the six main waste dumps of the district (Figure 7). The biggest one is located 4 km away from the city near Pechurky settlement. 8,000 tons of wastes are annually stored in this place (Figure 8). According to the municipality a location for (authorized) waste storage in Slantsy town has been selected. This planned new landfill would be located in the area of the old industrial waste water ponds of *AO Slantsy* (Figure 9).

Location	Distance to the nearest settlement (km)	Date of appearance	Waste amount (m^3)	Area (ha)
Slantsy town	5	1972	350,000	3
Tchernovsky/ Monastyrek	1,5	1985	5,000	0,5
Staropolje	0,5	1975	3,000	1,5
Penino	1	1975	3,000	1
Zagrivje	1	1995	3,000	1
Novoselje	0,3	1983	2,000	1

Figure 7. Biggest unauthorized domestic waste dumps (Source : Slantsy municipality, 2006)

Figure 8. Domestic wastes along the road (left); Pechurky waste dump (right)

As in most places in North West Russia (DANCEE, 2003), suburban and rural areas are generally not serviced by regular collection services, which means that residents must resort to illegal dumping of waste. This lack of means leads to waste collection and storage within and near the houses that creates unsanitary conditions around storage points. Similarly, household hazardous waste (used accumulator batteries, PVC, mercury lamps, etc.) are not collected nor treated.

Leachates within landfills and other waste storage areas may be emitted to soil and water and contain generally high concentrations of organic carbon, ammonia, chloride, potassium, sodium, heavy metals, organic and microbiological components (EC, 2000).

Figure 9. Selected location for the new planned municipal landfill

- ***Water abstraction***

In Slantsy town

Surface water from *Pjlussa* river is used for Slantsy water supply (water intake point is located 4km upstream Slantsy town). It is estimated that approximately 95% of the urban population is supplied with tap water. Production and distribution of water in Slantsy are the responsibility of *Vodokanal*. About 15,000m^3 are pumped every day in *Pjlussa* river and treated near to the intake point in a cleaning station where measurements are carried out every three hours.

The average level of water supply for drinking water and domestic needs is 253 litres per inhabitant per day. As mentioned by DANCEE (2003), this level of consumption is twice the consumption of Western Europe countries, especially due to an inefficient distribution system with high level of losses. According to the National Environmental Action Plan for Russia, water losses are reported to be 40-50% of the abstracted amount of water (5-15% in western European countries).

According to the results of the interviews, the main problem with drinking water supply to urban population is the bad state of the network that leads to turbidity and high content in iron in tap water. As in Estonia (UNECE, 2001), distribution network for drinking water are old and made of iron, which is particularly sensitive to the corrosiveness and causes leakages in the pipes. Distribution losses may therefore be important and Iron content in distributed water generally exceeds the limit. Before using this water for cooking or drinking purposes, it should at least be filtrated and boiled. Some people do not even use this water for washing. Alternatives sources of drinking water are in general deep boreholes located in the former mining area (mine n°1) or outside of the city.

The source of urban water supply may change in the coming years: it is likely that Kirova mine water would be used to supply water for Slantsy. A cleaning station was built in the Kirova mine field but it still does not function. The use of mine water for domestic supply is still controversial (quality of mine water is not well known).

Capacity of all water pipe-lines for the end of 2004	**m^3/day**	**55,900**
incl. the largest plants (with capacity)		Project/fact
surface	m^3/day	50,000 / 15,500
underground	m^3/day	400 / 400
Water amount supplied to all consumers per year	**m^3/year**	**3,700,000**
incl. by consumer groups		
industrial plants	m^3/year	100,000
budgetary field	m^3/year	200,000
population	m^3/year	3,200,000
Household water use per one person	**l/day**	**253**
cold water	l/day	133
hot water	l/day	120
Water pipe-lines extent	km	167,3
incl. municipal one	km	42,8

Figure 10. Water supply data in Slantsy town (Source: Slantsy municipality, 2006)

In rural settlements

Groundwater resources are mainly used for domestic supply in rural areas, with approximately 2,400m^3 abstracted per day. Three layers of aquifers are exploited: the *Ordovician*, the *Cambrian-Ordovician* and the *Lomonosov* aquifers. The majority of households and farms obtain their water from wells and boreholes into the *Ordovician* layer (Figure 11). It is estimated by the municipality that 10% of the rural population is supplied with tap water. There are no quality measurements of the water abstracted for domestic use.

120 wells and boreholes are known by the *Sevzapgeology* Company in the district (at a depth from 40 to 280m). Approximately 50 of them are still used today. These wells/ boreholes are not protected from polluting sources such as waste dumps, cattle graves, roads, and fertilisers for example (see Figure 12) and chronic health risks could exist from contamination of the well water due to the shallowness of the wells which make them vulnerable to surface run-off. The drainage area of wells needs to have some minimal protection and simple disinfection treatment.

Concerning the abandoned/ deserted wells and boreholes (approximately 70 in the district), they were generally not tamped and are still not protected from polluting sources (see Figure 12).

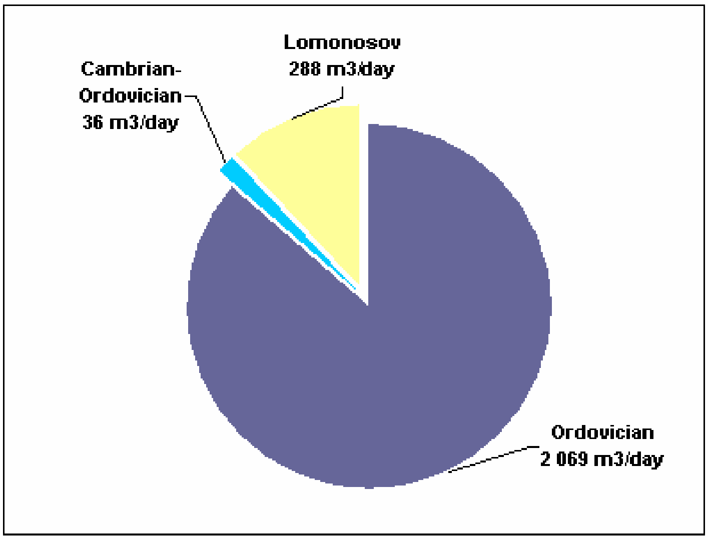

Figure 11. Water abstracted from aquifer for domestic use in rural settlements (Data source: Slantsy municipality, 2006)

Figure 12. Drinking water borehole in Bolshiye Polja (left); Abandonned rural well (right)

2.2. AGRICULTURE

There are three main state farms (*ZAO Rodina*, *ZAO Zagrivskoye*, and *ZAO Osminskoye*) and some private farms located within the Slantsy district. Various types of agricultural goods are produced: arable lands, meadows, pastures, cattle-breeding farms (livestock, pig farms and poultry farms), dairy farms. Statistical data concerning agricultural land use, types of crops, yields, and surfaces are not available.

The interviews highlight the huge decrease in agricultural activity these last years, and in particular the decrease in the livestock as well as the decrease in the purchase of fertilisers and pesticides. In a general way, livestock and crops products seem to have strongly decreased in Russian Federation since the beginning of the 90s[3].

№	Location of the farm	Owner	Cattle population	Pigs population
1	Vyskatka	*ZAO Rodina*	712	0
2	Monastyrek	*ZAO Rodina*	387	0
3	Perebor	*ZAO Rodina*	706	0
4	Kushela	*ZAO Rodina*	182	0
5	Popkova Gora	*ZAO Rodina*	388	0
6	Porechje	*ZAO Osminskoye*	213	0
7	Shakitsy	*ZAO Osminskoye*	433	0
8	Zamoshje	*ZAO Osminskoye*	405	0
9	Ovsische	*ZAO Osminskoye*	805	0
10	Zagrivje	*OOO Zagrivskoye*	500	0
11	Krivitsy village	Private	0	20
12	Chudskaya Gora	Private	0	20
13	Zagorje	private	10	10
	Total		4741	50

Figure 13. Main farms in the district of Slantsy (Source: Slantsy municipality, 2006)

[3] http://geoconfluences.ens-lsh.fr/doc/etpays/Russie/RussieVoc.htm

2.3. INDUSTRIAL & MINING ACTIVITIES

The main industrial plants of the district are concentrated in Slantsy town, in the area of the oil shale deposit and mainly on the right bank of *Pjlussa* river (Figure 14). Fuel industry is represented by *OAO Leningradslanets* (oil shale mining company) and *AO Zavod Slantsy* (oil shale processing company). Oil shale is also used by *OAO Tsesla*, the largest cement factory in Leningrad region that exploits the Pechurky limestone deposit between *Narva* and *Pjlussa* rivers. Chemical industry is represented by *Polymer* plant. There are also wood processing enterprises (*OOO Dok*, *Slantsy forestry*, *OOO Pjlussa forest*) and agro-food factories (*Slantsevsky meat production*, *Slantsy cannery plant*).

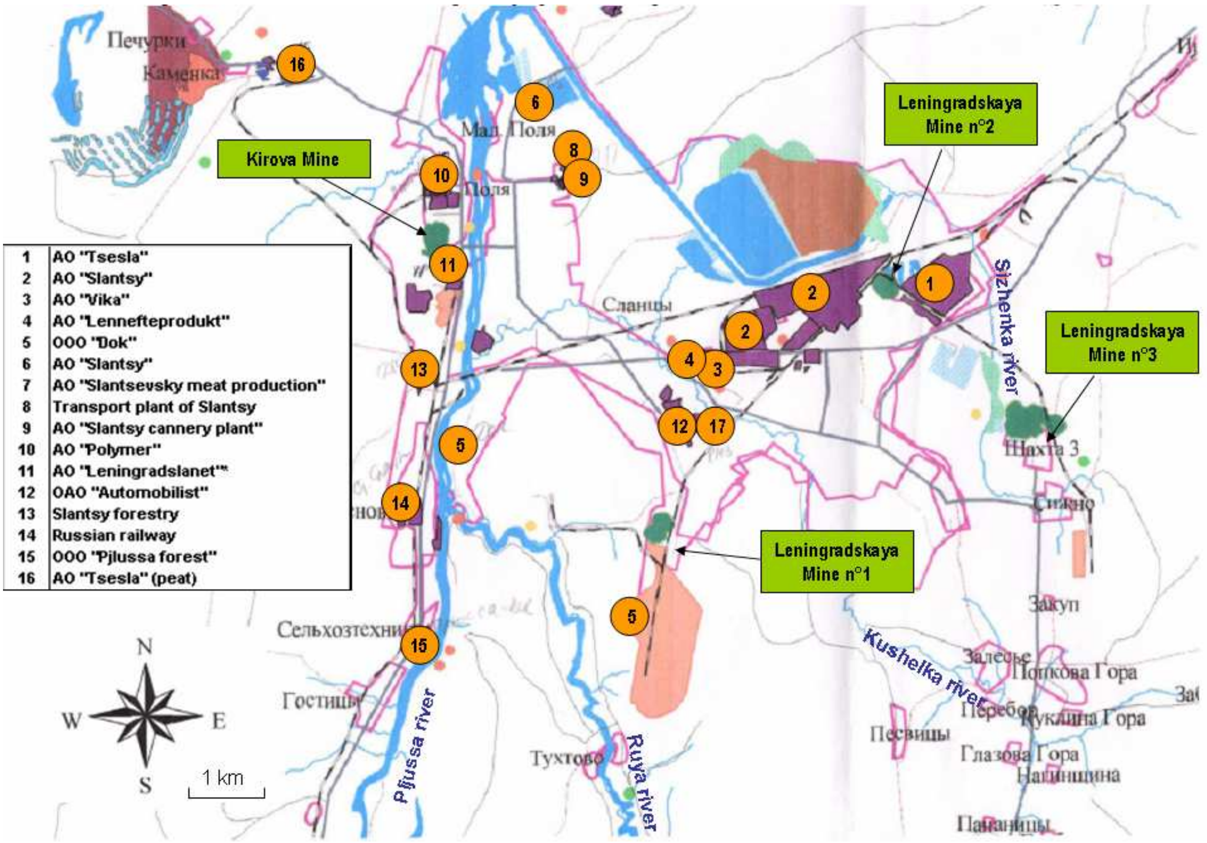

Figure 14. Main industrial and mining units in Slantsy (Data source : Slantsy municipality)

These industrial and mining activities have exerted (and still exert) various pressures on the environmental resources (ground- and surface water, soil, air): (i) Polluting pressures by toxic substances through industrial waste water discharge into surface water without treatment, leaching water through huge amounts of mining waste dumps, atmospheric emissions for example; (ii) Quantitative pressures characterised by the formation of a depression cone due to the dewatering of mines.

According to the results of the interviews, polluting pressures due to industrial activities have significantly decreased these last years, especially since the closure of the mines at the end of 2005. Nevertheless, huge quantities of ash deposits, semi-coke heaps and mining wastes are still in place. Measurements indicate exceeded (from 3 to 16 times) content of heavy metals in soil over the major part of Leningrad mine field.

2.3.1. Oil shale mining

Leningrad oil shale deposit was exploited since the 1930s by *Leningradslanets* mining company. Two mine fields were exploited: Leningradskaya mines on the right bank of *Pjlussa* river and Kirova mine on the left bank. Part of oil shale produced in Slantsy was exported to Narva power plants in Estonia. Electricity produced in Estonia with Russian shale was returned to Russia.

In the 1990s, Leningradslanets has produced some 2.5 million tones of oil shale a year. Approximately 3,500 persons were employed by the oil shale mining company. 70% of the oil shale was exported to Estonia. The remaining was processed in the local factory *AO Slantsy* in order to produce oil and other chemical products using oil shale[4]. In 2002 this quantity was reduced to 1.1 million tones. At the end of 2005 Estonia ceased importing oil shale produced in Slantsy and *Leningradslanets* Company stopped the exploitation of oil shale[5]. In 2006, mines were closed but groundwater was still pumped (approximately 70,000m^3 per day). The mining complex has been recently (January 2007) bought by the *Renova* company. Economic situation may thus change in the coming months since it is expected to invest in new equipments and rise production at 2.5 million tons a year[6]. Mining waste dumps consist mainly in limestone and shale ash (approximately 36.6 million tones of waste are still in place). Ash ponds are generally located around the dumps to receive drainage water before being discharged into the rivers.

Total area of Leningradskaya mine fields amounts to 273 km². Remaining resources amount to 154 million tones. Works were carried out at the depth of 100m. Four pumping stations are still in place. Drainage and mine waters of mine n°1 are discharged without treatment into *Ruya* river in the southern and central part and into *Kushelka* river in the northern part. Drainage and mine water from mine n°3 are discharged into *Sizhenka* river (Annex 2).

Total area of Kirova mine amounts to 17 km². The reserves (about 15 million tones) are not subject to be exploited due to some technical conditions. In 2000 it was decided to liquidate the mine. Before closure, works were carried out at the depth of 70-80m. Mine water is still pumped (23,100 m3/day) and directly discharged (without treatment) into *Pjlussa* river (Annex 2).

- ***The oil shale properties***

The shale oil consists of about 30-40% of clots and homogeneous mass of organic substance (kerogen), fractured terrigenous material, 20-30% of pelitic component (clay), about 30-50% of calcite and magnium carbonate, 2-4% of disulphide iron and 5-10% of moisture.

Kerogen is a homogeneous highmolecular substance, insoluble in organic solvents. It has high combustion power (8,900 – 9,100 kcal/kg) and contains about 80 % of the

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[4] http://da.mod.uk/defac/colleges/csrc/document-listings/russian/f69/F69.chap4/

[5] http://www.sptimes.ru/story/19559, http://www.sptimes.ru/story/212,

[6] http://www.sptimes.ru/index.php?action_id=2&story_id=20048&highlight=leningradslanets (recent information, still need to be cross-checked)

volatile matters which escape under the heating to 390℃ without access for air in the form of pirabitumen (65%), gas and water vapors (15%). Elementary composition of kerogen is relatively constant: C (76,5%); H (9 to 9.9%);S (1.2 to 2%); N (0.2 to 0.5%); Cl (0.5 to 0.9%); O_2 (9 to 11%). Sulfur distribution in shale is as follows: sulphide (70%), organic (26%), sulphate (4%). It has been found that at a certain lithogenesis stage isolated gas bubbles of CO_2 (60% in composition), H_2 (20-26%) and CH_4 (13-19%) were formed in shale oil. The high content of heavy metals in these sediments enriched in carbon and iron sulphide has been found also in metamorphized analogues of Precambrian sapropel, i.e. shales in Finland. The carbonate shale part is represented mainly by calcite, in a lesser degree – by dolomite in the form of skeletal remains of various sea invertebrates and microscopical crystals.

- ***Pressures exerted on environment and natural resources***

The mine exploitation development results in the extraction on the earth ground of large masses of wastes. Every thousand tons of shale mining brings to the surface on average 100-115 m^3 of rocks. They are stored in the form of waste banks up to 60-80m high and ridged dumps (92%), as well as flat dump (8%). Rock dumps comprise argillites (60-80%), silstones (10-30%), sandstones (4-10%), limestones (up to 6%), pyrite (up to 10%), and coal (6 to 20%) but also wood and metal objects (tubes, wires, etc.). Leningradslanets has accumulated 30 million tons of wastes (limestone) with annual accumulation up to 2.5 million tons. During shale extraction, shale itself, adjacent strata and underground waters are extracted; methane, carbon dioxide and other gases together with mine dust are drawn off or spontaneously emitted into atmosphere.

Gases are escaping from the rock dumps, mainly during autocombustion. An average burning dump discharges annually from 620 to 1,280 tons SO_2, 3,000 to 5,000 tons CO, 230 to 290 tons H_2S, 11 to 30 tons NOx, 14,400 tons CO_2 (7,200 not burning). Sulfur oxides interacting with the atmospheric oxygen and water from sulphuric acid, with a release in the waters of the heavy metals contained in the rocks. In dump rocks weathering (and in particular during pyrite oxidation) the essential role is played by microbiological processes. The waters circulating in the waste dumps can be contaminated by numerous pollutants.

Main types of pressures that threaten the environment are: mine water discharge into surface water; run-off of drainage water from dumps into surface water; leaching of water from dumps into soil and groundwater / through ash ponds; atmospheric emissions of toxic substances through the burning of dumps; groundwater depletion/ depression cone/ hydrogeological properties modifications; risk of groundwater contamination if dewatering would stop.

According to the first progress report (2005), two areas are particularly polluted: (i) waste dump of Leningradskaya mine n°1 and adjoining territory up to Ruya river (area of 4 km²); (ii) three local polluters of Leningradskaya mine and mine n°3 with total area of 175 km², sludge reservoir, mine water reservoir and ash pond.

Figure 15. Leningradskaya mine n°3

Figure 16. Leningradskaya mine n°1 (left) ; Leningr adskaya mine n°3 (right)

Figure 17. Kirova mine water discharge point in Pjlussa river

2.3.2. Oil shale processing plant (Slantsy plant)

AO Slantsy produced oil and other chemical products using oil shale extracted in Slantsy area. *AO Slantsy* employed 2020 persons in 1999[7]. The shale was mainly processed by thermal treatment which produced shale resin (containing from 17.4 to 28% of phenols) and combustible gas. The resins were used to produce fuel and oil, bitumen, electrode coke, aromatic carbohydrates, tans, etc. In January 2007, economic situation changed since the plant was purchased by the Russian Gas&Oil Company Rosneft and will be transformed in an oil refinery[8].

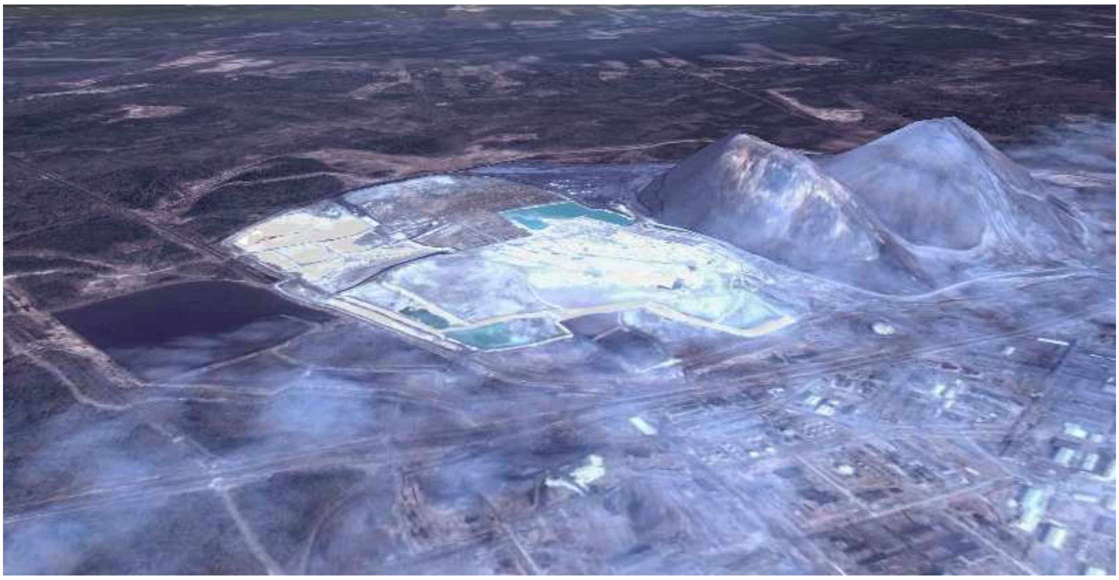

Figure 18. Satellite view of AO Slantsy

- ***Pressures exerted on environment and natural resources***

Oil shale processing activity causes an extraordinary high amount of pollution, both in the air, in the soil and in water (Figure 19). Storage of both solid and liquid wastes promotes manmade formations that could be dangerous sources of environmental pollution.

The waters (process, rainfall, surface) percolating through the wastes are able to remobilise the soluble components and carry them to the surface and underground waters. Variability of acid-base conditions determines different mobility of the chemical elements.

Pressures exerted by spent shale dumps. The shale from mines which is treated in the enriching factories (EF) is at the origin of waste shale dumps storage wich can pollute the surface water (through run-off of drainage water), groundwater (through leaching) and the atmosphere. Spent-shale disposal (ash, ash slag, etc.) is a major concern in oil-shale industry because of the volume of wastes to be disposed and the potentially harmful materials it contains. Leachates of spent shale are rich in phenolic

[7] http://da.mod.uk/defac/colleges/csrc/document-listings/russian/f69/F69.chap4/

[8] recent information, still need to be cross-checked

compounds, in larger quantities than in the raw shale leachate. Most compounds are present at the 10 to 50-ppb level, the exceptions being phenol, 5-methylresorcinol and resorcinol which are present in the 500 to 1,000-ppb range. These waters are characterised by very few nitrogen- or sulphur-containing organic compounds. Oil shale processing plant has accumulated about 70 million tones of ash wastes with an accumulation up to 2-2.5 million tones/ year (Sammet *et al.*, 2006).

Pressures exerted by waste water discharged into the "phenol channel" (Sizhenka river, length of approximately 5km) and treated in the Slantsy waste water plant before being discharged into *Pjlussa* river. According to Slantsy municipality, about 2 million m^3 of water (incl. 0.3 million m3 from groundwater) were used in 2005 for oil shale processing. In Estonia, the waste water discharges have strong impact on the surface water and groundwater quality; this impact is due to high content of phenols, oil, copper, lead, zinc, cadmium and mercury, released during oil shale processing (Perens *et al.*, 2001). The process water contained significant amounts of suspension particles, and flotation wastes 50-80 g/l (according to norm), such as flotreagent, flocculating agents, coagulants. Untreated and partially purified waters are discharged in the environment, and finally can reach the groundwater and, thus represent an important potential factor of downward migration of the chemical elements.

Pressures exerted through atmospheric emissions of toxic substances (SO_2, NO_X): During the process the vapors of phenols, carbon oxide, sulfur dioxide, carbohydrates and ash-shade dust were emitted in the atmosphere. Even after a three stages cleaning system, the drying units of EF used to release into the atmosphere up to 200-300 mg/m^3 of dust and fuel combustion materials.

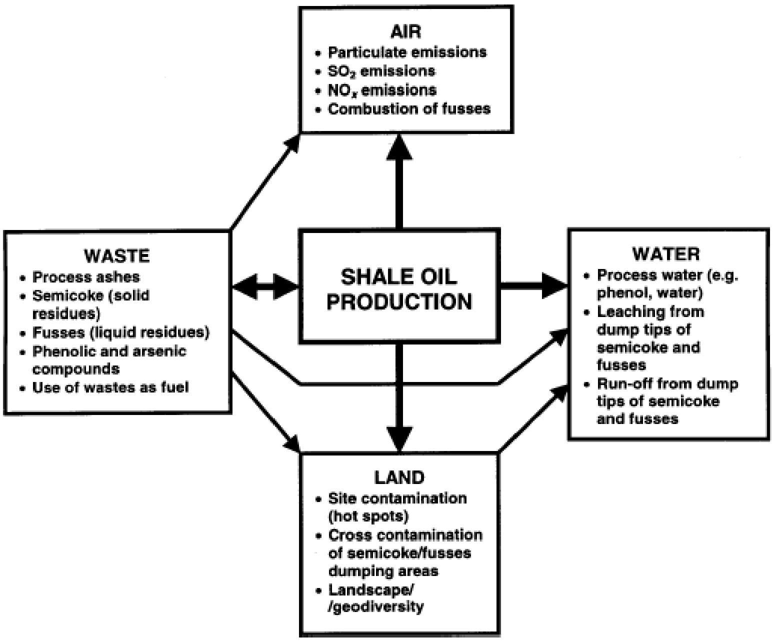

Figure 19. Environmental impacts of production of shale oil (Soone et al, 2003)[9]

[9] http://www.kirj.ee/oilshale/5_soone_2003_3s.pdf

Types of wastes	Waste storage (01.01.2004)	Annual waste storage	Annual waste use
Ashes	70.00	2.00	-
Coke	13.00	0.50	0.27
Kerogen	-	0.02	-
Flue ash	-	0.10	0.06
Ash-slag	10.00	0.44	0.44

Figure 20. Wastes storage and use (million of tones) by AO Slantsy according to the data of the Committee on use and protection of mineral resources (NARVA Progress report n°1, 2005)

2.3.3. Tsesla (cement factory)

According to the interviews, *Tsesla* was one of the most polluting industrial complex of the area in the past, especially through atmospheric emissions. Since this unit has been purchased by the German investor *Heidelberg Cement*, toxic emissions seem to have been decreasing significantly through the addition of filters. About 700,000 tons were produced in 2006. The following data have been provided by the municipality of Slantsy:

Water intake (2005): 444,000 m^3 incl. 144.000 m^3 from groundwater

Waste water discharge (2005): 198,000 m^3 without treatment.

Emissions to the air (2005): 948 tons (90% treated)

Toxic waste formation (2005): 73 tons (65% used and treated)

A new cement plant is planed to be built by 2009[10] by *LSR Construction* group, located near the limestone heaps from Leningradskaya mine n°1. The planned capacity of production is between 1 and 2 million tons of cement a year.

2.3.4. Polymer

The following data have been provided by the municipality of Slantsy:

Water intake (2005): 266,000 m^3 incl. 9,000 m^3 from groundwater

Waste water discharge (2005): 399,000 m^3 (incl. 374,000 without treatment).

Emissions to the air (2005): 21.4 tons (58% treated)

Toxic waste formation (2005): 267 tons (100% used and treated)

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[10] see http://www.sptimes.ru/story/18889

3. Diagnosis of the State of environmental resources

3.1. GROUNDWATER RESOURCES

3.1.1. Description of the groundwater resources

A) <u>Geology and hydrogeology of the district</u>

Slantsy mining district is part of the Luga monocline in the north-western part of the Russian platform. Geology is composed of Archaean-early-proterozoic formations of the cristalline basement and sediments of the Vendian-Paleozoic cover. The thickness of the sedimentary rocks is up to 400 m. The recent quaternary sediments cover presents a thickness from 2-6 m up to 13-19 m. Small outcrops of the *Ordovician* and *Devonian* deposits are met along the banks of *Pljussa*, *Ruya* and *Kushelka* rivers.

The carbonate rocks of the Ordovician outcrop, mainly in the northern part of the area, are called the Ordovician plateau. Devonian sediments are distributed along the remaining part of the area and form the Devonian plain.

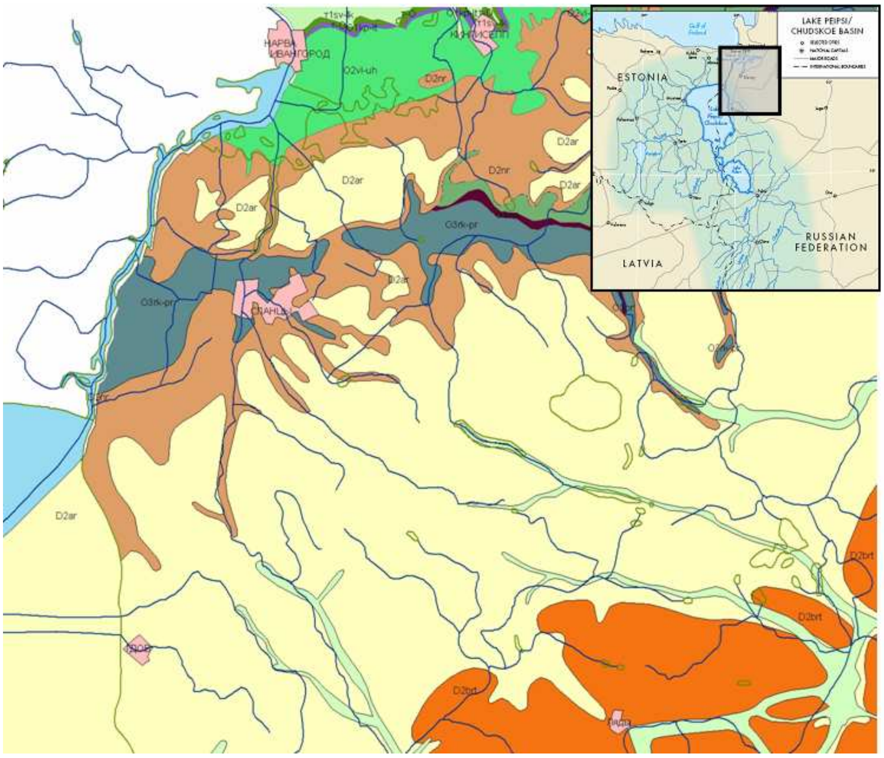

Figure 21. Geology of the region (1/500 000)

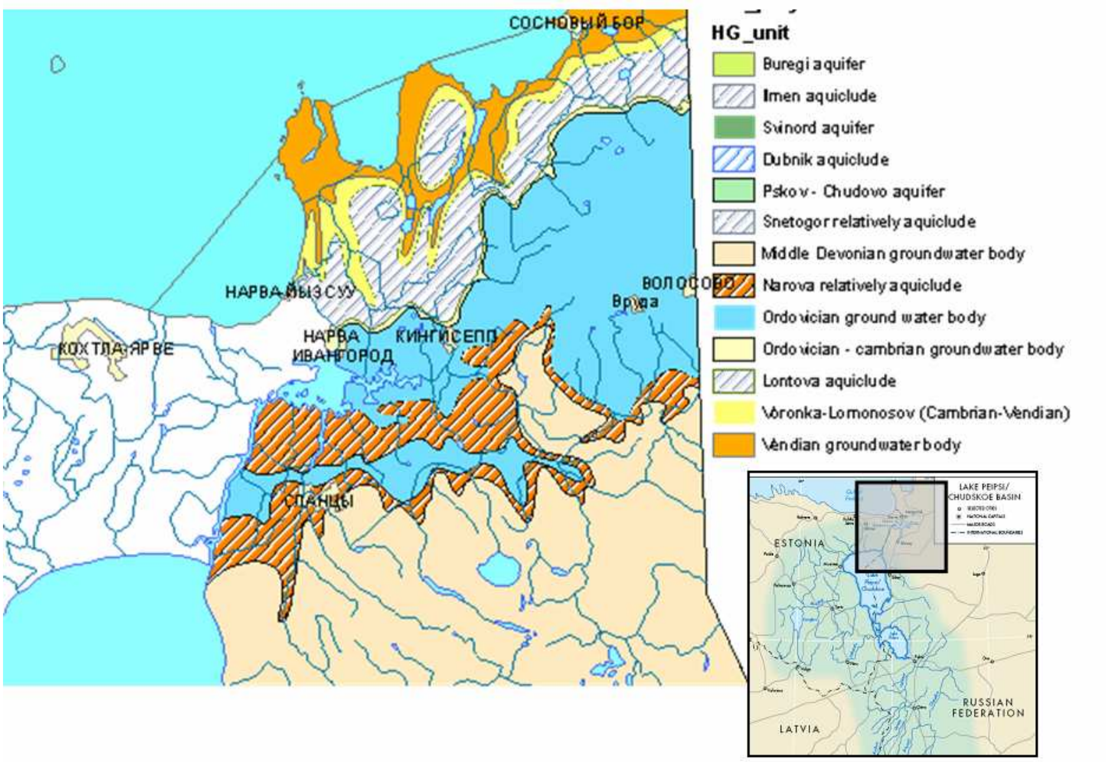

Figure 22. Subcrop map of the aquifer systems underneath the Quaternary (E. Sammet, 2006, 1/900 000)

Hydrogeologically the study area corresponds to the northwestern part of the Leningrad artesian basin. The water-bearing systems are hosted by the quaternary and prequaternary sediments. Aquifers and water complexes of the upper part down to the *Lomonosov* aquifer are characterized by a diversity of recharge and circulation of the groundwater. The lower aquifers (*Voronka*, *Lomonosov* and *Vendian* aquifers as well as waters from the fractured crystalline basement) present a lower permeability, have chloride-sodium composition and are classified as salty with a total mineralization of1.5 to 5.0 g/l.

Below the Leningrad oil shale deposit there is a regional aquitard (*lower Cambrian* blue clay of *Lontova* aquifer) which protects the *Lomonosov* aquifer from pollutions originating from the above strata. Above the *Lontova* aquitard, the following aquifers are dewatered by the mine belong to the *Ordovician* complex: *Nabalsky-Rakversky, Keilasky-Jikhvy, Kukersky and Tallinsky-Volkhovsky aquifers*.

Several aquitards used to separate these aquifers: *Oandussky*, *Vazaversky*, *Kukersky* and *Latorpsky*, of which only *Oandusky* (dense clay and marl) and *Kukersky* (industrial stratum of oil-shale) could be considered as impervious. These aquitards were considered, before the exploitation of the oil shale, as impervious layers with limited vertical drainage between the aquifers. Today the dewatering of all this layers, in relation with the exploitation of the mines have modified the structure of these layers and increased considerably the vertical permeability between the aquifers, i.e. several well individualized aquifers before the mine exploitation could be today, considered as constituting one aquifer due to the importance of the hydraulic connections between them.

From the top to the bottom one can find the following succession of aquifers (see Annex 3):

- ***The Quaternary aquifers***

Alluvial, lacustrine, bog, lacustrine-glacial and fluvioglacial deposits could be considered as water bearing layers. They lie on loamy valdai moraine. Water-bearing rocks are sands of different grain and rarely sandy loam. The Aquifer thickness usually amounts to 1-5 m and only in some deep valleys it reaches 20-30 m. This water complex is not protected from the surface pollution infiltration. The water from the quaternary aquifers is used for water supply mainly through private wells.

The location of the paleovalleys filled by quaternary rocks is an important parameter in the understanding of the circulation of the shallow waters. These valleys can represent preferential drains crossing the prequaternary layers and present a preferential pathway for the quaternary waters (easily polluted) to reach the mining zone due to the pumping scale in this area.

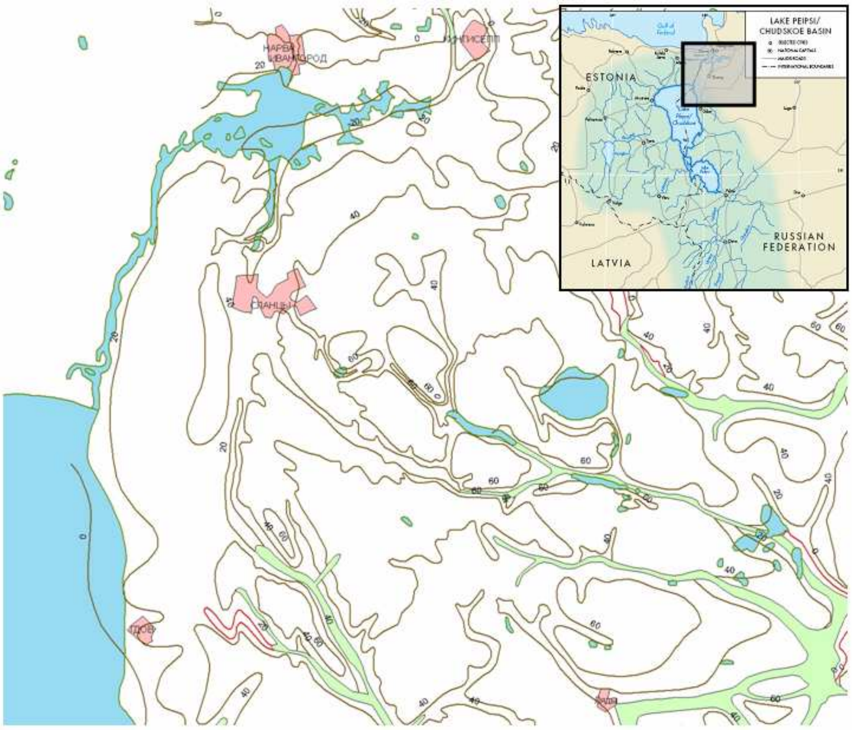

Figure 23. Distribution of the paleovalleys in the study area (1/500 000)

- ***The Devonian aquifers***

Arjukjulask terrigenous water complex

This complex is distributed in the northern and southern parts of the area: it is present as small spots in the area of the oil-shale field (southern part of the Leningradskaya mine). The water-bearing rocks are fine-grained sand and sandstone, rarely siltstone with thickness from 1 up to 15m. In the southern part the aquifer is used for agricultural water supply. Its natural protection from the surface pollutions is weak and its contribution to the pumped water for the dewatering of the mine is small.

Narovsk terrigenous carbonate series

They are distributed in the northern and southern parts of the area. Along the shore of Narva reservoir and in Narva river outlet there are laid under the quaternary sediments. This complex is usually represented by three members: the upper (sandy-clay) with thickness 3-11 m, the middle (dolomite-marlaceous) with thickness 10-12 m and the lower (clay-marlaceous) with thickness 4-5m. In some parts when the serie is close to the surface the rocks of the Narovsk water complex are more fractured and as a consequence this aquitard become an aquifer that can be tapped for groundwater exploitation. The Narva aquifers involvement in the dewatering of the mines is not significant. As an aquitard[11] the Narva layer prevent the migration downwards of the water from the Pljussa river.

- ***The Ordovician aquifers***

Rjagaversk-Upperordovician carbonate aquifer

It is distributed to the south from Rjagaversk scarp. Water-bearing rocks are limestone and dolomites overlapped by thin quaternary sediments in most of the Leningrad field and by Devonian sediments in the area adjacent to Narva reservoir and in the northern part of Narova and Pljussa rivers interfluves. Thickness of this water series is 5-17 m. Underlying rocks are clay and marlstone limestone of Hirmuzesk series of the middle Ordovician. The peculiarity of these rocks is their high karstification. Surface karst is represented by karst craters and small caves found for example along Sibirsky stream. Underground karst has been crossed by numerous wells.

The results of the monitoring of the area showed that the water-bearing series is isolated from mines. However, significant volume of waters falls in the mines by the non-plugged wells. This artificial communication decreases the amount of water that can be pumped from this aquifer for drinking water supply. In the area of the gas-shale plant, the waters from this water series are polluted by shale-processing products. According to the estimations of 1979 up to 500 m^3/h of water percolate into the Leningrad mine and more than 100 m^3/h reach the Kirov. These figures have not been updated recently.

[11] Narva geological layers can be considered, according to their proximity to the ground surface, as an aquifer or an aquitard

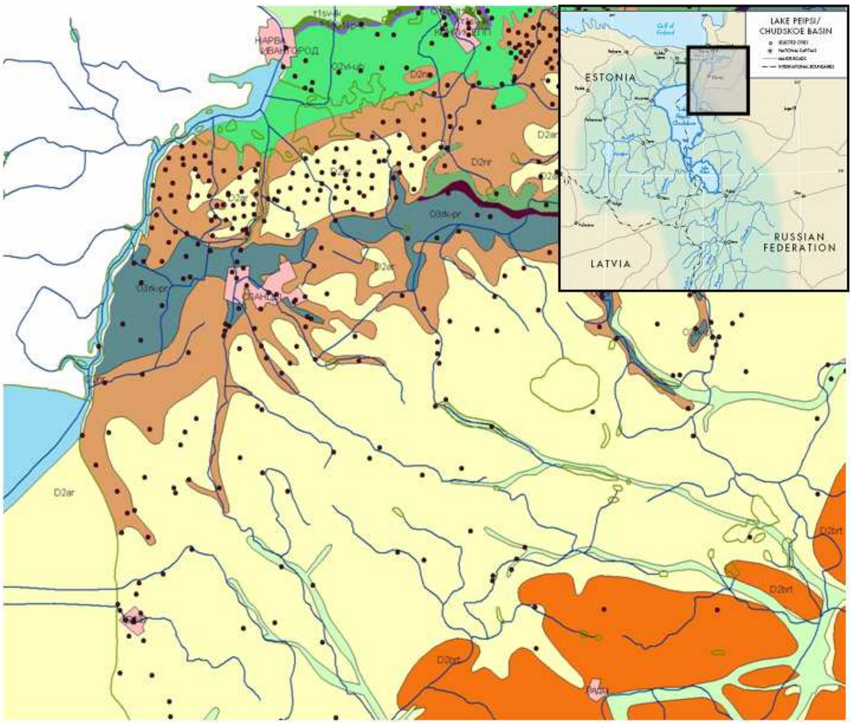

Figure 24. Location of the boreholes reaching the Ordovician geological layers (1/500 000)

Volkhov-Keilask carbonate serie

This serie is distributed all over the territory and it combines a complex succession of carbonate, argillaceous and shale strata with a total thickness up to 80m. There were three water-bearing formations composing this serie.

Yikhvinsky-Keilask carbonate water-bearing formation

It is represented by weakly karsts dolomite limestone and argillaceous limestone. Water could get into the mines by the non-plugged wells where it mixes with water from the upper-layers aquifers.

Vijvikonask carbonate-clay water-bearing formation

It is represented by alternation of limestone, argillaceous limestone, oil-shale. Its thickness is 18-26m.This formation is partly dewatered within the mining area. Hydraulic connection between this aquifer and the upper potentially polluted water series is effective due to the existence of thin fractures and karst phenomena. These karstified zones have a complex morphological and geochemical zonality described when implementing special works provide water inflow to the mine from 0.1 up to 15-20 m^3/hour.

Duboviksky-Porozhsky carbonate aquifer

It is represented by karstified dolomite limestone and by dolomites of the Volkhov, Obukhovsky, Duboviksky and Porozhsky formations of the lower and middle Ordovician with a total thickness of 18-26m. Up to the beginning of the eighties, the diameter of the drawdown cone amounted to 35km. As a result of the drawdown in the central part of the field the piezometric surface became lower than the mine floor, and polluted mine waters were able to flow into the aquifer. Glauconitic clay sandstones and clays with thickness from 0.3 to 0.8 m at the base of this aquifer play the role of an aquitard

- ***The Cambrian-Ordovician terrigeneous complex***

It is distributed all over the territory. The water-bearing rocks are sands and fine-grained sands. Their thickness is 27-34 m. Nowadays a drawdown depression cone has been induced partly by the pumping in the mine; its depth amounts to 80-85m. In fact this drawdown is related also to the water flow in the mine works as well as the exploitation of aquifer for drinking and industrial watersupply. There is a danger of groundwater pollution from mine working in the central part of the developed field. *Cambrian-Ordovician aquifer* lies at a depth of more than 100 m and could interact with the upper aquifers only in fractured zones. Its water is hydrocarbonate chloride-sodium, with a content of chloride up to 60 mg/l.

- ***The Lomonosov-Voronka aquifer.***

It is distributed all over the area. Water-bearing rocks are fine-grained sandstones with alternation of clays with thickness 10-15 m. As a results of the pumping for drinking water supply, by the beginning of the eighties the level in the area of Slantsy town was decreased by 70m. This drawdown leads to the drop of production of the wells in Kingisepp, Ivangorod and Narva towns. This aquifer is not connected with the mines and it is protected from the pollution by upper-laid regional waterproof aquitard (*Lontova*). But investigations carried out in the 70s revealed phenol pollution caused by water flow along poorly-equipped wells.

- ***The Vendian aquifer***

It is distributed all over the area, sandstones with alternance of clays and siltstones with a thickness 55-70 m. The aquifer is isolated from the upper layers by an impervious layer; it contains salt chloride sodium water that is used for balneal purposes.

B) <u>The hydrogeological regime in relation with the mining exploitation</u>

Before the extraction of the oil shale deposit the general flow of underground waters was directed towards the Gulf of Finland, while recharge variations were related to the rainfall conditions.As mentioned earlier, the extraction of the Leningrad oil shale deposit has induced a significant modification of the natural ground water hydrodynamic characteristics of numerous aquifers resulting in the formation of general water inflow in the mine, mainly, from the Wesenberg, Jöhve, Kuker and Tallinn horizons. The thousand of wells, the mining works and the dewatering of these works have strongly modified the original hydraulic links and the importance of the water flows between the different aquifers.

The main aquifers, whose behavior is determined by the operating conditions of the Kirov and “Leningradskaya” mines, are *Wezenberg*, *Kukruse* and *Tallinn* aquifers that belong to the carbonate Ordovician layers. The shale oil exploited layer is located at the bottom of the *Kukruse*aquifer. The *Wezenberg* aquifer is fed by precipitation infiltration across its complete outcropping area. Under the man-caused conditions, the *Kukruse* and *Tallinn* aquifers are fed by the flow from the *Wezenberg* aquifer.

Underground waters are flowing into the mining excavations and then discharged in the rivers. The *Kukruse* aquifer is in hydraulic connection with the mining excavations mainly at the boundary of the mine. Indeed the inflow of water from the Kuker horizon takes place mainly at the perimeter of the mining area. The *Wezenberg* aquifer is also in general connection with the works by vertical drainage through a weakly impervious aquitard (the *Shundorov* strata). Outside the mining area, the *Wezenberg* and *Tallinn* aquifers flow into the *Kukruse* one in the areas where the piezometric level in the *Kukruse* aquifer is lower than in the adjacent aquifers.

The importance of the volume of water flowing in the mining works is in relation with the existence of weakly impervious aquitards below the water-abundant *Wezenberg* horizon and *Tallinn* horizon. Outside the extraction area, groundwater flows in Kuker and Tallinn horizons are characterized by subhorizontal direction with average seepage gradients of about 1%. Basing on analytical results, it can be assumed that the aquifers located both above and below the mined oil-shale layer provide up to 75-80% of the total mine water inflow. The extent of this connection is in relation with the extent of the mining zone and the pumping station associated. The groundwaters are recharged by percolation of rain and melt water through the top soils.

Therefore, due to the exploitation of the Leningrad deposit mines, significant modification of the natural ground water regime took place. At present, mine galeries are the main ways of draining ground waters from the *Kuker* and *Tallinn* aquifers. Inflow of water in the mine works of Kirova mine amounts to 1,000-1,100 m^3/hour and reaches 3,500 m^3/hour in Leningradskaya mine. This Inflow of water is also in relation with the drainage of the *Wezenberg* aquifer which also discharges into the *Pjlussa* and its feeders. The draining influence of the mines extends to 10-20 km from the borders of the mining area. While the general direction of regional groundwater remained unchanged with a flow towards the Gulf of Finland, logically and due to the pumping rate the local flows around the mines are converging towards the pumping wells zone.

The drawdown is at its maximum in the *Kuker* water-bearing horizon which is directly crossed by the mining galeries. The minimum drawdown is observed in the *Wezenberg* aquifer; however as mentioned earlier the water flows from this horizon along the drawdown cone to the *Kuker* water-bearing horizon which is drained by the mining galeries.

The head of the *Tallinn* aquifer is reduced too, due to the influence, on the vertical drainage, of the mine works dewatering. As a consequence the water flows from *Kuker* horizon to *Tallinn* horizon along the drawdown cone.

The amplitude of the seasonal variations of the piezometric levels has been modified in relation with the mine exploitation. In particular, the amplitudes of the water level variations in the *Wezenberg* aquifer measured above the mining zone reach 3-4 m and even more. Southeast-ward and northwest-ward from those areas, the amplitudes decrease as the general drawdown is here minimal.

From the information available it appears that roughly 50% of the water pumped in the mining areas is coming from the aquifers below the *Shundarosky* aquitard and 50% from the upper *Ordovician* aquifers.

						Top		Water level		
System	Division	Thickness		Aquifer/Aquitard Name	Lithology	Depth from surface (m)	Elevation (m)	Depth from surface (m)	Elevation (m)	Water mineralisation g/l
Devonian	Middle	20								
		100		Arukjulask Amatsky	Sand with sandstones and siltstones	0 --50	10 à -70	1 -- 25	25 -- 75	0.3 - 0.5 1 - 2
		31		Narva	Dolomite, marl, sandstones	0--120	-70 - 40	0 - 25	25 - 70	0.3 - 0.5 1 - 2
		20								
Orovician	Upper	17			Dolomite, limestone with interlayers of clay					
		14		Wesenberg- Rakvere		20 - 150	-80 -25	+10 - 40	35 - 65	0.3 - 0.5
		20								
	Middle	11			Carbonates					
		19								
		4			Limestone clay	25 - 155	-85 -30			
		35								
		15			Carbonates, limestones, dolomites					
		12				0 - 180	-120 -10	0 - 10	-45 - 65	0.3 - 0.9
		11		Kukruse		0 - 30	20 -150	5 -25	30 - 150	
		15			OIL SHALE mining zone					
		20								
		17		Tallin						
		11								
		5								
		6		Ordovician aquitard	Clint Shale (schistes noir)	0 - 75	-50 -25			
		10								
Cambrian	Upper	7		Obulus						
		9		Cambro Ordovician aquifer	Sands Sandstones	0 - 300	-200 -125	O - 70	-45 - 140	0.3-0.5
	Middle	17								
	Lower	19								
		16								
		130		Lontova aquitard	Clays	0 - 340	-240 - 100			
		12								
Vendian	Upper	15		Voronka Lomonosov	Sandstones, clays	20 - 400	-325 - 25	25 - 100	-10 - 60	0.3 - 0.7
		125		Kotlin aquitard	Clays	20 - 425	-350 - 20			
		40		Vendian						
		43			Sandstones, sands ans clay	100 - 475	-450 -(-100	0 - 40	-30 - 0	
		>346			Granite, Gneiss					

Figure 25. Aquifers distribution above and below the mining works

The monitoring of the piezometric levels of the different aquifers allows identifying the following main factors (Figure 25):

– On average the *Wezenberg* aquifer heads across the mining area are 40-45 m above the heads of the *Kukruse* aquifer, and are close to 20 m outside this area;

– The drainage from the *Wezenberg* aquifer into the *Kukruse* one across the mining area and outside of this large mining zone are similar;

– The *Tallinn* aquifer heads are on average 5m above the mining floor, however outside the mining area, the *Kukruse* aquifer heads are higher that the *Tallinn* ones.

In summer 2004 the piezometric levels of the boreholes, bored in the Kirova mine were the following (Figure 26):

Borehole number and aquifer	Occurrence depth(numerator) and elevation (denominator) of groundwater level in boreholes of a hydro-operated group, m			
	26.12.03	22.02.04	14.04.04	28.05.04
Borehole №1 – Wezenberg aquifer	16.85 26.93	16.65 27.13	16.63 27.15	20.24 23.43
Borehole №2 – Kukersky aquifer	20.30 23.42	20.42 23.30	21.03 22.39	21.70 22.02
Borehole №3 – Tallinn aquifer	66.40 -22.75	66.44 -22.81	67.63 -23.98	68.67 -25.02

Figure 26. Piezometric levels in the monitored Boreholes (Podsevalov, 2006)

C) Groundwater uses

The main aquifers taking part in watering of the mine works playing a role in the mine water flow and quality are the *Wezenberg*, *Kukruse* and *Tallinn* aquifers. These aquifers are tapped to supply the human activities. To provide economic and drinking water supply of the town and neighbouring places the waters of the *Wezenberg*, Cambrian-Ordovician (*Obolus*) and Lomonosov aquifers are used, while the waters of the *Tallinn* and *Obolus* aquifers are used for industrial purposes. The water-supply wells from the underground water are drilled in different parts of the town and they belong to several production factories, including *OAO Leningradslanets*.

№	Water intake point	Aquifer	Average annual water intake, m^3/day
1	Slantsy	Ordovician (pumping)	74,074
		Cambrian-Ordovician	501
		Lomonosov	1,940
2	Vyskatka	Ordovician	1,148
		Cambrian-Ordovician	33
3	Gostilitsy	Ordovician	123
		Cambrian-Ordovician	3
		Lomonosov	189
4	Ovsische	Ordovician	386
5	Staropolje	Ordovician	225
6	Novoselje	Ordovician	173
7	Kamenka	Lomonosov	99
8	Sosnovka	Ordovician	14
	Sub-total	Ordovician	76,143
		Cambrian-Ordovician	537
		Lomonosov	2,228
	Total		**78,908**

Figure 27. List of water intake points (Source: Slantsy municipality, 2006)

3.1.2. Assessment of the vulnerability and quality of groundwater resources

A) Aquifers vulnerability

The land-use activities that take place at the surface can affect groundwater quality, and the physical or geologic characteristics of the vadose zone and aquifer can provide protection or not from infiltrating contaminants. Land-use activities and aquifer sensitivity are combined to define a relative term that is used to qualify the real risk to a given aquifer: vulnerability. A vulnerability assessment defines the risk to an aquifer based on the physical characteristics of the vadose zone and aquifer, and the presence of potential contaminant sources. This can be an important tool for communities and private well owners interested in protecting the long-term viability of their drinking-water source. The implementation of land-use planning or zoning overlays based on aquifer vulnerability can prevent aquifer contamination by carefully locating potential contaminant sources in areas of very low aquifer sensitivity.

The Figure 28 shows that almost all of the aquifers close to the surface in the area of Leningrad oil-shale area are not protected from the potential surface pollution (industrial through the phenol pollution caused by shale-processing plant as well as by dump of liquid industrial wastes and agriculture through phosphate fertilizers and pesticides uses, nitrates and organic fertilizers). This is in relation with the low thickness (less than 5m) and rather high permeability of the quaternary. Another aquifer type of vulnerability is related to the drilling of thousand boreholes in the mining zone which can act as a preferential pathway and interconnection between aquifers. On the map the extension of the phenol pollution of the Cambro-ordovician aquifer demonstrates the importance of these phenomenons.

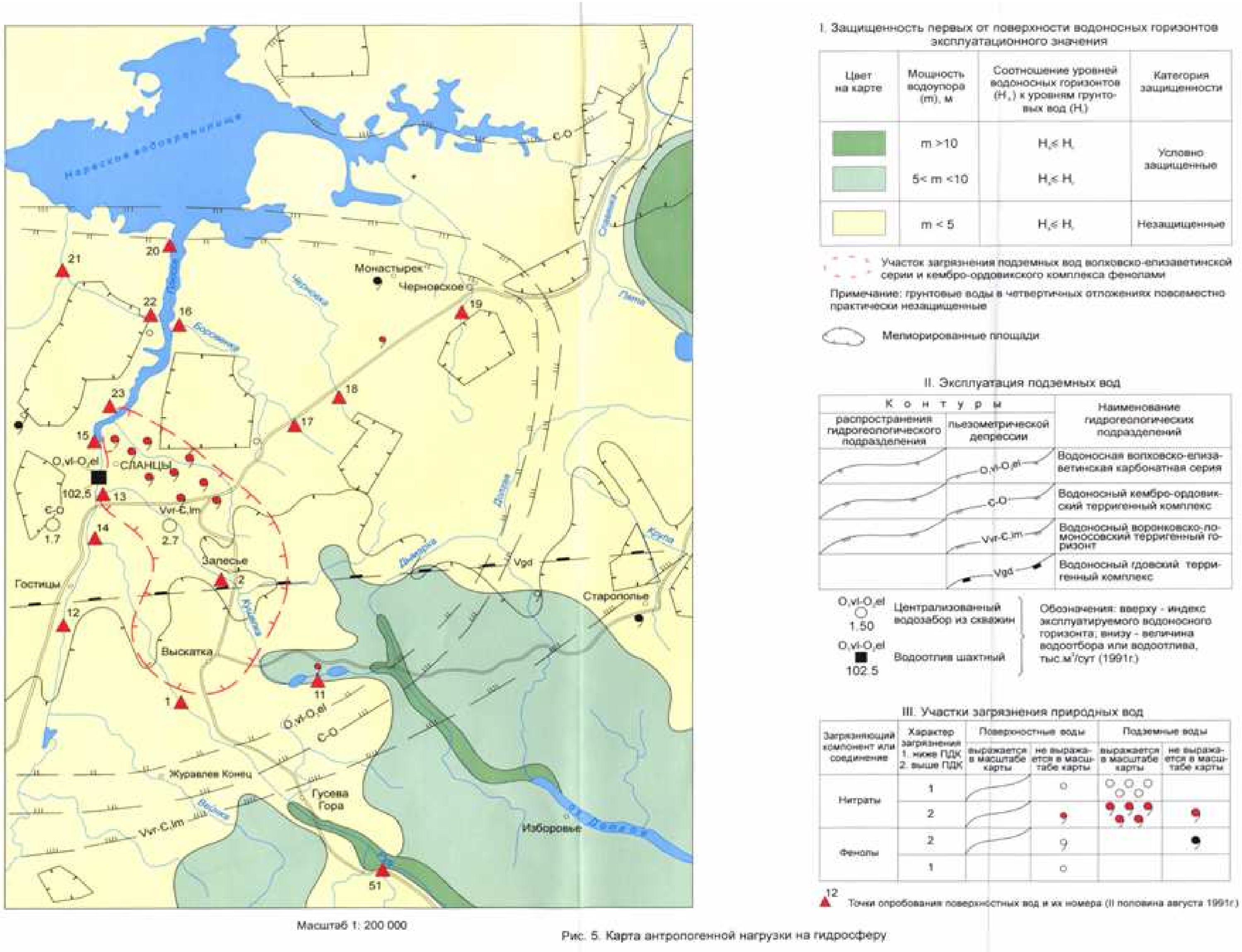

Figure 28. Vulnerability map and impacts identified (Sammet et al., 2006)

B) Aquifers water quality

The results of the chemical analysis of the water from the water-supply wells drilled in the *Wezenberg*, *Obolus* and *Lomonosov* aquifers are the following: concentrations of phenols and metals (exceeding the Maximum Permissible Concentration) are observed only for elements as manganese, beryllium, chrome, wolfram, barium and cadmium.

The ***Wezenberg*** aquifer is made of Upper Ordovician karstic limestone and dolomites. This layer lies generally directly under the quaternary deposits and is the most vulnerable to surface pollution including volatile phenols. This fact is confirmed by the results of the water analysis: the highest concentrations of phenols were observed in this aquifer. The pollution of this aquifer by phenols was also registered in the southeast part of the Kirova mine by results of sampling of wells 2 g/g and 1/7345 carried out in 1997-99 (0,016 - 0,003 mg/l). The concentrations of beryllium exceed the MPC by 1.5 times, and the concentrations of barium by 10 times.

The ***Tallinn*** aquifer underlying the *Kukruse* aquifer takes part in the watering of the mine works, where the piezometric level of this aquifer exceeds the level of the *Kukruse* aquifer. As there is no real confining bed between the *Tallinn* aquifer and the bottom of mine workings, it has been observed periodic occurrence of volatile phenols in concentrations from 0.002 to 0.02 mg/l in certain wells drilled through this aquifer both from the surface and from the mining zone. This fact indicates that in the mining area, where the piezometric surface of the *Tallinn* aquifer ranges below the mine works level, the infiltration of the potentially polluted mine water into this aquifer is possible.

The water of the ***Obolus*** aquifer was studied in detail in the 70s. According to the synthesis of numerous chemical analyses the concentration of volatile phenols in water-supply wells varied from 0.002 to 0.02 mg/l while phenols were discovered in the water of wells in 13 events out of 73. However, as a rule, these concentrations were not accompanied by other indicators of water pollution: odor of crude shale oil, increased oxidability, etc. It should be mentioned that the concentration in phenols is erratic: the same wells resampled later on could show the absence of volatile phenols. In 1997-99 the determination of volatile phenols was carried out in the water of four water-supply wells drilled from the surface, as well as in five underground wells drilled from the mine works of the Leningradskaya and Kirova mines. It was observed a periodic occurrence of phenols in the water of these wells. An anomalously high content of volatile phenols (0.034 mg/l) was also identified in the water samples from a borehole drilled closed to the Slantsy shale processing plant. The water of the *Obolus* aquifer contains chrome (0.0521 mg/l), wolfram (0.074 mg/l) – the concentrations of these components are close to the MPC, as well as for beryllium ($2.5 \cdot 10^{-3}$ mg/l), cadmium (0.018 mg/l) and barium (3.62 mg/l). The content of the last three elements in the water is tens times higher than the MPC.

In the ***Lomonosov*** aquifer, in the samples taken in 1997-99 from the water-supply wells located in the mining zone and in its vicinity, it was observed certain periodically occurring concentrations of volatile phenols (0.001 - 0.058 mg/l). Taking into account that this aquifer is overlaid by almost 100-meter regional stratum of Cambrian clays, it is only possible to explain this phenolic pollution of the water by a migration downward of the polluted surface water or a mine water migration through the leakages of the casing of these production wells. In the water of the *Lomonosov* aquifer the concentrations are above the MPC for chrome (0.0846 mg/l), cadmium (0.005 mg/l), beryllium ($2.7 \cdot 10^{-4}$ mg/l) and barium (1.32 mg/l).

C) ***Mine water quality***

Before closure of Kirova mine the works were carried out at the depth of 70-80 m (in Leningradskaya mine at the depth of about 100 m). Therefore the chemical composition of the different pumped mine waters is very similar as the two mines are hydrogeocally connected. Nowadays the mine waters pumped from the two mine fields are discharged in the *Pljussa* river directly of through the Ruya, Kushelka and Sizhenka rivers (Annex 2). The analysis below is based on mine water discharges quality data (Annex 6) provided by Podsevalov (2006).

***pH*.** According to requirements for composition and properties of water in fishing water bodies, pH value must not exceed 6.5 – 8.5. The pH in mine waters is close to 7. Sometimes it goes down to 6.5. Such variation in mine water could be put in relation to the formation of acid mine drainage in relation to the oxidation of the sulphide minerals. However this production of acid is here limited (as the resulting pH is only 6.5) due (1) to the buffering action of the limestone rocks preventing a generation of highly acidic water and (2) to a dilution due to the inflow in the mining area of groundwater from the different aquifers below and above the mining area.

Hydrocarbons*.* Oil products are complex, variable and diverse mixture of substances. Significant quantities of petroleum compounds are discharged into surface waters through the sewage systems of the oil –processing enterprises, oil refining, chemical, metallurgical and other plants,. Oil products exist in different forms that can potentially migrate downwards to reach the groundwater. However the content of oil products in the mining and surface waters does not exceed the MPC.

Phenols are one of the key potential pollutants in an oil shale context. In 2005, excess of the MPC for phenols was observed in the southern discharge of the Leningradskaya mine n°3 and Kirova. In all water samples taken dur ing underground hydrochemical surveys in 1999-2000 at the abandoned Kirova mine it was detected the presence of volatile phenols which concentrations exceeded the MPC. The maximum concentrations of volatile phenols (0.0065 – 0.010 mg/l) were registered in the water samples taken from drainage ditches disposing the mine water to the South water header. In the water of the South water header itself, which receives the mine water from the area of flooded mine workings, the concentration of phenols reached 0.010 mg/l, while in water of the Central mine drainage the content of phenols did not exceeded the MPC.

Phenols are derivatives of benzole with one or several hydroxyl groups and commonly are divided into two groups – volatile phenols with vapours (phenol, cresols, xylenols, etc.) and non-volatile phenols.

The possible sources of phenol resulting in the pollution of the mine water are the following:

- *Industrial wastes of the shale processing factory:* the phenol pollution of the underground mine water by industrial wastes of the oil-shale processing factory (§ 2.4.2) can occur below several zones due to the leakage of the process water from storage of liquid wastes of the oil shale treatment plant and phenolic water drainage from the factory. The pollution of the underground water of *Wezenberg* aquifer and, accordingly, of the mine water takes place as a result of influx of the water from this aquifer through technical boreholes, karstic features and fractures. The air deposition of contaminated gases and particles in the Slantsy area – as a result of wind pollution by materials of coke ash dumps and emissions of the factory, represents another source of contamination that can at the end reach the groundwater.

- *Hydrolysis of oil shale directly in the mine workings:* The second possible reason of occurrence of phenols in the mine water is the oil shale hydrolysis running intensively in the zones where the mine water is in contact with the oil shale layers. The results of the hydrochemical sampling of the mine water at the currently flooded south wing of the Kirova mine may indicate that the scale of the phenolic pollution of the mine water increases during the flooding of the mines. The concentrations of volatile phenols have reached 0.01 mg/l, i.e. have exceeded the MPC by a factor of 10. It will be important to follow in the future this concentration in phenols to follow this chemical trend.

Sulphate. The average content of sulphate ion in the mine waters was equal to 57–88mg/l in 2005 and 50-119 mg/l in 2006 (below the maximum permitted limit: 300 mg/l). The content of sulphate is low confirming that the process of oxidation of sulphides minerals is limited or/and that there is a dilution by the waters originating from the different aquifers. Sulphates are also present in the waste waters from sewage systems and farms.

Ammonium. The content of ions of ammonium in the mine water varies but does not exceed the established MPC standards for the fishery ponds. The main sources of ammonium ions in water reservoirs are stock-rearing farms, industrial and household waste waters, surface runoffs from farmlands in an event of application of ammonium fertilizers, as well as waste waters of alimentary timber and chemical, coke-chemical and chemical plants.

Fluorine. The content of fluorine in the mine water is increasing in certain zones of the two mining areas but is still below the MPC. In the natural water the fluorine is presented in the form of fluoride-ion. Its high content (from 0.1 to 0.38 mg/l) is connected with destruction of fluorine-containing minerals (apatite, tourmaline). The fluorine is introduced into the river and mine water from soils and rocks as a result of the groundwater pumping network. The content of fluorine at the flood period is always lower than at the low-water season as the portion of the seepage flow is reduced. A high concentration in fluorine in the water (more than 1.5 mg/l) has a harmful effect on people and animals and may cause a bone disease (fluorosis). The content of fluorine in the potable water is limited. However, a very low content of fluorine in the potable water (less than 0.01 mg/l) is also harmful to human health and poses hazard to produce caries of teeth.

Iron. The content of iron in the mine water is characterized by a great variability. In 2005 the content of total iron was 0.16 mg/l in the water of the Leningradskaya mine n°3, while in the water of the Kirova mine it reached 0.88 mg/l. In 2006 the variation was from 0.06 to 0.7 mg/l. The main sources of iron compounds in the surface and mine water are in relation with the processes of natural weathering of rocks. This natural occurrence is confirmed by the content of total iron in the surface waters upstream of the mine discharges with a variation from 0.18 mg/l (the *Ruja* river) to 0.7 mg/l (the *Pjlussa* river), which exceed the established MPC for fishery water basins (0.1 mg/l).

Heavy metals. The comparison of the results of mine water sampling of Leningrad Institute of Mines in 1972 and the water samples taken during underground hydrochemical surveys in 1999-2000 has shown a distinct trend in change of concentrations of heavy metals in the mine water. If over the period from 1972 till 1997 it was observed a significant growth of their concentration, the results of underground hydrochemical surveys in 2000 indicate a decrease of concentration of heavy metals.

The concentrations in heavy metals (except copper) in the mine waters are today (2005 and 2006) well below the Maximum Permissible Limit, or even below the detection limit (mercury, arsenic, zinc, cadmium, chromium). The occurrence of the most of heavy metals in the mine water composition could be related both to oxidation of sulphide minerals and hydrolysis of oil shale. These processes may facilitate accumulation of heavy metals in the mine water. The sulphide minerals which are present in the veins mineralization, as well as a in the dolomitisation zones, are related with fissures and karst developments. The cavernous limestones of *Wezenberg* zone very often contain impregnation of pyrite, blende and galena. The areas rich in sulphides often are observed on the borders of the dolomitization zones. Sulphides are met in the form of not discernible crystals of several millimetres and the druses reaching several centimetres in diameter. The trace element analysis of oil shale show the presence of vanadium, tin, molybdenum, nickel, cobalt and a number of other trace elements.

Copper. The content of copper in the mine water has increased at almost all pumping stations. The content of copper is characterized by inconstancy: from concentration which is lower than the detection limit up to values above the MPC (maximum of 13 µg/l in 2006 in the central Leningradskaya mine). The presence of copper in underground waters is conditioned by the interaction of water with copper-containing rocks.

Barium. The concentrations of barium in the mine water exceed the MPC for potable water. One should search for the reasons of rather high concentrations of barium in mineralogical and crystal-chemical composition of limestone: barium being an alkaline-earth element is capable to substitute Ca and Mg in a crystal lattice of carbonates. Thus, the anomalous concentrations of barium have a natural and not a man-caused origin.

D) <u>Impact from the mining activities on groundwater quality</u>

The dewatering of the mines plays a significant role in the evolution of the chemical composition of the groundwater. The drawdown depression of the piezometric surfaces has an impact on the hydraulic pattern and relation between the different aquifers and this drawdown induces new chemical reactions in the dewatered zone like, for example, the oxidation of the sulphides with a generation of sulphates and solubilisation of the heavy metals.

The development of significantly large and deep piezometric depression has resulted in a gradual decrease of the *Tallinn* aquifer role in watering of mine workings, which has been revealed by general decrease of concentration of chlorine-ion in the mine water inflow. At the same time, the role of the water inflow from the upper aquifers, which hydrochemical conditions were disturbed by technical ponds and all kinds of waterways emerged on the surface, has started to grow considerably. The pollution, which is connected with general pollution from the ground surface and atmospheric precipitation due to the operation of the shale processing factory and other factories in Slantsy, began to reach the productive *Kukruse* aquifer.

3.2. SURFACE WATERS

3.2.1. Surface waters system

Mine fields of *OAO Leningradslanets* are located both in the *Pljussa* and *Narva* rivers basins (Gulf of Finland watershed). Leningradskaya mine field is situated under the following small rivers watersheds: *Ruya*, *Kushelka*, *Sizhenka*, *Borovenki*, *Tchernovki* and *Pjata*. Kirova mine field extends partly under the watersheds of *Zaseka*, *Tcherjomukha* (*Narva* river tributary) and *Pljussa* rivers. Average watershed elevation amounts to 50-90 m above sea level.

Pjlussa river. About 20 km of the total *Pjlussa* river length (281 km) extends within the mine fields of the Leningrad deposit. River watershed area amounts to 6,550km^2. The width of the river near Slantsy town is 40-70m, depth is not more than 2m, flow speed 1.5m/s. Average annual water flow amounts to 20m^3/s but it varies during the year: from 10.9 m^3/s in February up to 142 m^3/s in April. In the Slantsy town itself the mine water from Kirova mine is discharged into *Pjlussa*. *Pljussa* river crosses quaternary and Devonian clay-sandy deposits and it crosses carbonate rocks of the middle Ordovician one in Slantsy town area; one can observe here a large number of springs flowing most time of the year.

As mentioned earlier *Pljussa* river water nowadays is used for Slantsy water supply (the water intake point is located 4 km upstream from the town). During summer-autumn season there could be water deficiency. The main tributaries of *Pljussa* river are:

Ruya river has a length of 48 km and extends along the Leningradskaya mine field, The average annual water flow is about 2 m^3/s. Its valley is cut into the Devonian sediments, with a maximum depth of 10-15 m. The Valley width amounts up to 1 km; the river's width is usually 8-10 m up to 25m, its depth is 0.5-1.5 m. The average annual flow is from 1.87 up to 2.34 m^3/s where the maximum is 52.2 m^3/s during the periods of flooding. The minimal flow was observed in August 1959: 0.34 m^3/s. Nowadays *Ruya* river received the mine waters (both central and southern outlets of the first area of Leningradskaya mine).

Kushelka river flows in the central part of Leningradskaya mine field and has a similar length and water flow as *Ruya* river. It flows into *Pljussa* river at the southern outskirts of Slantsy town. The width of its valley is usually 100-300 m. The bed's width is 4-5 m, the depth is up to 1m. Average low-water flow is 0.2 m^3/s, it increases when flooding by 10-12 times. Besides precipitation the river receives spring water from the Devonian sediments (in the lower course it received water from the middle Ordovician aquifers). The river length is more than 40 km.

Sizhenka river is 12-15 km long; it springs from the waterlogged plain near Sizhino village (the third area of Leningradskaya mine), runs across all industrial zone of the town and flows into *Pljussa* river through an artificial channels system. It received mine pumping water and industrial discharges from some plants including the cement plant and the oil-shale processing plant.

There is also *Borovenka* river that flows into *Pljussa* river to the north from Slantsy town. Both *Tchernovka* and *Schuchka* rivers flow into *Narva* water reservoir.

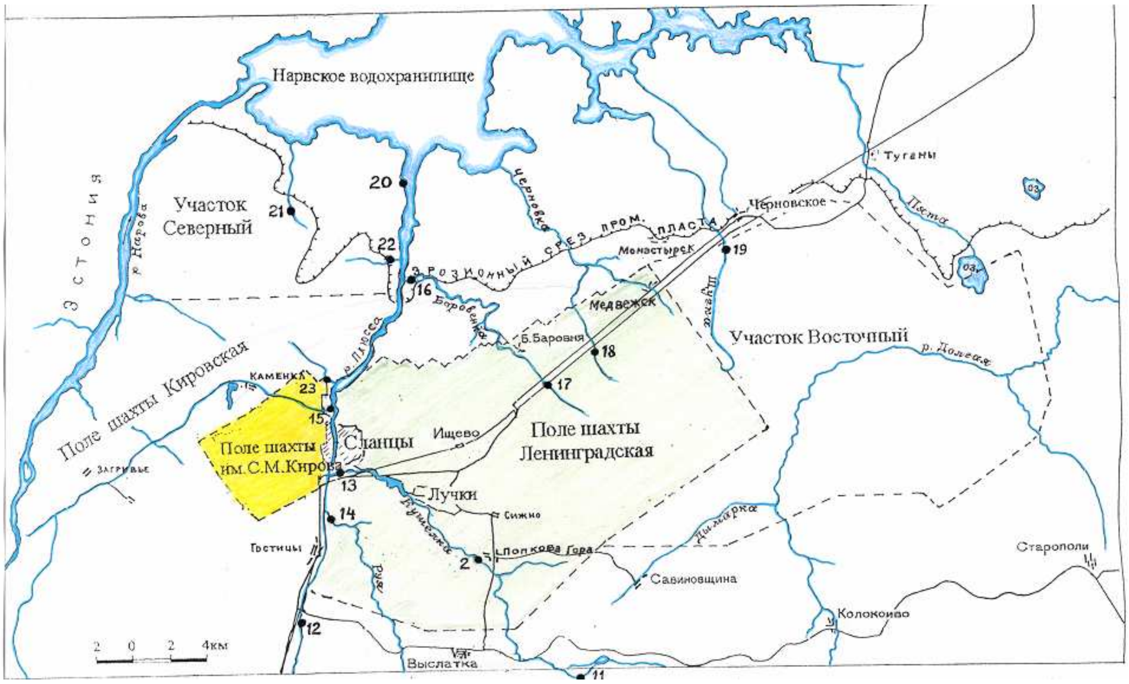

Figure 29. Regional surface water sampling points

3.2.2. Surface waters quality

The quality of the surface waters in the region were obtained during the sampling campaigns performed in August 1991 (Annex 7).

These data are given as an indication of the changes which occurred in relation with the evolution of the mining activities and associated industrial activities on the environment and in particular on the downstream ecosystems. These impacts are clear in terms of phenols, heavy metals (especially lead) and show the level of the background values in the catchments located outside the mining and industrial areas.

According to the NARVA Progress report n°1 (2005) w aters of *Pljussa* river near Slantsy town were characterized as “polluted” (V class) and one could defined there increased content of solute iron (8.2 and 6.7 MPC), of copper (8.2 and 11.1 MPC) and manganese (10.1 and 10.8 MPC). The highest copper concentration (27 MPC) was measured down-stream of Slantsy town and both manganese (24.2 MPC) and iron (8.7 MPC) concentrations up-stream of the town. The highest lead concentration (19 mg/l – 3.2 MPC) was registered down-stream of the town in March 2003. The concentrations of cadmium (1.3 MPC in August) and zinc (10 MPC in April) were also quite high. The average content of oil products remained at the level of 2002 and did not exceed MPC (0.8 MPC).

Observation district		Water pollution index							
		1987	1988	1989	1990	1991	1992	2002	2003
Pljussa river		1,66	-	2,2	1,89	2,57	2,61	3,52	4,89
Slantsy town		2,01	-	1,75	2,05	2,78	2,83	3,05	5,71
		Water quality class							
	1986	1987	1988	1989	1990	1991	1992	2002	2003
Pljussa river	II	III	III	III	III	III	IV	IV	V

Figure 30. Evolution of Pljussa river pollution according to the data of the Yearbook of surface water quality (NARVA Progress report n°1, 2005)

The comparative analysis of mine water and *Pljussa* river water composition in 2004 shows that the mine waters were as a whole of better in quality (excepted for barium) than *Pljussa* river water used for drinking water supply of Slantsy town. The report also contained the data about evaluation of mine water reserves in Kirova mine in amount of 23,200 m^3/day, including 9,200 m^3/day for water supply.

The content of phenol found at that time indicates that it exist a source of phenol upstream of the *Pljussa* river basin (natural or industrial). In 2005 and 2006 (Annex 7) no anomaly in the phenol content was detected. However the iron, manganese, aluminium, suspended matters, BOD5 and copper are above the MPC in the water upstream the central pumping discharge. It does exist a few discharges from industrial activities upstream but their influence on the global quality of the *Pljussa* river is not known.

It can be concluded from the tables of analysis of the surface waters upstream and downstream the different mining water discharges that (Annex 7):

- In the *Pljussa* river down the central pumping discharge there is a dilution effect resulting mainly in lower values of lead, copper, barium and slight increase in manganese and light decrease of the pH.

- In the *Pljussa* river down the “phenol channel”, in the *Sizhenka* river, *Kushelka* river, the *Ruya* river down the mining discharges, the concentration of the chemical elements upstream and downstream of the mining discharge are as a whole similar. The concentrations in phenols, in 2005 only, are above the MPC in the *Kushelka* river both upstream and downstream despite the dilution effect by the mine waters.

- The phenols are present in the surface waters upstream the mine discharges showing the influence of the surface pollution from the wastes dumps and ponds.

- The dilution effect of the surface waters by the mine waters is effective for some elements and should vary according to the seasonal flow of the different rivers.

3.3. AIR QUALITY

Emissions to the air from stationary sources (plants) and highways together with air pollution import from Estonia also play a certain role in Slantsy area pollution. For example, according to some calculations in 2002 impact of Estonia on the territory of Leningrad region was evaluated by the following figures (in brackets amount of Leningrad region impact on Estonia):

Sulphur - 25,400 (1,900) tons per year

Nitric oxide – 5,000 (1,300) tons per year

Reduced nitrogen – 4,200 (600) tons per year

Impact station of Estonian oil-shale processing plants on Leningrad region amounts to 30 km, i.e. it covers almost total area of Leningradskaya mine field. On the whole in Slantsy town average level of air pollution with some components in 2001-2003 was characterized by the following figures:

Indicators	**Content in mg/m^3**		
	2001	**2002**	**2003**
Suspended matters	0.2	0.1	0.2
Nitrogen dioxide (NO_2)	0.02	0.04	0.03
Hydrogen sulfide (H_2S)	0.002	0.002	0.003
Phenol	0.002	0.002	0.002

Figure 31. Air pollution in Slantsy town(NARVA Progress report n°1, 2005)

The amount of air origin pollution was studied in different years (1979 and 2000) by means of chemical analysis of snow specimens taken in the area at the end of winter. The obtained data have shown a considerable pollution of the snow specimens and have allowed to identify the most vulnerable areas to this pollution in the region, as well as to evaluate the role of the shale-processing plants in the contamination of the snow cover.

The source of atmospheric phenol emissions was the unit of compartment furnaces (due to coke quenching with phenol-containing water). The particles and gas emissions are carried by wind on considerable distances and cause pollution of the lands and, then the groundwater not protected from the surface pollutions.

The infiltration of phenols down to the shallow aquifers is characterized by a seasonal process. During the winter period there is an accumulation of phenols in the blanket of snow, while the concentration distribution over the different areas of the territory depends on the prevailing direction of winds, topography and land use, distance from the shale processing factory, etc. When the snow melts the phenols infiltrate down and reach the non protected part of the aquifers. The phenols introduced in the aquifers are transferred by the underground water flows to the pumping zone (mining area) and then discharge to the rivers. While the flows move to the the pumping zone (depression cone) the concentration of phenols in the groundwater decreases due to the dilution effects.

In some snow samples the concentrations reached 0.007 mg/l. The concentrations of phenols in snow samples exceeded by several times the concentrations observed in the mine water. East of the Slantsy processing plants the concentrations of phenols in the snow samples decrease gradually. The content in chemical elements was also determined in the snow samples. It was observed the presence of Cr, Mn, Co, Ni, Zn, Pb, Cu in concentrations not exceeding the MPC for potable water, while the presence of elements such as As, Hg, Cd, Mo, Ba was not detected. In the summer period there is a permanent precipitation of phenols with the rainfall over the area and then percolate down to the aquifers.

3.4. SOIL QUALITY

The highest concentration in the table of elements of 1-3 dangerous classes are found in the industrial zones and in the ash-disposal area of the oil shale processing plant. Maximal phosphorus content is observed in inhabited area where storage of other elements is 2-3 times less than in industrial zones. On the whole Slantsy town is exposed to significant anthropogenic impact. Inhabited and recreation areas are characterized by allowable degree of soil pollution with local areas of dangerous pollution with heavy metals. Industrial zones are characterized as moderate dangerous and dangerous; one could not reveal too polluted areas. Radiation level on the total area is within the limits. One does not expect strong migration of dangerous pollutants from existing and potential sources.

Behind the border of Slantsy town the main pollution sources of both surface and ground water are untreated discharge water from the fields and cattle-breeding farms. Soil pollution could be made also as a result of water discharge from the same cattle-breeding farms directly to the soil or due to usage of fertilizers and pesticides. Therefore agricultural land-users are considered the most dangerous for the environment in the countryside.

Basing on total indication of soil pollution one revealed the area of the highest anthropogenic pollution (intensity from 3 up to 16) to the south-east from Slantsy town where refuse heaps, dumps etc. are located. It is a potential area of soil chemical pollution. The maximal content of heavy metals is defined in the industrial zone. The basic pollutants in all these zones are stibium, zinc, thallium, and also lead and wolfram (Sammet *et al.*, 2006).

4. Overview of potential impacts due to water resources contamination

4.1. MPCS AND WATER USES

In Russian Federation, water resources are monitored using physicochemical and biological studies and by comparing the results of analyses with the standardized indexes of tolerable concentrations including MPC (maximum permissible concentration). Three types of water are usually distinguished: drinking water, natural water (incl. recreation, fish culture) and waste water (incl. industrial and domestic waste water, run-off and storm water). The requirements for the quality of water of different types are set in different standards papers) (Kutseva *et al.*, 2004). The figure below compares MPCs required for various types of water with concentrations registered in 2005-2006 in *Pjlussa*, *Ruya*, *Sizhenka* and *Kushelka* rivers (based on 2005-2006 Figures in Annex 6 & 7) and in mine water discharge from Leningradsakaya and Kirova mine.

(mg/l)	MPC (a)	MPC (b)	MPC (c)	MPC (d)	MPC (e)	*Pjlussa river*	*Ruya river*	*Sizhenka river*	*Kushelka river*	Kirova mine water	Leningrad. mine water
Iron	**0.3**	**0.3**	**0.1**	3	**0.1**	X	X	X	X	X	X
Nitrate	45	45	40	-	-	Ok	Ok	Ok	Ok	Ok	Ok
Chlorides	350	350	300	350	300	Ok	Ok	Ok	Ok	Ok	Ok
Sulphates	500	500	**100**	500	**100**	Ok	Ok	Ok	Ok	Ok	X
Copper	1	1	**0.001**	0.5	**0.001**	X	X	X	X	X	X
Mn	**0.1**	-	-	-	-	X	Ok	X	Ok	Ok	Ok
Aluminium	0.5	0.2	**0.04**	1	-	X	X	X	X	Ok	X
Ammonia	2	1.5	-	20	-	Ok	Ok	Ok	Ok	Ok	Ok
BOD5	-	**2**	-	500	**3**	X	X	X	X	X	X
Oil prod.	0.1	0.3	**0.05**	4	**0.05**	Ok	Ok	Ok	X	Ok	X
Phenol	**0.001**	**0.001**	**0.001**	0.01	-	X	Ok	Ok	X	X	X
Lead	0.03	0.01	0.006	0.1	0.1	Ok	Ok	Ok	Ok	Ok	Ok
Cadmium	0.001	0.001	0.005	0.01	-	Ok	Ok	Ok	Ok	Ok	Ok
Zinc	5	1	0,01	2	-	Ok	Ok	Ok	Ok	Ok	Ok
Arsenic	0.05	0.01	0.05	0.05	-	Ok	Ok	Ok	Ok	Ok	Ok
Barium	**0.1**	**0.7**	**0.74**	4	-	X	X	X	X	X	X

MPC (a) : drinking water from central water supply (from underground, surface and combined water sources ;

MPC (b) : water for social and domestic use (incl. Recreation) ; MPC (c) : surface water used for fish-breeding and fisheries ;

MPC (d) : waste water ; MPC (e) : storm/ run-off

X: at least one result of the monitoring campaign exceeds one MPC; Ok: all MPCs are met for each monitoring campaign

Figure 32. Comparison between MPC and surface water and mine water discharge quality (MPC data from Kutseva et al., 2004 ; concentration from Podsevalov, 2006)

This comparison shows that drinking water quality, recreational activities and fisheries may be affected by the current state of contamination of surface water resources by organic pollutants, phenol and heavy metals.

When considering mine water quality (in close relation with surface water as mine water pumped are directly discharged into surface water), organic pollutants, phenol an heavy metals are also the main pollutants exceeding MPCs. Kirova mine water quality may become of a great concern is the coming years as it is planned (but it is still a controversial issue) to use mining water withdrawal in volume about 1,000 m^3/hour (24,000 m^3/day) to provide Slantsy town with drinking water. Some results show that mining water would thus require a treatment before use as a drinking water.

Concerning groundwater quality, monitoring results were too sparse for being compared to MPC for drinking water use. The analysis carried out in chapter 3.1.2 underlines the presence of some contaminants (volatile phenol, beryllium, cadmium) in groundwater, sometimes 10 times higher than the MPCs. It was recognized from the chemical analysis done in the past that the contamination level of the underground water from the aquifers used for economic and drinking purposes was much lower in comparison with the mine water, which composition is logically linked to the chemical and physical interaction water-rocks in the dewatered mining zone

Nevertheless (i) high level of polluting pressures, (ii) low thickness of protection of the upper aquifers and (iii) the presence of numerous boreholes that can act as a preferential pathway and interconnection between aquifers make the vulnerability of aquifers in the area high. But given that the extent of the drawdown zone is considerable, it can be supposed that most of the pollution precolating from the soil is stored in this large almost non saturated zone and could be remobilised only in case of mine flooding when the rising groundwater will reach them.

4.2. DESCRIPTION OF POTENTIAL IMPACTS

4.2.1. Overview of potential impacts

In a cost-benefit analysis perspective, assessing the potential economic benefits of the implementation of pollution management measures is the same as assessing the cost/ damage resulting from water resources degradation that could be avoided through the implementation of these management measures.

Various types of water uses may be damaged by water resources degradation: additional treatement needed for drinking water supply, loss of income for fisheries activities and recreational activities, loss of biodiversity in the area, loss of income due to contamination of crops and vegetables growing in gardens, damage to health, etc. A first attempt was made to assessing the resulting cost of water resources degradation through the interviews. The results of these interviews higlight that most people are not aware of potential pollution of water resources: they generally do not develop adaptive strategies to mitigate potential impacts and do not bear directly additional cost due to pollution. For instance: even if fishes caught in the river smell phenolic compound, people eat and bought these fishes; even if water quality from rural boreholes is unknown (not monitored), people drink it, etc.

Lack of objective and representative water quality monitoring results, lack of environmental awareness of people, huge socio-economic problems in the area especially due to high rate of unemployment make it difficult to assess quantitative impacts of water resources degradation. In this context, it is likely that the main types of damage due to water pollution in Slantsy mining area are related to damage to human health and ecosystems.

4.2.2. Human health and environment

This is in accordance with the assumption of Pearce *et al.* (1993) who have argued that the most important and immediate consequences of environmental degradation in the developing world take the form of damage to human health. Contamination of drinking water, crops and gardening, recreational areas and fishes identified as impacts in Figure 1 can lead to human health damage. During the interviews (Annex 1), human health appeared as one of the most quoted concern of people in the district (59%). Nevertheless, health professionals suppose that many diseases are provoked by bad social and financial situation of the inhabitants: poverty, bad conditions of work, lack of medical assistance, etc (Tsepilova *et al.*, 2006) and causal links with bad environmental state of water resources are not well established. Figure 33 gives some data about population sickness rate in the Slantsy district.

According to the results of the interviews (Tsepilova *et al.*, 2006), morbidity (including oncological and allergic diseases, gastrointestinal and respiratory pathology) in the Slantsy district doesn't differ from the average figures of the Leningrad Region. On the other hand experts and inhabitants of Slantsy note that (i) the rate of allergic diseases among children is very high; (ii) a gastrointestinal pathology named "Slantsy gastritis" exists i.e. specific to Slantsy ecological situation; (iii) neurologic morbidity increases including among children; (iv) the number of oncological diseases increases.

Two links must be established in estimating the monetary values of changes in human health that are associated with environmental changes: (i) the link between the environmental change and the change in health status; (ii) the link between the change in health status and its monetary equivalent, willingness to pay or willingness to accept compensation (WHO, 2000). Two main components are often taken into account while measuring cost of illness due to environmental factors: (i) the loss of earnings (working days) due to illness and (ii) the cost of medical treatment (Reddy *et al.*, 2006).

Unfortunately few studies related to links between health and environment are available in Russian Federation. There is a need to identify more precisely which infectious diseases are related to water quality and how they are most efficiently addressed. Similarly, the chemical components that locally are having a potential impact on public health should be better identified and monitored (DANCEE, 2003).

	Children	Adults and teens
Respiratory apparatus	917.40	190.90
Average for the region	*934.38*	*217.36*
Urogenital system	18.60	30.90
Average for the region	*28.88*	*38.26*
Digestive apparatus	21.90	34.40
Average for the region	*104.16*	*52.60*
Skin and subcutaneous fat	5.40	5.50
Average for the region	*43.85*	*28.13*
Congenital anomaly	11.50	0.70
Average for the region	*12.70*	*1.45*
Musculoskeletal system and connective tissue	3.50	64.10
Average for the region	*18.11*	*49.47*
Separate states appeared during intrauterine period	1.80	-
Average for the region	*4.86*	
Blood and hemopoietic organs disease	7.20	2.70
Average for the region	*11.12*	*3.25*
Mental disorder	32.90	27.20
Average for the region	*20.01*	*42.69*
Blood circulation	5.00	96.80
Average for the region	*12.95*	*115.20*
Endocrine diseases	8.30	49.40
Average for the region	*19.23*	*26.34*
Trauma and intoxication	91.20	133.10
Average for the region	*46.75*	*56.91*

Figure 33. Population sickness rate in Slantsy district (compared to Leningrad Region) in 1992 (converting to 1,000 people). From Sammet et al., 2006

5. Existing and potential environmental effects of existing and future mine flooding

Some of the negative consequences of the mine closure on the environment are now documented in Western Europe. The final closure is accompanied by the end of decades of regional scale dewatering generating potential subsidence and surface flooding due to the new natural discharge with a potential of aquatic pollution.

5.1. POTENTIAL CHEMICAL IMPACTS INDUCED BY THE PARTIAL FLOODING OF THE KIROVA MINE AND FUTURE (?) FLOODING OF THE LENINGRADSKAYA MINE

5.1.1. Hydrogeology

The flooding of the Kirova mine by stopping the pumping of the groundwater in underway and the variation of the piezometric levels and the chemical composition of the water are monitored by the Ecological Monitoring Centre.

This monitoring is very crucial as it is difficult to predict the environmental impacts related to the mine flooding. The key potential negative impacts could be:

- rising of the levels of the shallow aquifers, inducing a flooding of the Slantsy area;
- pollution of the aquifers water by the mine water and pollution of surface water bodies and water ways associated.

The complete stop of the pumping system in Kirova mine may result in partial or full flooding of the excavation area, rising the heads of aquifers (*Wezenberg*, *Kukruse*, *Tallinn*), which have being drained during the mine operation and care and maintenance period, and subsequently a rising the water production at the western flank of Leningradskaya mine. At the same time a shallow groundwater rise due to the rise of the *Wezenberg* aquifer head cannot be excluded.

However the above mentioned changes of groundwater hydrodynamic behavior and the negative effects of these changes are only potential and require a more accurate evaluation when taking into consideration all hydrogeological and technological conditions of the project in question.

It is impossible today to predict accurately the final environmental impacts resulting from the flooding of the Kirova mine as it is highly dependant of the new hydrogeological conditions (existence of an increased drainage through the fractured body of carbonate rocks above the mined-out space, flow through the mine of water from the *Wezenberg* and *Tallinn* aquifers and along the perimeter of the mined-out area from the *Kukruse* aquifer, etc.) and the geometry of the mining zone (room-and-pillar system and slope, hydraulic connection between Kirova and Leningradskaya mines).

It has been calculated that 280 m^3/hour from the *Wezenberg* aquifer, 195 m^3/hour from the *Kukruse* aquifer and 30 m^3/hour from the *Tallinn* aquifer will inflow the flooded mined-out zone of the Kirova mine. Water inflows from the flooded mined-out area of the Kirova mine into Leningradskaya mine will increase gradually during the mine flooding, however the maximum flow should not exceed 410 m^3/hour.

The flow of mine waters from the mining zone into the *Tallinn* aquifer will be 70 m^3/hour. It should be noted that in certain parts of the mining zone, the flow of mine waters into the *Tallinn* aquifer takes place, while in other ones the underground waters of this aquifer flow into the mined-out zone.

Under the new hydrogeological conditions (increased vertical drainage and hydraulic conductivity) the flooding of the mine may result in a significant change of the water level of the near-surface aquifers in water valleys with a possible level rise often causing the flooding on the low elevation areas in the Slantsy district.

It could happen under certain conditions, that the increase of levels of the shallow aquifers would be limited due to intensive discharge of groundwater into the rivers.

As a consequence it is probable that a minimum pumping rate of the waters will be necessary to prevent this potential large scale flooding.

A few years ago a hydrogeological model was applied on the hydrogeological consequences of the flooding of the Kirova mine. The conclusions were the following: the flood of Kirova mine can lead to a change in the hydrodynamic regime of underground waters in essence over the area of mining operations closure. Maximum changes will be logically experienced by the *Kukersky* water-bearing horizon. The water-inflows into the Leningradskaya mine will increase to 750 m^3/day from which about 400 m^3/day will comprise the filling through the pillar of the manufactured space of Kirova mine. The levels of the *Tallin* water-bearing horizon in the mine field will increase by 20-25m along the area of cleaning works will be practically close to the bench marks of the *Kukersky* water-bearing horizon. A difference in the levels of the ground water and *Wezenberg* water-bearing horizon reaches 10 m; therefore the flood of mine practically will not influence a change in the formed regime of the ground water-bearing horizon and will not lead to the additional water-table elevation of the earth's surface and the bogging up of territory. A change in the hydrodynamic regime of the *Kukersky* and *Tallin* horizons will probably involve the transformation of the conditions for the migration of chemical constituents in the underground waters in the section of layer, near the field of Kirova mine.

The stabilization after cutting of mine waters in mine workings on the mark of approximately +5 m it is reached approximately in 800 days since the beginning of the flood of mine. The complete stabilization of the piezometric level will be reach 1,000-1,500 days after the beginning of the flood of mine.

5.1.2. Water quality

If the flooding of the mine induces a pollution of the mine waters, these waters will be able to go through the *Kuker* water-bearing horizon to the Leningradskaya mine and also to the *Tallinn* water-bearing horizon used for water supply.

In the past decades the hydrodynamic behavior of underground waters in the Kirova mine area has stabilized. It is likely that hydrochemical behavior at this stage can be considered quasi-stationary. But the change of hydrodynamic behavior due to the rewatering of the Ordovician complex level could cause in the futur the transformation of the migration conditions of the groundwater chemical components.

Indeed during the mine flooding the existing sources of phenol pollution remains. Similar to the mine operation period simulation, the two variants of pollution arrival from the earth surface are being considered with its further spread in the thickness of Ordovician rock complex. The first possibility is that the pollution infiltrates with the polluted precipitation and spread in the Ordovician aquifers. The second possibility is that the *Wezenberg* aquifer is considered to be a direct, stable in time source of phenol pollution of the *Kukruse* and *Tallinn* aquifers. As the previously conducted investigations have shown, the phenols concentration in the mine waters during the mine flooding may reach 0.01 mg/l (as a result of oil shale hydrolisis). The prediction calculations were made for periods of 3 and 10 years after the beginning of the mine flooding.

Three years after the flooding a significant phenol concentration rise was predicted in comparison to the operation period data, the value of concentrations being higher than maximum permissible concentration or close to them both in the *Kukruse* and in the *Tallinn* aquifers. Microcomponent (metal) pollution prediction showed that a number of components in a few years will be a few times higher than the MPC, and a polluted zone could extend in the *Tallinn* aquifer.

5.2. CASE STUDIES OF MINES FLOODING

Even if it is not easy to predict the final level of the groundwater and its quality, it is known from examples of previous mine flooding in Russia that the negative impacts can be, in some cases, important. For example in the *Kizelovsky* coal basin: 14 mines in this basin were closed, the springs of polluted mine waters occurred on twelve sites in the valleys of the *Vilva* and *Kosva* rivers with a total flow of 2,500 m^3/hour. The mine waters mineralization increased up to 25 g/l (during the mines operation it was 1-3 g/l, and very seldom reached 10 g/l). The content of ferrous iron in mine waters increased up to 5 g/l (with a maximum allowable concentration being 0.3 gr/l), therefore the pollution of twenty small and medium-sized rivers could be traced along dozens of kilometers beginning from the mine waters discharges down to the mouths. According to some assessments, more than 3 tons of sediments are discharged every hour in rivers. A real threat has been created towards the *Vizeysk* aquifer, which is used for water-supply.

Another type of environmental problem occurred during the closure of the mines in the *Podmoskovye* coal basin with the existence of a vulnerable aquifer (*Upinsk* aquifer), which is used as a main source for drinking water (with a productive rate of 30,000 m^3/hour). The groundwater pollution became possible after the mine closure through mine rooms, pillars and the existence of many boreholes.

Practically in all regions concerned by the mine flooding the escape of toxic gases (“dead air”) is observed. For example, in 2002 it was established that in the already closed parts of the mines at that period, 90 zones were specified as dangerous for gas escape, 980 zones were identified as threatened zones (within the limits of these zones 7,552 dwelling houses and 482 industrial building are located).

In Estonia the oil-shale groundwater level during the exploitation has been dropped due to pumping from the mines at 50–60 m and from open-pits at 25-30 m. In the dewatered area the *Nabalasky-Rakversky* aquifer is not suitable for water supply due to dewatering of water-bearing rocks in the area with radius of 1 km around mines, *Keilasky-Kukruzesky* aquifer – in a radius of 6-7 km, *Lesnamjagisky-Kundasky* aquifer (in the bottom of oil-shale industrial layer) – in a radius up to 25 km.

Total area of exhausted and flooded open-pits and mines amounts to 250 km^2. As a result of surface anthropogenic disturbance this vulnerable groundwater can be easily polluted. After the closure of 9 mines and pits, the mineralization of water sharply increased up to 2 g/l and sulphate content increased up to 500 mg/l but is decreasing since 2005.

There is a pollution of groundwater with oil-products, phenols and hydrocarbons within the area in a radius up to 500 m around the mining dumps and semicoke production. Recently a decrease of content of the most pollutants has been observes although the quality of *Keylasky-Kukruzesky* aquifer is still deteriorating (mineralization may reach 1.8 g/l, content of SO_4^{2-} - up to 875 mg/^{l} and chlorine – up to 150 mg/^{l}).

Environmental problems are also related to the Narva heating-power station area with mainly pollution concerns caused by the ash-disposal areas and the ponds of liquid wastes that are located close to *Narva* river and Narva water reservoir. This water has a mineralization up to 15-19g/l, content of Cl 1,600-1,800 mg/l and SO_4^{2-} 3,500-4,200 mg/l. In the area close to the power station an important pollution of the first shallow aquifer (*Lasnamjagisky-Kundasky* aquifer*)* was identified resulting in a high content in potassium, chlorine and sulphate, and in some places there is also an increased content of barium and manganese.

6. Conclusion

The environmental situation today

The environmental situation in Slantsy mining region is connected to the exploitation of Leningrad oil-shale field, shale-processing plants, cement works and other plants located mainly in Slantsy town, the agriculture activities, the sewage system treatment and disposal, etc.

The most dangerous activities and sources of pollution associated with the mining activities are the following: ash dumps, ash ponds, coke dumps, heat power plant. The other potential sources of pollution in relation with *OAO Leningradslanets* are the shale dumps and the waste dumps. The temporary shut of the mining and shale treatment operations has changed significantly the intensity of the industrial pressure on the groundwater. However all the industrial wastes stored in the area should still be considered as potential sources of contamination.

Interviews have also highlighted other environmental issues: agricultural and industrial activities, rural and urban households also exert important polluting pressures on water resources through poorly treated waste water discharge and storage of hazardous solid wastes. Quality of drinking water supply is also a big concern of both rural and urban inhabitants.

Key pollutants today are the phenols, organic compounds and heavy metals. The presence of volatile phenols in natural waters is connected mostly with the activity of the shale-processing plant, which former operation was accompanied by accumulation of large quantities of polluted surface industrial waste containing derivatives of oil shale processing and enrichment. Hard waste were stored, liquid waste were accumulated into settling ponds and after preliminary refining were discharged through system of channels outside the limits of the purifying plant. Leakage of water from the ponds and the channels (mainly the "phenolic" channel) situated within the limits of the mine activities percolating down to the aquifers, as well as the aerial contamination of the environment, represented the main hazard of phenolic ground-water pollution in this area.

The environmental situation in the future

It should be kept in mind that the general hydrogeological context shows that the extent of the drawdown zone is considerable and for that reason all the pollution percolating downward will be "stored" in this large almost non saturated zone and then potentially remobilised when the rising groundwaters (induced by a flooding) will reach them. Indeed in the dewatered zone the pollutants infiltrating from the surface through the fractures and karstic zones can either reach finally the groundwater or be stored in the dewatered zone. It is difficut to assess the risk and the contribution to the so called polluted chemical flush which is generally related to the flooding of a mine.

The Kirova mine, (under partial flooding) and Leningradskaya mine (if flooded in the future) can be considered as a potential source of phenols and possibly of heavy metals. If it is the case the Kirova mine flooding could cause a significant rise of pollutants concentration in the adjacent aquifers and additional content in phenols and heavy metals in the mine waters in the Leningradskaya mine.

The monitoring and the decision about a complete stop of the pumping or the need for a minimum rate of dewatering is capital and should rely on a cautious follow up of the piezometric levels and the water chemical analysis. A chemical flush phenomenon (with a high content in heavy metals) is regularly observed during the flooding of mines, this high initial contamination is decreasing with time to reach after years an asymptotic low level in contaminants. A potential benefit of the flooding (especially if the closing works of the mine are done) is the decrease of the rate of oxidation of the sulphides.The foreseen closing works of the mine will also allow the slowing the hydrolysis of the shale and the associated release of phenols. Of course it will not solve the potential contamination of the groundwater through the percolation of phenols from the ground surface sources of pollution.

The recent acquisition of the mining complex by new investors will without doubt have huge positive economic impacts on the Slantsy mining area and modify the scenario of the mines flooding. In all cases the existing hydrogeological links between the Kirova mine and the Leningradskaya mine will require a common management strategy. Indeed, as mentioned earlier the flooding of Kirova mine will increase the water flux towards the Leningradskaya mine and modify the chemistry of the water pumped in the latter.

Next step: Identification and design of a programme of measures

The design of the programme of measures aiming at improving the environmental situation will be addressed in a forthcoming report. It will be based on the results of this initial characterisation and scenarios of potential evolution. This programme of measures will consist in declining, for each type of pressures exerted on the water resources (and described in the chapter 2) a set of technical measures that could be implemented to improve waste and water management process in order to save and protect ground and surface water resources, provide all users with an appropriate water supply and treat liquid and solid waste efficiently. It will also include measures to limit the potential environmental and economic impacts in case of mine flooding. Economic, organisational and regulatory instruments may also be proposed to help the implementation of technical measures. The design of the programme could be inspired by what has been done in similar mining areas of Estonia.

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Annex 1

Stakeholders' consultation

1- Context and objectives

One of the objectives of the project consisted in identifying, characterising and quantifying when possible, the different impacts of oil-shale mining pollution. The project will analyse impacts of pollution on the state of the environment (groundwater pollution, pollution of rivers and induced ecological impacts) as well as the impacts on the society and the economy. Stakeholders have been consulted to identify these impacts, as they have a good knowledge of the real problems in the field.

The main objectives of the stakeholders' consultation were:

(i) to identify and quantify the different impacts of mining industry on the environment (groundwater, rivers, wetlands, etc..) and on different type of human activities (agriculture, fisheries, rural and urban settlements, light and heavy industry, etc.)

(ii) to describe the socio- economic dimension of these impact : reduction of income, increase of expenses for specific groups of actors, etc. For instance; households forced to abandon their water well and buy bottled water; loss of food/income for fishermen due to reduction of fish population after pollution of rivers by mining, etc.

2- Methodology

The consultation was conducted by the Sociological Institute of St Petersburg. 29 stakeholders were interviewed from April to July 2007. Stakeholders were selected to cover various water users and institutional categories, including representatives from municipalities and other territorial bodies, representatives from industrial activities, drinking water company, housing services, health services, journalism (Figure 34). The interviews were guided by a semi-open questionnaire organised in 23 questions jointly draft by BRGM and the Sociological Institute. Although it had been proposed by Brgm to facilitate the description and location of the main water management issues, it was not possible to use a map during interviews.

Category	Number
Administrative bodies	9
Health services	3
Water services	2
Education	1
Industry	9
Bank	1
Journalism	4
Total	**29**

Figure 34. Number of stakeholders consulted per category

3- Main results

According to the results of the consultation of experts and stakeholders in the Slantsy district, it appears that the mining impact is only part of a general context of problems which are related either with other environmental issues or with direct socio-economic preoccupations (increasing unemployment, etc.). Other human pressures may significantly affect the state of water resources in the Slantsy district. Main stakeholders' concerns are summarised in the following Figures.

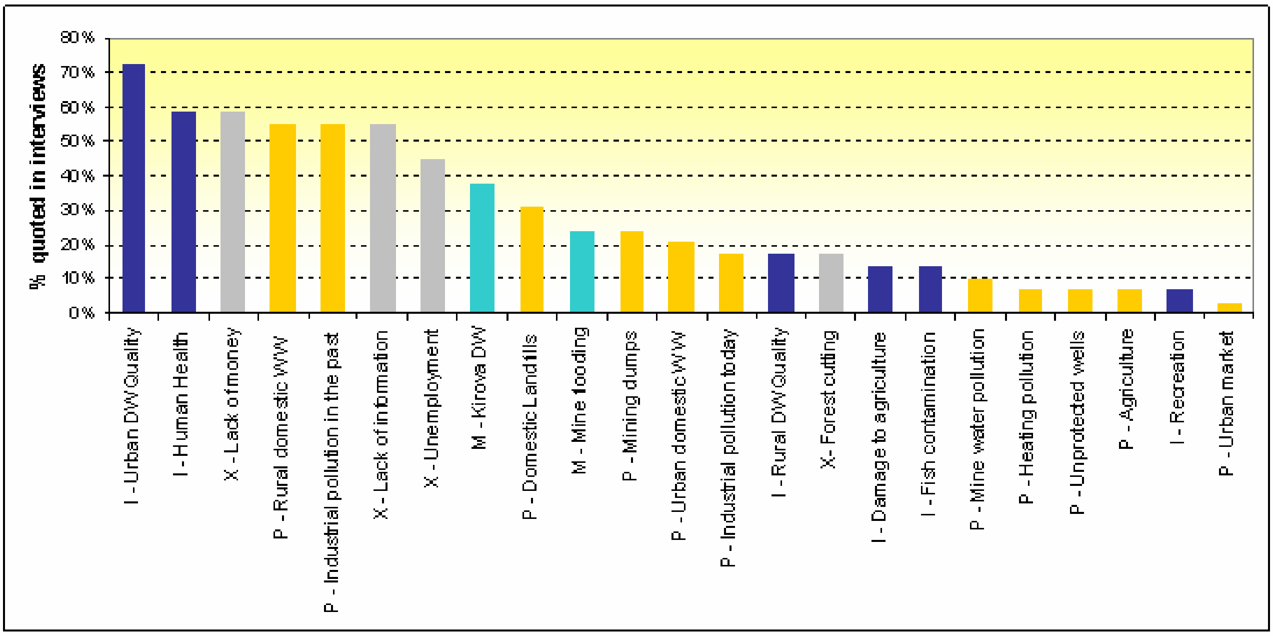

Figure 35. Main concerns about Slantsy area quoted by stakeholders (blue: types of impacts (I); orange: types of pressures (P); turquoise: Kirova/ flooding concerns (M); gray: other concerns (X))

Main types of pressures exerted on water resources	**Number of answers (% quoted)**
Rural domestic waste water discharge	16 *(55%)*
Past industrial pollution (emission to the air/ water)	16 *(55%)*
Domestic (unauthorized) landfills	9 *(31%)*
Mining (and oil shale processing) dumps	7 *(24%)*
Urban domestic waste water discharge	6 *(21%)*
Industrial pollution (emission to the air/ water)	5 *(17%)*
Mine water discharge	3 *(10%)*
Heating pollution	2 *(7%)*
Unprotected wells	2 *(7%)*
Agriculture (cattle graves)	2 *(7%)*
Urban market	1 *(3%)*

Figure 36. Perception of pressures exerted by human activities on water resources

Main types of impacts to water uses	Number of answers (% quoted)
Urban drinking water contamination [1]	21 *(72%)*
Human health [2]	17 *(59%)*
Rural drinking water contamination	5 *(17%)*
Damage to agriculture (soil contamination)	4 *(14%)*
Fish contamination	4 *(14%)*
Absence of recreational areas	2 *(7%)*
[1] Tap water mainly degraded due to worn network	
[2] Links between morbidity/ mortality and environmental degradation are not clearly established. Poverty, poor nourishment, bad working conditions may also affect human health	

Figure 37. Perception of impacts due to water resources degradation

Other major concerns	Number of answers (% quoted)
Lack of financial means	17 *(59%)*
Lack of information about water resources quality	16 *(55%)*
Unemployment	13 *(45%)*
Kirova mine water used as drinking water	11 *(38%)*
Mine flooding	7 *(24%)*
Forest illegal cutting	5 *(17%)*

Figure 38. Perception of other concerns

Interviews and main concerns quoted by stakeholders are fully analysed in Tsepilova *et al.* (2006).

Annex 2

Mine discharges location

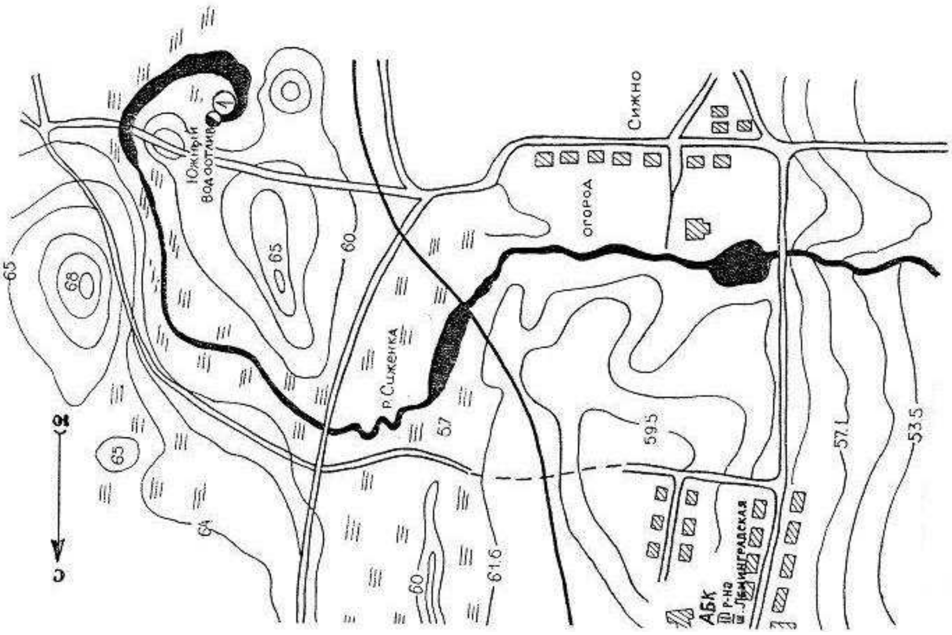

Figure 39. Sizhenka river (1. The station of "Southern" pumping place)
Source: Podsevalov, 2006

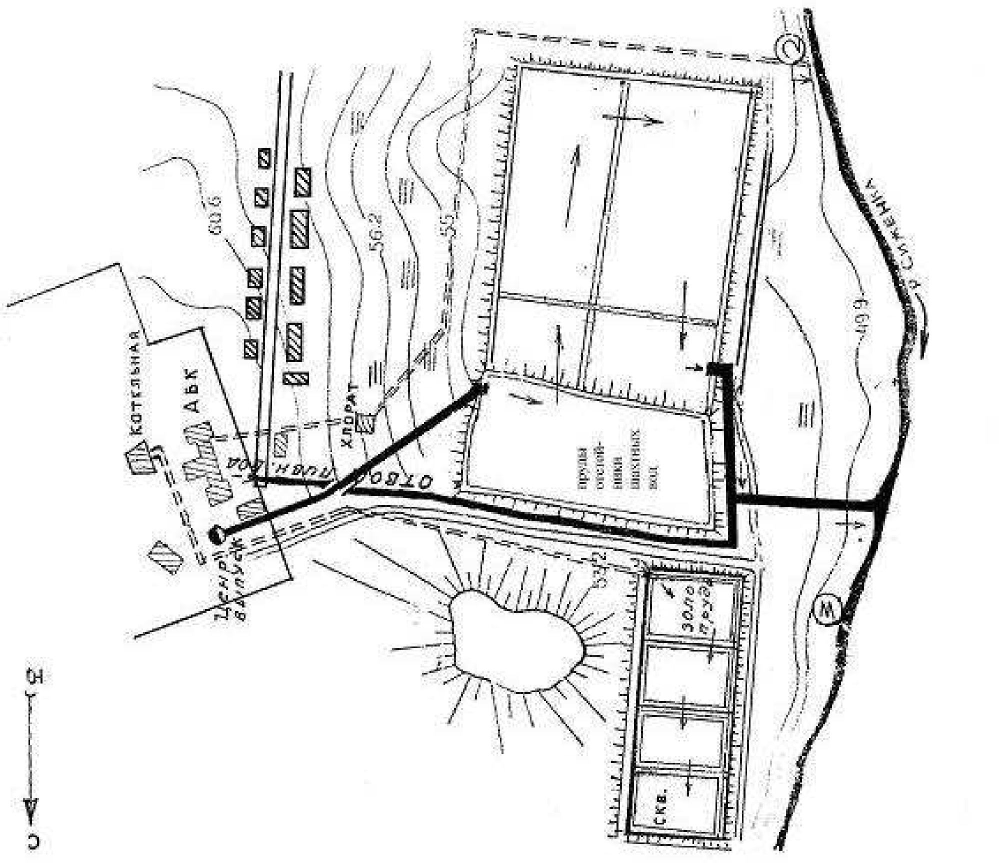

Figure 40. Sizhenka river (2. The station of household runoff; 3.The station of "Central" pumping)
Source: Podsevalov, 2006

.

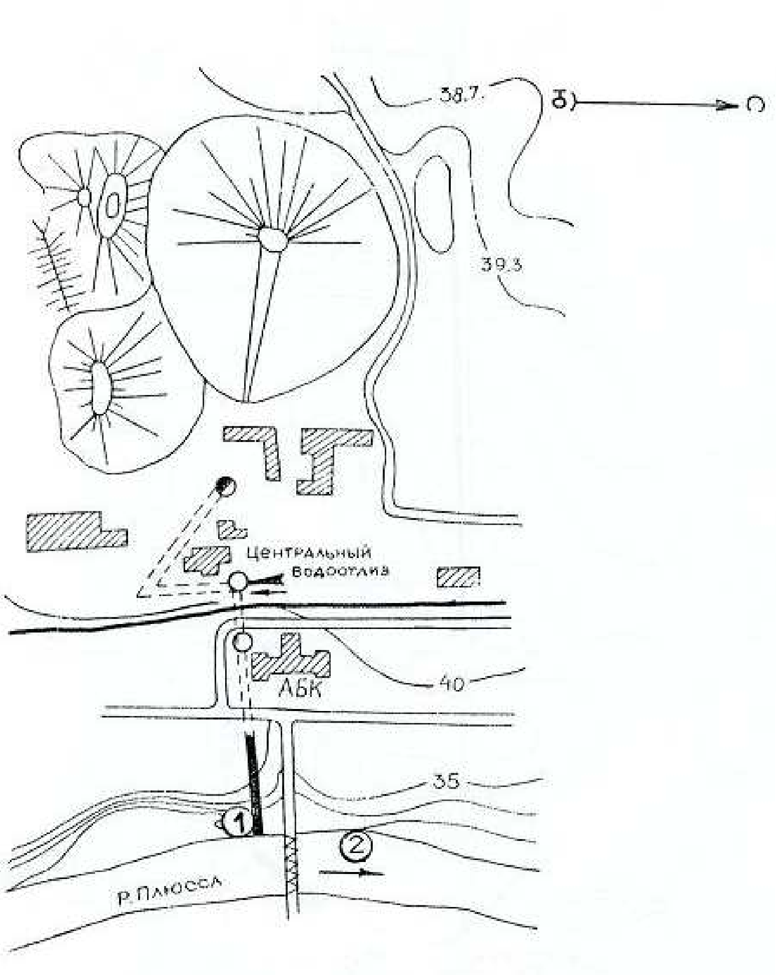

Figure 41. Pljussa river (1. Mine water discharge point in the Pljussa river; 2. The station of "Central" pumping) – Source: Podsevalov, 2006

Annex 3

Aquifers and aquitards in Leningrad oil shale deposit

Aquifers and aquitards	Index	Short lithological description	Thickness, m	Parameters of aquifers		
				k, m/day	T, m^2/day	a, m^2/day
Quaternay water-bearing complex of quaternary groundwater	Q_{III-IV}	Granular sands, gravel-pebble and detritus deposits	2-5	0,1-9		
Starved aquitard	$Q_{IV,}$	Loamy soil, moraine clay and ribbon clay	2-3	менее 0,01		
Starooskolsky aquifer	D_2	Sands, sand stone with siltstone	1-12	1-4		
Relative aquitard	D_2	Sand-clay-marl pack	3-11	менее 0,01		
Narovsky aquifer of fractured or sometimes karst water	D_2	Dolomite-marl deposit	10-12	0,01-12,5		
Relative aquitard in the lower part of Narovsky aquifer	D_2	Clay-marl rocks, basal layer	4-5	менее 0,01		
Vezenbergsky (Rakversky) aquifer of karst-fractured water	O_3	Dolomite and dolomited limestone	10-24	1-21	12-120	10^6-10^7
Bazalemsky aquitard	O_2	Clay, clay limestone	0,8-2,3	менее 0,01		
Ievsky aquifer of karst-fractured water	O_2	Limestone: dolomited limestone with some porous parts	12-25	1-4	8-10	10^7
Shundorovsky aquitard	O_2	Clay-marl-dolomite with bentonitis clay	8-10	менее 0,01		
Kukersky aquifer of fractured karst water	O_2	Clay limestone and dolomited with kukersite interlayers	18-26	0,1-3,6 до 5,4	20-30	$3{,}5\cdot10^{2}$-$1{,}8\cdot10^{3}$ μ=0,015-0,072
Kukersky-Ukhakusky aquitard	O2	Alternation of marl, clay dolomite and kukersite, includes indusrial layer	10-12	менее 0,01		
Tallinn aquifer of karst-fractured water	O2	Dolomited limestone, dolomite	18-26	0,05-6,2 до 15,3	30-160	1,7·10 4 μ=0,027
Leatsky aquitard (earlier Mjaekjulasky)	O1	Glauconitic sandstone; clay and marl	0,3-0,8	4·10-5	2·10-4	
Obolovy aquifer, porous-formation water	O1	Sands, sandstone porous, fine-granular with clay interlayers	27-34	1,8-8,0,в среднем 3	50-200	(2-4) ·105
Lontova aquitard	Cm1	Clays, argillite	30-100	менее 0,001		
Lomonosov aquifer (earlier nadljaminaritovy)	Cm1	Sandstone with clay interlayers	16-51	0,8-1,7	61,8	3,3·10 5
Kotlin aquitard	Pt	Thin clay and siltstone	до 120	менее 0,01		
Gdov aquifer of porous-fractured-formation water	Pt	Arkosic sandstone with clay interlayers, siltstone and sands	55-70	1-2	50	
Relative aquitard of residual soil	Pt	Clay talus of crystal rocks	2-6	менее 0,1		
Complex of interstitial water of crystal basement	Ar+Pt	Gneiss, granite, metamorphic rocks				

Figure 42. Description of aquifers and aquitards in Leningrad oil-shale deposit area (Source: Podsevalov, 2006)

Annex 4

Data on pumping water volumes from mines

	Inflow m^3/hour	Number of hours	Amount of days	Volume of discharged water
Kirova mine "Central pumping"				
January	210	24	31	156,240
February	195	24	28	131,040
March	204	24	31	151,776
Totally for three months				439,056
April	207	24	30	149,040
May	204	24	31	151,776
June	201	24	30	144,720
Totally for three months				445,536
July	201	24	31	149,544
August	198	24	31	147,312
September	202	24	30	145,440
Totally for three months				442,296
October	210	24	31	156,240
November	210	24	30	151,200
December	210	24	31	156,240
Totally for three months				463,680
Totally for the year				1,790,568

Figure 43. Data on pumping water volume from mines (Source: Podsevalov, 2006).

	Inflow m³/hour	Number of hours	Amount of days	Volume of discharged water
"Leningradskaya" mine "Central" pumping				
January	419	24	31	311,736
February	400	24	28	268,800
March	404	24	31	300,576
Totally for three months				881,112
April	381	24	30	274,320
May	396	24	31	294,624
June	388	24	30	279,360
Totally for three months				848,304
July	373	24	31	277,512
August	381	24	31	283,464
September	366	24	30	263,520
Всего за квартал				824,496
October	291	24	31	216,504
November	371	24	30	267,120
December	373	24	31	277,512
Totally for three months				761,136
Totally for the year				3,315,048

Figure 44. Data on pumping water volume from mines (Source: Podsevalov, 2006).

Annex 5

Drawdown piezometric curves for the different aquifers

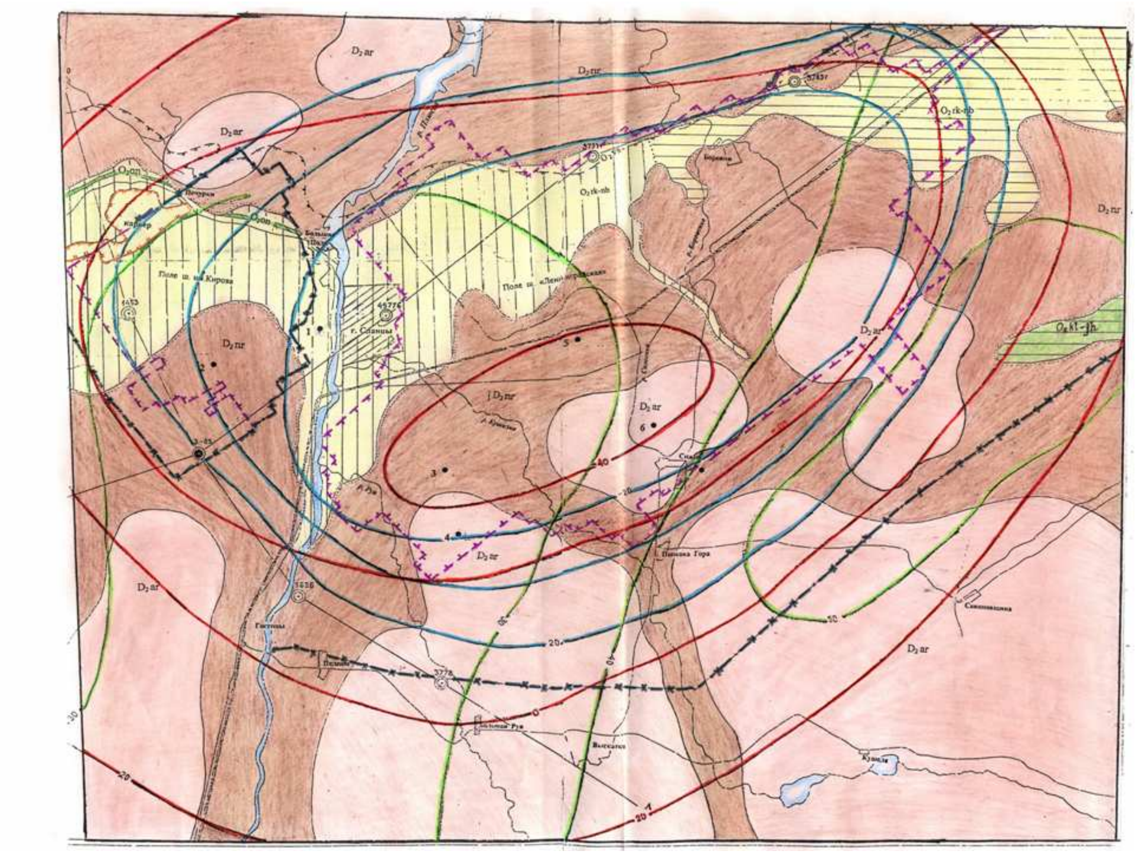

Figure 45. Drawdown piezometric curves for the different aquifers (Source: Sammet et al., 2006)

Рис.2. ГИДРОГЕОЛОГИЧЕСКАЯ КАРТА
РАЙОНА ШАХТНЫЙ ПОЛЕЙ
Масштаб 1 :75 000

УСЛОВНЫЕ ОБОЗНАЧЕНИЯ

1. Распространение водоносных и водоупорных горизонтов

D_2ar	Арукюлаский водоносный горизонт. Пески, алевриты
D_2nr	Наровский водоносный горизонт. Доломиты, мергели, песчаники
O_2 rk-nb	Ракверско-набальский водоносный горизонт. Известняки
O_2 on	Оандуский водоупорный горизонт. Глины
O_2kl-jh	Кейласко-йыхвиский водоносный горизонт. Известняки, доломиты

2. Водопроводимость водоносных горизонтов

до 50 м^2/сут.

100 – 200

200 – 500

3. Гидродинамические показатели

50 — Пьезоизогипсы ракверско-набальского горизонта

20 — То же кукерского горизонта

0 — То же таллинско-волховского горизонта

4. Другие обозначения

Контур отработанного подземного пространства

Карьер известняков «Печурки»

1 ● Выпуск шахтных вод на поверхность

Границы шахтных полей

1,2 – Центральный и Южный выпуски шахты им.С.М.Кирова

3,4 – первого района, 5 – второго района и 6,7 – третьего района шахты «Ленинградская»

А — Б Скважина на разрезе

3-03 Скважина наблюдательная

Annex 6

Mine water dicharges quality data

Indicator	Units	Authorized MPC of hazard. substances in	Central, Kirova mine 2005	Central, Kirova mine 2006	Southern, Kirova mine 2005	Southern, Kirova mine 2006	Central Leningradskaya mine 2005	Central Leningradskaya mine 2006	Southern, Leningradskaya mine 2005	Southern, Leningradskaya mine 2006	Central, mine №3 2005	Central, mine №3 2006	Southern, mine №3 2005	Southern, mine №3 2006
iron	mg/l	0,1	0,88	0,075	0,11	0,095	0,124	0,1	0,121	0,55	0,185	0,565	0,16	0,37
calcium	mg/l	180	72,6	74,4	74	77	84	99	84,7	102	79,5	91	70	90
magnesium	mg/l	40	36,4	30,6	33,5	30	44,3	43	44,7	42	37,75	37	35	37,6
nitrate	mg/l	9,2	0,59	0,5	0,5	0,52	0,79	0,835	0,8	0,87	0,78	0,58	0,46	0,4
nitrite.	mg/l	0,024	0,028	0,006	0,018	0,006	0,018	0,006	0,018	0,006	0,024	0,011	0,016	0,02
chlorides	mg/l	300	17,5	33,8	21	27,5	20	22	20	22	15,6	15	14	16,3
sulphates	mg/l	100	62,23	50,9	60	50,7	78,5	114	88	119	61,5	66	57	58,1
ammonium	mg/l	0,39	0,25	0,055	0,355	0,074	0,21	0,09	0,196	0,105	0,415	0,155	0,14	0,13
fluoride	mg/l	1,2	0,1	0,29	0,17	0,165	0,23	0,27	0,26	0,24	0,38	0,54	0,31	0,58
manganese	mg/l	0,01	0,018	0,017	0,023	0,025	0,043	0,01	0,043	0,025	0,035	0,042	0,024	0,028
aluminium	mg/l	0,04	0,012	0,03	0,015	0,015	0,015	0,022	0,016	0,037	0,015	0,013	0,015	0,01
pH	pH	6:-9	7,6	7,4	7,37	7,3	7,4	7,15	7,5	7,15	7,1	7,55	6,4	7,55
Total hardness	mg-equ/l	7	6,7	6,25	6,5	6,3	7,85	8,5	7,9	8,6	6,95	7,66	6,4	7,6
suspended matters	mg/l	0,25	2,5	7,85	3,5	2,75	2,36	3,6	2,63	7,85	4,3	9,4	3,6	11
BOD_5/PK	$mg0_2$/l	3,0	4,2	4,54	4,55	4,5	4,35	3,73	4,35	4,1	4,2	5,75	4,35	4,9
Oil products	mg/l	0,05	0,012	0,012	0,021	0,009	0,017	0,083	0,0155	0,083	0,045	0,042	0,046	0,13
phenols	mg/l	0,001	0,00085	0,00085	0,00068	0,00125	0,00073	0,00095	0,0188	0,0042	0,0009	0,0011	0,0026	0,0011
phosphates	mg/l	0,1	0,058	0,054	0,066	0,059	0,056	0,05	0,085	0,07	0,063	0,05	0,057	0,05

Indicator	Units	Authorized MPC of hazard. substances in water	Central, Kirova mine 2005	Central, Kirova mine 2006	Southern, Kirova mine 2005	Southern, Kirova mine 2006	Central Leningradskaya mine 2005	Central Leningradskaya mine 2006	Southern, Leningradskaya mine 2005	Southern, Leningradskaya mine 2006	Central, mine №3 2005	Central, mine №3 2006	Southern, mine №3 2005	Southern, mine №3 2006
nickel	mg/l	0,01	-	0,0105	-	0,042	0,026	0,01	0,01	0,01	-	0,01	-	0,01
lead	mg/l	0,03	0,0011	0,0012	0,0015	0,002	0,0013	0,0014	0,0001	0,0019	0,0014	0,0018	0,0015	0,0015
cadmium	mg/l	0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
zinc	mg/l	0,5	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
copper	mg/l	0,001	0,0036	0,01	0,0064	0,21	0,013	0,011	0,0069	0,01	0,0038	0,016	0,0047	0,018
mercury	mg/l	0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005
arsenic	mg/l	0,005	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
chromium	mg/l	0,005	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
molybdenum	mg/l	0,25	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025
barium	mg/l	0,7	1,2	0,23	1,1	0,45	0,95	0,6	0,65	0,45	0,78	0,7	0,5	0,46
boron	mg/l	0,5	0,1	0,1	0,11	0,1	0,23	0,21	0,24	0,15	0,15	0,1	0,23	0,23
beryllium	mg/l	0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002
strontium	mg/l	0,4	0,2	0,26	0,13	0,21	0,15	0,13	0,21	0,24	0,22	0,18	0,26	0,3
selenium	mg/l	0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005

Figure 46. Mine water discharges quality in 2006 – Source: Podsevalov, 2006

Annex 7

Surface water quality data

water chemical analysis in Pljussa river Basin

№ of sample № про-бы	Location Место взятия	Content in 10⁻³ g/dm³ Содержание в 10^{-3} г/дм^3						Content in Содержание в 10^{-6} г / дм^3				
		Pesticides Пестициды										
		cCu	cCl	cP	J	Br	F	Cu	Zn	Pb	Co	Ni
1	2	3	4	5	6	7	8	9	10	11	12	13
20	Р. Плюсса, в устье	0.4	-	-	1.9	-	0.18	8	<5	3.3	0.2	1.2
21	руч. Темница-Крав	0.3	-	-	1.27	-	0.2	6	6	10.6	<0.2	4.5
22	руч. в 4 км. к югу от пробы №20	0,19	-	-	4.0	2.39	0.41	2	24	2.9	0.2	1.2
23	Руч. в 2 км. к ССВ от дер. Бол. Поля	1,19	-	-	-	0.66	0.25	4	6	9.5	2.5	5.3
15	р. Плюсса, сев. конец дер. Бол. Поля	0,03	-	-	0.85	-	0.41	10	6	3.8	<0.2	0.8
16	р. Боровенка, в 100 м. от устья	0.1	-	-	1.27	0.8	0.46	12	<5	<2	0.5	1.3
17	р . оровенка у моста на шоссе в Сланцы	0.1	-	-	-	1.6	0.2	2	<5	2.2	0.2	2.4
18	р. Черная у ж/д моста	0.14	-	-	-	1.06	0.3	6	<5	0.47	0.2	11.1
19	р. Щучка в 300 м выше ж/д моста	0.05	-	-	-	1.6	0.35	3	12	5.7	<0.2	2.1
13	р. Кушелка в устье	0.19	0.05	-	-	0.53	0.5	7	<5	<2	5.6	3.2
11	р. Кушелка у дер. Кушелка	0.2	0,005	-	-	1.86	0,8	4	11	<2	1.8	1.8
2	р. Кушелка у дер. Залесье	0.19	0.005	-								
14	р. Руя в устье	0.03	-	-	1.69	-	0.46	5	<5	3	0.4	0.9
1	р. Руя у дер. Кривицы	0.18	-	-								
51	р. Руя у дер. Новоселье				-	-	0.72	7	11	2	<2	0.7
12	р. Плюсса в 2 км. выше д. Гостицы	0.3	-	-	-	1.86	0.46	6	5	<2	0.4	1.4

Figure 47. Chemical analysis in Pjlussa river basin (SGE 2006)

№ sample № про-бы	Место взятия Sample place	pH	Hardness Жесткость общ. мг-экв	Solid Сухой ост. м residue	Содержание в 10^{-3}. г/дм^3 NH$_4$	Ca	Mg	Fe общ.	Cation Сумма катио-нов sum	Cl	SO$_4$	NO$_3$	NO$_2$	Anion Сумма анио-нов sum	O$_2$	SiO$_2$	Oil Нефте-прод. prod.	Фено-лы Phenols
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
20	р. Плюсса, в устье	8.3	2.9	170 / 164.3	0.1	41.1	10.3	0.45	55.9	12.4	17.3	3.0	0.05	176.1	14.4	*5.5	-	0.013
21	руч. Темница-Крав	8.0	2.4	186 / 152.2	1.5	44.1	2.4	1.1	50.2	8.9	18.7	1.3	0.096	145.5	36.8	14.4	0.35	0.007
22	Руч. в 4 км. к югу от пробы №20	8.1	2.9	173 / 164.6	0.6	40.1	10.9	1.1	55.5	7.1	15.0	2.0	0.18	179.1	16.0	8.0	0.5	0.011
23	Руч. в 2 км. к ССВ от дер. Бол. Поля	8.3	6.4	339 / 331.2	0.16	64.7	38.9	1.4.	105.9	39.0	28.6	2.0	0.034	362.5	7.7	9.2	0.3	0.007
15	р. Плюсса, сев. конец дер. Бол. Поля	8.2	2.5	168 / 149.2	0.5	40.1	6.1	1.0	50.9	10.6	6.6	0.7	0.026	155.9	14.1	10.7	0.15	-
16	р. Боровенка, в 100 м/ от устья	8.2	3.5	207 / 203.3	0.8	52.1	10.9	0.74	65.0	7.1	30.2	0.5	-	205.7	22.4	16.8	0.25	0.0135
17	р . Боровенка у моста на шоссе в Сланцы	8.2	2.6	174 / 161.0	0.82	44.1	4.9	0.9	127.4	8.9	8.2	0.4	0.066	160.7	24.0	18.2	0.2	0.07
18	р. Черная у ж/д моста	8.2	1.8	145 / 134.3	0.8	35.1	-	1.3	45.7	8.9	6.2	0.4	0.038	127.4	22.4	17.3	0.6	0.005
19	р. Щучка в 300 м. выше ж/д моста	7.75	2.0	137 / 128.0	2.3	35.1	3.0	2.2	41.5	7.1	15.6	0.4	0.05	122.3	42.4	13.0	0.5	0.0135
13	р. Кушелка в устье	8,25	4,7	271 / 256,3	0,5	54,1	24,3	0,43	81,1	19,5	38,1	1,3	0,06	269,9	10,2	11,4	-	-
11	р. Кушелка у дер. Кушелка	7.8	3.2	196 / 182.6	0.5	40.1	14.6	0.56	61.1	10.6	4.9	0.62	0.03	203.4	12.5	12.3	0.6	-
2	р. Кушелка у дер. Залесье	8.4		214 / 184.7	0.1	36.1	17.0	0.39	59.2	14.2	17.9	-	-	196.9			0.3	-
14	р. Руя в устье	8.2	4.15	2656 / 232.0	1.6	47.1	21.9	0.38	70.9	14.2	39.5	1.0	0.02	238.0	10.6	12.2	0.1	-
1	р. Руя у дер. Кривицы	8.5		236 / 223.5	0.2	36.1	30.4	0.46	69.9	14.2	9.2	-	0.078	235.5			-	-
51	р. Руя у дер. Новоселье	8.5	2.8	182 / 166.6	0.1	34.1	13.4	0.5	54.9	7.1	4.1	1.0	0.02	184.3	6.4	13.4	-	-
12	Р. Плюсса в 2 км. выше д. Гостицы	8.5	2.55	162 / 153.2	0.2	34.1	22.5	0.43	59.1	10.6	5.6.	0.62	-	152.9	11.8	9.6	-	-

Figure 48. Chemical analysis in Pjlussa river basin - Source: Sammet et al., 2006

Indicator	Units	Authorized MPC of hazard. substances in water	Pljussa river. 100 m to the south from the surrent	Pljussa river. 100 m after centr. pumping	Pljussa river 50 m to the phenol channel	Pljussa river. 50 m after phenol channel	Puya river. 100 m to the south discharge	Puya river. 300 m after central pumping	Sizhenka river. 300 m above the south pumping	Sizhenka river. 300 m down of central pumping	Kushelka river before the discharge	Kushelka river after discharge
iron	mg/l	0,1	0,66	0,7	-	-	0,71	0,18	1,04	0,35	0,52	0,53
calcium	mg/l	180	21,2	25,5	32	32	33,5	70,3	20,45	63	31	32
magnesium	mg/l	40	9,2	10,5	15,8	15,8	18,08	36	8,25	40	16,4	16,7
nitrate	mg/l	9,2	0,47	0,5	0,57	0,73	0,82	1,0	2,18	1,0	1,0	0,97
nitrite.	mg/l	0,024	0,024	0,03	0,052	0,054	0,049	0,02	0,016	0,024	0,176	0,039
chlorides	mg/l	300	12,95	14	13	15,5	14	24,6	23,27	23	10,7	12
sulphates	mg/l	100	17,75	15	10	15,3	17,25	87	10	50	16,25	14
ammonium	mg/l	0,39	0,925	0,98	0,57	0,7	0,61	0,47	1,425	0,7	0,815	0,72
fluoride	mg/l	1,2	0,46	0,5	-	-	0,268	0,27	0,725	0,55	1,19	0,25
manganese	mg/l	0,01	0,07	0,09	-	-	0,054	0,056	0,21	0,05	0,09	0,07
aluminium	mg/l	0,04	0,041	0,05	-	-	0,044	0,025	0,049	0,032	0,035	0,04
pH	pH	6:-9	7,06	6,9	6,6	6,6	7,5	7,6	7,4	7,9	7,53	7,6
Total hardness	mg-equ/l	7	2,31	2,15	2,9	2,78	3,25	6,6	1,55	6,8	2,95	3,1
suspended matters	mg/l	0,25	2,95	2,63	-	-	3,38	4,9	12,8	8,7	3,615	3,2
BOD_5/PK	mg0_2/ l	3,0	5,13	5,3	-	-	5,6	5,5	4,13	3,8	5,18	4,9
oil products	mg/l	0,05	0,009	0,008	-	-	0,019	0,012	0,01	0,01	0,05	0,056
phenols	mg/l	0,001	0,0005	0,0005	-	-	0,0007	0,00073	0,00084	0,0007	0,0068	0,0012
phosphates	mg/l	0,1	0,085	0,09	-	-	0,12	0,065	0,14	0,077	0,14	0,1

Indicator	Units	Authorized MPC of hazard. substances in water	Pljussa river. 100 m to the south from the surrent	Pljussa river. 100 m after centr. pumping	Pljussa river 50 m to the phenol channel	Pljussa river. 50 m after phenol channel	Puya river. 100 m to the south discharge	Puya river. 300 m after central pumping	Sizhenka river. 300 m above the south pumping	Sizhenka river. 300 m down of central pumping	Kushelka river before the discharge	Kushelka river after discharge
nickel	mg/l	0,01	-	-	-	-	-	-	-	-	-	-
lead	mg/l	0,03	0,0013	0,0015	0,0001	0,0014	0,0021	0,002	0,0012	0,0018	0,0015	0,0014
cadmium	mg/l	0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
zinc	mg/l	0,5	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
copper	mg/l	0,001	0,01	0,012	-	-	0,09	0,098	0,082	0,04	0,081	0,093
mercury	mg/l	0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005
arsenic	mg/l	0,005	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
chromium	mg/l	0,005	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
molybdenum	mg/l	0,25	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025
barium	mg/l	0,7	1,3	0,46	1,2	0,61	0,6	0,29	0,8	0,7	0,6	0,58
boron	mg/l	0,5	0,1	0,21	0,15	0,1	0,12	0,15	0,13	0,16	0,15	0,18
beryllium	mg/l	0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002
strontium	mg/l	0,4	0,2	0,16	0,25	0,26	0,24	0,13	0,13	0,14	0,15	0,23
elenium	mg/l	0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005

Figure 49. Surface water quality upstream and downstream the mining water discharges – 2005 (Source: Podsevalov, 2006)

Indicator	Units	Authorized MPC of hazard. substances in water	Pljussa river. 100 m to the south from the surrent	Pljussa river. 100 m after centr. pumping	Pljussa river 50 m to the phenol channel	Pljussa river. 50 m after phenol channel	Puya river. 100 m to the south discharge	Puya river. 300 m after central pumping	Sizhenka river. 300 m above the south pumping	Sizhenka river. 300 m down of central pumping	Kushelka river before the discharge	Kushelka river after discharge
iron	mg/l	0,1	0,35	0,36	-	-	0,31	0,7	0,16	0,36	0,31	0,287
calcium	mg/l	180	14,3	18,1	34	22	24	80	20,5	70,7	27	32
magnesium	mg/l	40	8,9	8,7	19,2	34	17,5	30	10,5	34,5	15,9	10
nitrate	mg/l	9,2	2,5	2,8	0,18	0,24	5,5	2,97	0,14	1,61	6,1	6,0
nitrite.	mg/l	0,024	0,008	0,0083	0,069	0,075	0,009	0,006	0,0085	0,01	0,0103	0,006
chlorides	mg/l	300	10	10	17	13	10	23	12,5	17	10	10
sulphates	mg/l	100	10	10	10	14	10	95	10	60	13,3	15
ammonium	mg/l	0,39	0,8	0,8	0,37	0,47	0,63	0,34	0,95	0,17	0,33	0,34
fluoride	mg/l	1,2	0,17	0,29	-	-	0,6	0,5	0,85	0,46	0,6	0,067
manganese	mg/l	0,01	0,163	0,193	-	-	0,09	0,06	0,07	0,032	0,043	0,063
aluminium	mg/l	0,04	0,06	0,087	-	-	0,077	0,05	0,016	0,009	0,043	0,043
pH	pH	6:-9	7,43	6,93	7,6	7,6	7,4	7,6	7,5	7,4	7,5	7,5
Total hardness	mg-equ/l	7	1,4	1,6	3,3	3,2	2,63	6,6	1,9	7	2,66	2,4
suspended matters	mg/l	0,25	2	2,7	-	-	13,7	2	7	7,6	8	6,3
BOD_5/PK	mg0_2/ l	3,0	5,87	6,1	-	-	4,9	5,69	5,4	4,9	3,53	5,4
oil products	mg/l	0,05	0,005	0,0067	-	-	0,005	0,018	0,021	0,021	0,005	0,005
phenols	mg/l	0,001	0,00077	0,0011	-	-	0,0007	0,00073	0,00085	0,0005	0,0005	0,0005
phosphates	mg/l	0,1	0,53	0,058	-	-	0,078	0,05	0,155	0,05	0,084	0,091

Indicator	Units	Authorized MPC of hazard. substances in water	Pljussa river. 100 m to the south from the surrent	Pljussa river. 100 m after centr. pumping	Pljussa river 50 m to the phenol channel	Pljussa river. 50 m after phenol channel	Puya river. 100 m to the south discharge	Puya river. 300 m after central pumping	Sizhenka river. 300 m above the south pumping	Sizhenka river. 300 m down of central pumping	Kushelka river before the discharge	Kushelka river after discharge
nickel	mg/l	0,01	-	-	-	-	-	-	-	-	-	-
lead	mg/l	0,03	0,0031	0,0013	0,0013	0,0011	0,0016	0,0012	0,0021	0,0015	0,0015	0,001
cadmium	mg/l	0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
zinc	mg/l	0,5	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
copper	mg/l	0,001	0,015	0,0012	-	-	0,33	0,001	0,008	0,017	0,009	0,001
mercury	mg/l	0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005
arsenic	mg/l	0,005	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
chromium	mg/l	0,005	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
molybdenum	mg/l	0,25	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025	<0,0025
barium	mg/l	0,7	1,4	0,48	1,35	0,46	0,68	0,6	0,71	0,43	0,74	0,56
boron	mg/l	0,5	0,21	0,12	0,1	0,1	0,15	0,13	0,2	0,1	0,13	0,11
beryllium	mg/l	0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002
strontium	mg/l	0,4	0,25	0,16	0,23	0,19	0,18	0,3	0,22	0,24	0,16	0,16
selenium	mg/l	0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005

Figure 50. Surface water quality upstream and downstream the mining water discharges – 2006 (Source: Podsevalov, 2006)

Quantative chemical research Количественные химические исследования.		
Определяемые показатели Indicators	Результаты исследований Results	Допустимые уровни Allowable level
Цветность Chromaticity	250,0 ± 25,0 градусов	не более 20 градусов
Мутность Turbidity	1,16 ± 0,12 ЕМФ	не более 2,6 ЕМФ
Запах Odour	1 балл, застойный	не более 2 баллов
Привкус Taste	0 баллов	не более 2 баллов
Водородный показатель (pH)	7,39 ед.pH	в пределах 6-9
Нитрит-ион Nitrite	0,068 ± 0,0095 мг/дм^3	3,1 мг/дм^3
Нитраты Nitrate	0,55 ± 0,099 мг/дм^3	не более 45,0 мг/дм^3
Окисляемость перманганатная Oxidability	27,94 ± 6,98 мг/дм^3	не более 5,0 мг/дм^3
Щелочность Alkalinity	1,50 ± 0,37 мг-экв/л	по факту
Хлориды Chloride	3,80 ± 0,95 мг/дм^3	не более 350,0 мг/дм^3
Сульфаты Sulphate	<10 мг/дм^3	не более 500,0 мг/дм^3
Железо Iron	0,4 ± 0,099 мг/дм^3	не более 0,3 мг/дм^3
Жесткость общая Hardness	1,23 ± 0,0615 мг-экв./л	не более 7,0 мг-экв./л
Сухой остаток Solid residue	270 ± 24 мг/дм^3	не более 1000,0 мг/дм^3
Кальций Calcium	13,1 ± 1,31 мг/дм^3	по факту
Магний Magnesium	4,86 ± 0,49 мг/дм^3	50,0 мг/дм^3
Сероводород Hydr. suphide	менее 0,002 мг/дм^3	0,0003 мг/дм^3
Бикарбонаты Bicarbonate	91,57 ± 4,58 мг/дм^3	по факту
Натри (Na$^+$)	9,66 ± 1,45 мг/дм^3	200,0 мг/дм^3
Ртуть Mercury	менее 0,00005 мг/дм^3	не более 0,0005 мг/дм^3
Бор Boron	<0,1 мг/дм^3	не более 0,5
Барий Barium	0,47 ± 0,05 мг/дм^3	не более 0,7 мг/дм^3
Бериллий Beryllium	<0,0002 мг/дм^3	не более 0,0002 мг/дм^3
Фториды Fluoride	<0,02 мг/дм^3	1,2-1,5 мг/дм^3
Алюминий Aluminium	0,07 ± 0,02 мг/дм^3	не более 0,5 мг/дм^3
Марганец Manganese	0,020 ± 0,050 мг/дм^3	не более 0,1 мг/дм^3
Мышьяк Arsenic	менее 0,005 мг/дм^3	не более 0,05 мг/дм^3
Никель Nickel	0,048 ± 0,012мг/дм^3	не более 0,1 мг/дм^3
Кобальт Cobalt	менее 0,005 мг/дм^3	не более 0,1 мг/дм^3
Молибден Molybdenum	менее 0,003 мг/дм^3	не более 0,25 мг/дм^3
Медь Copper	<0,002 мг/дм^3	не более 1,0 мг/дм^3
Цинк Zinc	0,5 ± 0,1мг/дм^3	не более 0,5 мг/дм^3
Свинец Lead	0,17 ± 0,034 мг/дм^3	не более 0,03 мг/дм^3
Кадмий Cadmium	менее 0,001 мг/дм^3	не более 0,001 мг/дм^3
Хром Chromium	менее 0,005 мг/дм^3	не более 0,005 мг/дм^3
γ-ГХЦГ (линдан) Lindane	менее 0,0001 мг/дм^3	не более 0,002 мг/дм^3
ДДТ (сумма изомеров) DDT	менее 0,0001 мг/дм^3	не более 0,002 мг/дм^3
2,4 Д	менее 0,001 мг/дм^3	не более 0,03 мг/дм^3
Нефтепродукты Oil-products	<0,005 мг/дм^3	не более 0,1 мг/дм^3
Фенольный индекс Phenol index	0,0012 ± 0,00078 мг/дм^3	не более 0,25 мг/дм^3
ПАВ (поверхностно-активные вещества) tamol	<0,025 мг/дм^3	не более 0,5 мг/дм^3
Полифосфаты Polyphosphate	<0,05 мг/дм^3	не более 3,5 мг/дм^3
Суммарная альфа-активность α-activity	до 0,01	не более 0,1
Суммарная бета-активность β-activity	до 0,12	не более 1,0

Figure 51. Chemical composition of Pjlussa river (water intake point 28th April 2003)
Source : Sammet et al., 2006.

Annex 8

Soil quality data

Таблица 4

Content of chemical elements in soil of Slantsy town

Содержание химических элементов в почвах г. Сланцы

Элементы / Elements	Районный фон / Regional Background	Статистические характеристики / Statistical: Min	Max	Среднее / Average
		Элементы 1 класса опасности / I dangerous class		
Hg	0,03	0,01	0,48	0,06
Pb	19,10	7,00	1402,00	76,17
As	2,62	1,50	13,00	4,52
Cd	0,17	0,03	0,97	0,35
Zn	43,10	40,00	700,00	116,72
Se	1,00	0,75	0,75	0,75
		Элементы 2 класса опасности / II class		
Ni	15,30	2,50	30,00	7,39
Co	4,10	2,08	5,00	2,79
Cr	12,50	5,00	40,00	14,00
Mo	1,08	0,50	3,00	1,09
Cu	18,00	10,00	150,00	34,067
Sb	0,15	2,07	6,76	31,02
		Элементы 3 класса опасности / III class		
Mn	117,70	50,00	800,00	256,22
V	16,20	5,00	20,00	9,50
Sr	111,00	100,00	700,00	146,67
Ba	202,00	83,33	500,00	157,78
W	1,00	0,83	12,50	2,98
		Прочие элементы / Other elements		
Ti	1522,00	150,00	1500,00	788,89
Zr	139,80	40,00	300,00	148,11
Nb	5,40	4,17	15,00	7,11
Ag	0,01	0,02	0,80	0,07
Sn	1,37	0,50	10,00	1,20
Ge	0,59	0,42	0,83	0,51
Ga	11,00	1,50	3,00	1,87
Be	0,70	0,83	2,00	1,15
Y	16,70	5,00	20,00	10,22
P	302,90	150,00	2000,00	490,00
Li	15,30	5,00	30,00	9,50
Bi	0,19	0,04	0,43	0,14
Tl	0,29	0,27	1,60	0,62
Zc		0,00	124,74	15,46

Примечание: – содержания элементов даны в мг/кг;
– объем выборки составляет 30 проб.

Figure 52. Source : Sammet et al., 2006

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