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Pöyry Energy Oy
Lithuanian Energy Institute

Environmental Impact Assessment Report
New Nuclear Power Plant in Lithuania
August 27th 2008

Organizer of proposed economic activity:	**Lietuvos Energija AB**
Developer of EIA report:	**Pöyry Energy Oy (Finland)** **Lithuanian Energy Institute (Lithuania)**

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BI – Institute of Botany;
FI – Institute of Physics;
GGI – Institute of Geology & Geography;
LEI – Lithuanian Energy Institute;
NVSPL –The National Laboratory of the Public Health Care;
VPI - Vilnius Pedagogical University.

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Report	15 August 2008	

GLOSSARY

Activity	The quantity A for an amount of radionuclide in a given energy state at a given time, defined as $A=dN/dt$, where dN is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval dt. The unit of activity is the s^{-1}, termed the Becquerel (Bq), 1 Bq = 1 s^{-1}.
Aerosol	Small floating particle
AGIR	Advisory Group on Ionising Radiation
ALARA	As Low As Reasonable Achievable. This is an internationally recognized acronym which requires that the radiation dose to personnel which results from work with radioactive substances is minimized to the greatest possible extent, except where the additional cost or impracticality of further dose-reduction measures would be unreasonable when compared to the additional dose-reduction obtained by the adoption of those measures. The ALARA principle is progressively used in environmental issues as well.
Alpha/ beta/ gamma emitters	Nuclei that emit alpha, beta or gamma type of ionizing radiation
AOO	Anticipated Operational Occurrence
Aquifer	An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.
ASKRO	Part of a permanent real-time environmental and sanitary control system. The purpose of the system is to inform the population on radiation security.
Background contamination	Levels of hazardous substances in the environment that are either naturally occurring, from an off-site source or a result of general contamination in the area.
bar	A unit of pressure. 1 bar = 100 000 pascal (Pa). Atmospheric pressure is approximately 1 bar.
BDBA	Beyond Design Basis Accident
Bq, Becquerel	The SI unit of activity, equal to one transformation per second.
C-14, carbon-14	In addition to radon, the Carbon-14 isotope is the most significant source of radiation exposure in a uranium fuel cycle.
Cloud shine	Exposure to gamma radiation from radioactive materials in an airborne plume
Collective dose	Product of the number of persons of the exposed population group and the average dose per person; unit mansievert [manSv]
Condenser	Condenser converts and recovers the steam that passes through the turbine from its gaseous to its liquid state
Cooling water	Cooling water is sea/lake/river water used in a condenser for cooling the steam coming from the turbines back to water. Cooling water does not come into contact or mix with the process waters of the nuclear power plant.
D&D	Decontamination & Decomissioning
DBA	Design Basis Accident
DCD	Design control documentation
Deuterium	Isotope of hydrogen which nucleus contains one proton and one neutron
Direct cooling system (DC)	Cooling water is taken from water reserve (e.g. lake), led through a heat exchanger and the warmed water is discharged back to the reserve.
E.ON	E.ON AG; Germany based energy corporation
EDF	Electricité de France
Effective dose	Includes both external (cloud shine and ground shine) and internal (inhalation and ingestion) dose

Efficiency	The ratio of the amount of electric energy produced by a power plant to the amount of energy contained in the consumed fuel.
EIA	Environmental impact assessment.
Electrical power	The rate at which electrical energy is generated at power plant
EnBW	Energie Baden-Württemberg AG
Enrichment	Concentration of a substance. Before enrichment, uranium is converted in gaseous form through chemical processes to uranium hexafluoride (UF_6). The enrichment of uranium hexafluoride is executed either by gas diffusion or nowadays increasingly by centrifuge methods by utilizing chemical and physical characteristic of the uranium.
Environmental Management System (EMS)	EMS serves as a tool to improve environmental performance. Defined in ISO 14001 standard. Provides a systematic way of managing an organization's environmental affairs and is the aspect of the organization's overall management structure that addresses immediate and long-term impacts of its products, services and processes on the environment.
Equivalent dose	The absorbed dose adjusted for the relative biological effect of the type of radiation being measured
EUR (European Utilities Requirements document)	the European Utility Requirements (EUR) document aim at harmonisation and stabilisation of the conditions in which the standardised LWR nuclear power plants to be built in Europe.
Eutrophication	Eutrophication is an increase in nutrients in an ecosystem.
External exposure	The dose that Includes the dose from cloud shine and the dose from ground shine
FCS	Favourable conservation status
Fission	The splitting of a heavy atomic nucleus into two parts, accompanied by the release of fast neutrons.
FMI	Finnish Meteorological Institute
Fujita classification	A scale for rating tornado intensity, based on the damage tornadoes inflict on human-built structures and vegetation. Scale: F0-F12. F0 corresponds to wind speed of 64-116 km/h. F12 is equal to 1 Mach.
Gaseous radioactive emissions	Radioactive material particles released from the source to atmosphere.
GE	General Electric Company
Ground shine	Exposure to gamma radiation from radioactive materials deposited on ground
Half-life	The time it takes for the amount of radioactive matter to be reduced to half as a result of radioactive decay, i.e. as half the matter is converted into another type of matter.
Heavy water	Heavy water is chemically the same as regular (light) water, but with the two hydrogen atoms (as in H_2O) replaced with deuterium atoms (hence the symbol D_2O). Deuterium is an isotope of hydrogen; it has one extra neutron.
HVAC	Heating, Ventilating and Air Conditioning
IAEA	International Atomic Energy Agency, The IAEA is the world's center of cooperation in the nuclear field. The Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies.
INES	International Nuclear Event Scale, is used for facilitating rapid communication to the media and the public regarding the safety significance of events at all nuclear installations associated with the civil nuclear industry, including events involving the use of radiation sources and the transport of radioactive materials.
INPP	Ignalina nuclear power plant

Integrated Monitoring (IM)	Simultaneous measurement of physical, chemical and biological properties of an ecosystem over time and across compartments at the same location.
Internal exposure	The dose due to inhalation or ingestion of radioactive material
InterRAS	A computer software for assessing the implications of nuclear accidents used in the first phase of an emergency
Ionising radiation	Radiation capable of producing ion pairs with differing charges in the biological environment.
ISO 14001 standard	An international voluntary standard describing specific requirements for an EMS(Enviromental management system). ISO 14001 is a specification standard to which an organization may receive certification or registration. Published by International Organization of Standardization.
Isotope	Atoms of the same element differing from each other in the number of neutrons in their nucleus. Almost all natural elements occur as more than one isotope.
Isotope-specific analysis	Analysis of masses by mass spectrometry and neutron activation analysis and analysis of radiation from the atom, as is done by α-, β-, γ– and sometimes X-Ray spectrometry.
Light water	Regular water, H_2O
LOCA	Loss Of Coolant Accident
LRDB	Lithuanian Red Data Book serves as a legal document on which the protection of rare and endangered plant, fungi and animal is based.
LULUCF (Land use, land use change and forestry)	Tree-planting projects, reforestation and afforestation, designed to remove carbon from the atmosphere
Maintenance	Complex of planned and systematically implemented activities aimed at ensuring reliable operation of systems (components) and maintaining their design characteristics within their design lives. Maintenance includes general service, overhaul, medium and current repair works, replacement of spares and design modifications of systems (components), as well as tests, inspections and calibration whenever necessary.
Mansievert (manSv)	A unit of collective dose. If, for example, each person in a population of 1000 members receives an average radiation dose of 20 millisieverts, the collective dose is 1000 x 0,02 Sv = 20 manSv
Monitoring zone	An area in which monitoring is performed.
MOX fuel	Mixed oxide fuel. Blend of oxides of plutonium and natural uranium, reprocessed uranium, or depleted uranium.
MW, megawatt	A unit of power (1 MW = 1 000 kW).
MWd(th)/TeU	The energy produced per initial unit of nuclear fuel weight.
NNPP	New nuclear power plant
NRDB	Natural Resources Data Base
Nuclear fission	Nuclear reaction of a heavy atomic nucleus and neutron which leads to subdivision of nucleus into two fragments and producing 2-3 fast neutrons.
Nuclear fuel	Nuclear materials used for nuclear power generation.
Nuclear materials	Any metal alloy, chemical compound or material mixture which contains plutonium, uranium (enriched in the isotope 235 or 233; or depleted) and thorium.
Nuclear Power Plant (NPP)	A complex of equipment and buildings intended for generating electricity or electricity and heat by using nuclear fuel.
N/A	Not applicable
OKB	*Опытное конструкторское бюро*: Development Design Bureau
Precipitation	Any product of the condensation of atmospheric water vapor that is deposited on the earth's surface

Project implementing company	Project implementing company is responsible for carrying out project implementation activities in compliance with the safety requirements imposed on nuclear activities. Having fulfilled the requirements laid down in legal acts and having received authorisations and licences, the project implementing company become the operator of the nuclear power plant and expand electricity generating capacities in accordance with the procedure laid down by legal acts. (ref. The Republic of Lithuania Law on the Nuclear Power Plant, State Journal, 2007, No. 76-3004)
Project organization	Organization, which is responsible for the proposed economic activity (Lietuvos Energija AB)
Radiation	
Alpha	Alpha radiation is of positively-charged particles emitted from the nucleus of an atom. Alpha particles are helium nuclei, with 2 protons and 2 neutrouns
Beta	Particle radiation consisting of electrons or positrons
Gamma	Gamma radiation is radiation travelling as electromagnetic waves whose wavelength is smaller and energy higher than those of X-rays
Radioactive emissions	Radioactive pollutant in gaseous form, as aerosols, liquids or in other form released into environment.
Radioactive materials	Material containing one or more radionuclides which activities must be considered from the point of radiation protection.
Radioactive noble gases (RNG)	The noble gases are helium (He), neon (Ne) argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Some of these isotopes are radioactive. The permanent activity monitoring of radioactive noble gases (Ar-41, Kr-85, Kr-85m, Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135m, Xe-135, Xe-138) released to atmosphere at Ignalina NPP is performed.
Radioactive waste	Spent nuclear fuel and other materials for which no further use is foreseen and which contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels.
Radioactivity	Transformation of an atomic nucleus into other nuclei. A radioactive nucleus emits radiation characteristic to the transformation (alpha, beta or gamma radiation).
Radionuclides	An unstable form of a nuclide
RADIS	Automatic Measurement Systems Division. Maintains the automatic gamma-monitoring network and the mobile radiological laboratory.
RBMK	*Reaktor bolshoy moshchnosti kanalniy* is a Russian water-cooled graphite-moderated channel-type reactor type used in INPP
Reactor types	
CANDU reactor	CANDU (CANada Deuterium Uranium) is a pressurized heavy water reactor which uses natural uranium (0,72% U-235) as a fuel and heavy water for cooling and neutron moderation.
ACR	The Advanced CANDU Reactor can be considered as a hybrid form of PWR, having a different reactor design. It is a light-water-cooled reactor that incorporates features of both Pressurised Heavy Water Reactors (HWR) and Advanced Pressurized Water Reactors (APWR) technologies.
BWR	Boiling Water Reactor: A light-water reactor in which water used as the coolant boils as it passes through the reactor core. The resulting steam is used for driving a turbine.
HWR	Heavy-Water Reactor in which heavy water is kept under pressure in order to raise its boiling point, allowing it to be heated to higher temperatures and thereby carry more heat out of the reactor core.
LWR	Light Water Reactor: Reactor type in which regular water is used for cooling and as a moderator. Most nuclear power plant reactors in the world are light water reactors.
EPR	European Pressurized Reactor.
PWR	Pressurized Water Reactor: A light-water reactor in which the water used as coolant and neutron moderator is kept under such a high pressure that prevents it from boiling regardless of the 300°C temperature. The water that has passed through the reactor core releases its heat to the

	secondary circuit water in separate steam generators. It boils into steam that is used for driving a turbine.
RWE	RWE AG; Germany based energy corporation
SA	Severe Accident
SAC	Special Area of Conversation
SPZ	Sanitary Protection Zone: A special territory or a site of radioactive contamination where the irradiation level may exceed the prescribed norms under normal operational conditions of a nuclear facility.
SAR	Safety Analysis Report
SCI	Sites of Community Importance
SILAM	Air Quality and Emergency Modelling System SILAM of the Finnish Meteorological Institute
SPA	Special Protection Area
Specific activity	Ratio of the sample's activity and its mass (unit – Bq/kg)
SNF	Spent Nuclear Fuel: Nuclear fuel irradiated in the active zone of a reactor if the organisation operating the reactor officially registers following the procedures set by the state or state delegated authority and/or the supervising institutions that the fuel will no longer be used in reactors.
Sv, Sievert	An ionising radiation dose unit indicating the biological effects of ionising radiation. As it is a very large unit, millisieverts (1 mSv = 0,001 Sv) and microsieverts (1 μSv = 0,001 mSv) are more commonly used.
Thermal power	The rate at which thermal energy is generated in the reactor
TLD stations	Thermoluminescent Dosimeter (TLD) stations are used to measure external radiation exposure rates in the site.
Tritium	Radioactive isotope of hydrogen (H-3). The nucleus of tritium contains one proton and two neutrons.
TWh,	Terawatt/hour: A unit of energy. One terawatt-hour equals one billion kilowatt/hours or one thousand gigawatt/hours.
UK HSE	United Kingdom Health and Safety Executive
UNECE, United Nations Economic Commission for Europe	Founded in 1947, UNECE, the United Nations Economic Commission for Europe, is one of the five regional commissions of the United Nations. Its aim is to strengthen the economic cooperation between its member countries.
UO_2	Uranium dioxide
Uranium	An element with the chemical symbol U. Uranium comprises 0,0004% of the earth's crust (four grammas in a ton). All uranium isotopes are radioactive. Natural uranium is mostly in the form of isotope U-238, which has a half-life of 4,5 billion years. Only 0,72% of natural uranium is in the form of isotope U-235, which can be used as a nuclear fuel.
US NRC	United States Nuclear Regulatory Commission
VATESI	Autonomous Lithuanian State Nuclear Power Safety Inspectorate
Waterborne releases	Radioactive effluents, released to environment.
WWTP	Waste water treatment plant
Yellowcake	Uranium concentrate; U_3O_8 (triuranium oxide)
Zircaloy	Group of high-zirconium alloys. Mainly used as cladding of fuel rods

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FIGURES

Geological maps by permission of Lithuanian Geological Survey.

EXECUTIVE SUMMARY

During spring of year 2007, Lietuvos Energija AB started an Environmental Impact Assessment (EIA) procedure for the construction of a new nuclear power plant (NNPP) to be located next to the present Ignalina nuclear power plant (INPP). The EIA is a prerequisite for the construction of such an important installation. It has to describe how the plant will influence the surrounding environment and evaluate if the impacts of the project are environmentally and socially sustainable. Only after the EIA has been exposed to the local and international communities and is approved by the Lithuanian Ministry of Environment can the project proceed. Based on Lithuanian regulations, the EIA procedure first involves preparation of an EIA Program (EIAP), which has to give the structure of the EIA and a description of the topics that will be studied and the methods to be employed. Based on the EIA Program, terms set by the Ministry of Environment, and received comments, an EIA Report (EIAR) is prepared, which describes the environment and assesses the environmental and social impacts of the project. The EIA Program was published July 26th, 2007, and it was approved by the Lithuanian Ministry of Environment on November 15th, 2007 after extensive national and international commenting. EIA Report has been prepared by an international consortium consisting of Pöyry Energy Oy and the Lithuanian Energy Institute (LEI) as commissioned by Lietuvos Energija AB. Preparation of the EIA Report began in February 2008 and the EIA Report was published and put on display for commenting on August 27th 2008.

THE PURPOSE, LOCATION AND SCHEDULE OF THE PROJECT

The project assessed in this EIA Report is the construction of a new nuclear power plant (NNPP) in the near vicinity of the present Ignalina nuclear power plant (INPP), in the municipality of Visaginas on the shore of Lake Druksiai in north-eastern Lithuania. The INPP is the main electricity source for Lithuania at the moment, but, as a condition of entry in the European Union, the Lithuanian government has agreed on shutting down the INPP since it does not meet the required safety standard conditions. The first unit of INPP was shut down in 2004, the second is still in operation and is to be shut down by the end of 2009. In order to face this electricity gap, the Lithuanian government started the decisional process for the construction of a new and safer regional NPP, capable of supplying also part of the neighbouring countries' needs for electricity.

The scheduled construction time for the new NPP is around 8-9 years from the start of the EIA procedure. This would mean 2015 as the earliest year for commissioning of the NNPP, which would match the forecasts of the Lithuanian National Energy Strategy.

PROJECT OPTIONS AND LIMITATIONS

There are two potential sites for the construction of the new NPP, both located on the shore of Lake Druksiai: Site No. 1 is situated east of Ignalina NPP and Site No. 2 is situated west of the existing INPP switchyard.

The choice of technology to be adopted in the new NPP is still open. All the suitable main reactor technologies (Boiling Water Reactor, Pressurized Water Reactor and Pressurized Heavy Water Reactor) have been evaluated in this EIA Report, considering different vendors, different power levels, the two site alternatives for the construction of the plant and different cooling alternatives. The maximum power output of the NNPP discussed in this EIA Report is 3 400 MW, with the number of reactors varying from 1 to 5 depending on the technological alternatives and total power generation capacity to be constructed. Different cooling system options have also been studied and the cooling capacity of and impacts on Lake Druksiai has been assessed.

LINKS TO OTHER PROJECTS AND PLANS

The new NPP will be erected next to Ignalina NPP, but will be operated by a different company. The location next to INPP provides the opportunity to utilise existing infrastructure, whenever this is feasible. This existing infrastructure that can possibly be utilised includes among others the cooling water inlet and outlet channels, electric systems and transmission lines, and monitoring systems. New facilities for storage of radioactive waste and spent nuclear fuel are under study and planning, and will be further studied and assessed in other EIA's.

The INPP provides district heating to the town of Visaginas. New gas fired boilers have been constructed to provide heat to the city after the shutting down of INPP. Producing heat for district heating in Visaginas is an option under consideration in the NNPP project.

Decommissioning of INPP will continue for decades, and will thus be ongoing during construction and operation of the NNPP. New radioactive waste handling and storage facilities will be constructed as part of the decommissioning project. The aggregated impacts of these projects have been assessed in this EIA.

The Visaginas municipal waste water treatment plant (WWTP), which INPP utilizes and which the NNPP will utilise, is to be modernised in a project which has started in 2008. After this the capacity and treatment efficiency will be sufficient for the NNPP.

IMPACTS DURING THE CONSTRUCTION PHASE

The construction of the power plant will require a vast amount of workers in the area. It is estimated that up to 3 500 workers will be needed for the construction, while around 500 employees will be needed during the operational phase, depending on the technology chosen and the operation procedures. Foreign work force will be required during the construction phase.

The new labour force needed for the construction of the power plant will affect the economics and demography of the region. The NNPP region in Lithuania and Latvia will for 5-7 years have to host an exceptional amount of people. This will lead to a significant demand for goods and services and very significant positive socioeconomic impacts.

The construction works have to be accurately organized, since they will involve a large amount of labour force in the vicinity of the decommissioning project of INPP. Attention will have to be paid to the problems that the vicinity of these activities can create to each other in terms of traffic and congestions.

The first step of the works will involve excavation works, with the removal of up to 1.4 million cubic meters of excavated and blasted materials. Disposal areas will be required for this amount of soil. The construction works will increase the amount of traffic (especially cars and trucks) on the roads connecting Visaginas with the power plant construction site. It is estimated that 1 800 cars, 100 trucks and 60 buses will drive back and forth every day, producing emissions and noise. The traffic will however not have long term impacts on the air quality. Dust will also be generated, but will only affect the area of the construction site.

The waters of Lake Druksiai as well as groundwater will not be significantly affected by the construction of the NNPP because of implementation of an appropriate waste water system. Any direct discharge of untreated and polluting or hazardous material in the lake's waters will be strictly forbidden.

A significant amount of ordinary waste will be generated in this phase, including recyclable waste, waste suitable for energy production and hazardous waste. The shares and proportions will depend on the ability of the project implementation company to minimize the waste amounts and maximise recycling of the waste.

The noise level during the construction years would increase, but the construction site is located in an uninhabited area.

There will be no radioactive releases during the construction phase.

OPERATIONAL PHASE IMPACTS

The state of waters

The new NPP will use water from Lake Druksiai for heat dissipation. The cooling water will be warmed up approximately ten degrees when passing trough the nuclear power plant in the case of direct heating, where the heated cooling water is discharged back to the lake. The quality of the cooling water will not change in any other way. Model computations of the impact of releases of warm cooling water to Lake Druksiai were carried out with a three dimensional hydrodynamic model. The effects of different NNPP thermal loads to the lake and different NNPP cooling water inlet and outlet locations on the water temperature of Lake Druksiai were investigated.

Based on modelling results and expert assessments it can be concluded that the ecologically acceptable thermal load to the lake will be approximately 3 200 $MW_{released}$, With this thermal load no significant impacts on the lake ecosystem are expected compared to the present state of the lake. With higher thermal load the impacts on the lake ecosystem start to be clear and significant.

The current outlet is the best alternative when the area warmed up is used as criteria. However, the different outlet options do not significantly differ from each other. The present NPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water.

The main hydrological impacts of the operation of the new NPP are the evaporative losses created when the heated cooling water will transfer the heat load to air by evaporation. According to water balance calculations the water resources will be adequate for the operation of the NNPP also during dry years.

During normal hydrological years the average lake level is not expected to fall below the normal and thus the hydrological effects on the lake and their ecological consequences are considered minor. During dry years the lake level would fall below normal, however staying above the minimum allowed regulation level (for approximately three successive dry years). Thus also the consequences of this kind of rare event can be estimated to be small.

All the waste waters from the new NPP will be treated according to regulations. The nutrient and other load from the NNPP will be small compared to the total load to Lake Druksiai coming from other sources.

Climate and air quality

The operation of the new NPP will cause very limited emissions, mainly from the back up diesel engines and the traffic. These emissions will not have a significant detrimental impact on the ambient air quality of the Visaginas region, also taking the background contamination into account.

Geology, soil and groundwater

No significant impacts on geological conditions, soil or groundwater are expected during operation of the NNPP in either site alternative.

Biodiversity

Lake Druksiai and several other areas in the region are included in a European Union network of protected areas named "Natura 2000" and certain values of these areas are therefore to be preserved under specific regulations of the EU. The main focus of biodiversity impact assessment has been on the Lake Druksiai Natura 2000 –area. Lake Druksiai has been included in the Natura 2000 network based on both the EU Birds Directive and the Habitat Directive. The main focus has been on the possible water temperature change in the lake due to cooling water discharge, and the potential impacts of this on biodiversity values. Lake Druksiai can for ecological reasons not tolerate the planned maximum power generation. A maximum thermal load of approximately 3 200 $MW_{released}$ can be discharged to the lake without significant adverse impacts on essential biodiversity values of the lake, including the designation values for Lake Druksiai Natura 2000 area, being anticipated. Mitigation measures for biodiversity impacts are required.

Noise and the presence of workers, as well as direct construction measures destroying habitats will cause adverse impacts on other biodiversity values as well in both site alternatives. These impacts can however be mitigated to an acceptable level.

Landscape, land use and cultural heritage

The assessment of the landscape of the area shows how it already has been damaged by the construction and operation of the present power plant. The NNPP project would not cause further particular damages to the landscape. Photomontages showing possible impacts on the landscape from the most significant viewing points have been prepared and are provided in the EIA report.

No impact on cultural heritage values is expected in either site alternative.

Socio-economic environment

A significant positive impact on the socioeconomic environment of the NNPP region is expected. The new activity would reduce the adverse effects of the closure of the INPP, which would let the region without its main employment source. A need for a large workforce, in the order of up to 3 000–3 500 workers, will occur during the construction phase. This workforce will to a significant extent utilize the services of the region in both Lithuania and Latvia, which will bring significant positive socioeconomic impacts to the region. About 500 employees would work permanently in the NNPP.

A resident survey was performed in the area of the town of Visaginas and its surroundings as part of the EIA. The results show how the attitude of the great majority of inhabitants is favourable to the NNPP project.

Public health

The NNPP and the related traffic can have an adverse impact on air quality but the impact is so minor that it will not affect public health. The levels of noise in the vicinity of the NNPP will stay below allowable limits. The main positive impacts of the NNPP on public health are through the areas of improved economy and social security.

There will be no radiological impact on the population during the operation of the NNPP. The annual dose of the critical group members of the population due to releases of radioactive effluents (both airborne and liquid) vary in the range from 3.4 to 43.4 µSv depending on the reactor type, capacity and total number of units. This is well below the dose constraint established for the protection of the health of members of the public, which is 200 μSv per year.

Based on experience from other countries and estimations about the impact of the NNPP on the public, the sanitary protection zone for the NNPP is suggested to be of 1 – 3 kilometre radius depending on the reactor type chosen. The proposed sites for the NNPP are within the existing INPP industrial site and sanitary protection zone. The shortest distance from the proposed sites to the boundary of the existing sanitary protection zone is about 1.5 km.

IMPACTS OF NUCLEAR FUEL PRODUCTION AND TRANSPORTATION

Fuel for the new power plant will be uranium dioxide and it will be procured from the international nuclear fuel market. The uranium market would operate regardless the implementation of the NNPP.

Uranium mining, processing and transportation are performed following national and international regulations and agreements, prepared in order to minimize the damages to the environment and the exposure of the workers to radioactivity.

Nuclear fuel would be transported to the NNPP either by train or by truck.

WASTE

Radioactive waste is the main by-product of a nuclear power plant, and the amounts can differ significantly with the different available technologies. Spent nuclear fuel is initially cooled down in pools contained in the power plant unit to decrease its radioactivity. Afterwards it has to be disposed of and for this purpose there are different options available. The capacity of the INPP spent nuclear fuel storage facility is almost spent and the facility would not be able to store spent nuclear fuel or radioactive material from the new NPP. The importance of the topic makes further studies and EIA's focused on this necessary, in order to find the best solution, considering the regional, national and international conditions.

The NNPP produces solid, liquid and gaseous radioactive waste, which have been studied in the EIA Report considering the different technological options. The operation of the NPP will cause no harmful radioactive releases or any radioactive contamination because of the waste produced. The amounts will be lower than the limits set by the national and international legislation and the surrounding environment will not be significantly affected.

The NNPP will also produce conventional and hazardous waste. The NNPP operators will establish internal operations to enhance recycling and set agreements with licensed waste management companies, able to dispose this waste amounts safely without any harm for the environment.

MONITORING SYSTEMS

Environmental legislation requires parties responsible for projects and operations affecting the environment to carry out environmental monitoring. The Ministry of Environment of the Republic of Lithuania controls implementation of environmental monitoring, quality of monitoring data and information, and compliance with the standards and other normative legislation. The monitoring system for the new NPP will be designed to fulfil all the requirements of the Lithuanian legislation and regulations, the IAEA recommendations and obligations under the United Nations Conventions. The existing INPP monitoring system will be utilized where applicable. All the monitoring systems and devices applied will however be modernized to meet the current requirements on preciseness and periodicity. The monitoring sites and objects will be kept unaltered when possible to assure the comparability of the existing INPP monitoring data with the new system.

TRANSBOUNDARY IMPACTS

The transboundary impacts are mainly socioeconomic or linked to the impacts on Lake Druksiai. Radiological transboundary impacts will not occur during normal operation of the NNPP.

A significant positive impact on the socioeconomic environment in the foreign parts of the NNPP region is expected, mainly in Latvia through the need for workforce, accommodation and services. No significant negative socioeconomic impacts are expected as the NNPP will be constructed next to an existing NPP, to which the surrounding areas have adjusted.

Evaporation of water by cooling the NNPP would reduce the overall volume of water in Lake Druksiai, thereby impacting the quantity of water discharged to River Prorva. The decrease of mean flow would impact the approximately 50 km long stretch of River Prorva before the confluence of River Dysna. The minimum allowable discharge in River Prorva will remain at the present level (0.64 m^3/s) in all of the cooling scenarios.

No significant transboundary impacts on terrestrial and semi-aquatic fauna, flora and biodiversity are expected.

NUCLEAR SAFETY AND RISK ANALYSIS

High safety culture and special safety principles and regulations are required in the design and operation of nuclear power plants. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation. All the most relevant principles of nuclear safety are clearly presented in the EIA Report, together with all the well-established procedures able to minimize any risk of accident. The use of nuclear power in Lithuania requires a license and it is regulated by law. The authorities involved in the safety of the nuclear installations in Lithuania are the State Nuclear Power Safety Inspectorate (VATESI), the Ministry of Health (via the Radiation Protection Centre), the Ministry of the Economy, the Ministry of Environment and the Ministry of Internal Affairs.

A risk analysis of potential accidents resulting from the proposed economic activity has been done according to the recommendations of normative document "Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity" as part of the EIA. Accidental releases from the NNPP and their impacts on the environment and public have been considered for two scenarios: design basis accident (DBA) and severe accident. Loss-of-coolant accident has been chosen as the DBA to be assessed since it envelopes the consequences of all DBA's. For the severe accident case the source term for release into the environment has been estimated based on a 100 TBq release of Cs-137.

The dispersion of accidental releases in these situations has been simulated with Air Quality and Emergency Modelling System SILAM of the Finnish Meteorological Institute (FMI). The approach applied is based on brute-force multi-scale computations of dispersion using actual meteorological data from weather archives. To cover all realistic meteorological conditions several cases in different meteorological conditions during the years 2001 and 2002 have been simulated.

The assessment of doses received by the public as a result of accidental releases is based on the results of the dispersion simulations and it utilizes empirical coefficients and methodologies for converting the modelled concentrations in air and depositions to doses. The exposure of the environment and people depends on the specific meteorological conditions during the accident and the geographical location of the receiving point and thus the results of the study are given as 2-dimensional maps of the exposure levels, which are not exceeded with a certain probability for any realistic meteorological conditions.

The results of the dispersion modelling and dose estimation have showed that the dose for the members of public caused by the Loss-of-coolant accident is less than 10 mSv as required by the Lithuanian Regulation. Sheltering is not necessary in Lithuania or abroad in case of both Loss-of-Coolant accident or a Severe accident, neither is evacuation, temporary relocation or permanent resettlement. The main protective actions in case of a Severe accident are iodine prophylaxis and restrictions on the use of foodstuffs, milk and drinking water. Some mostly short time restrictions of certain foodstuff will be needed in case of both severe accident and Loss-of-coolant accident.

To mitigate the consequences of an accident to the public, the power plant and rescue service authorities maintain emergency preparedness. The Lithuanian nuclear energy legislation sets requirements for civil defence, rescue and emergency response actions.

IMPACTS OF DECOMMISSIONING

The decommissioning phase is a long and expensive process that will generate both ordinary and radioactive waste. A relevant amount of resources and time can be saved designing a reactor with the coming decommissioning project in mind. Moreover, the fact that this phase will not occur before the end of the life cycle of the plant (around 60 years of operation) gives time to the power plant operators to gather the resources needed for the implementation of this phase.

Decommissioning of the NNPP will undergo appropriate environmental impact assessment in due time.

INTERACTION

One of the objectives of the EIA procedure is to increase availability of information of the proposed economic activity and improve the opportunities for citizens' participation.

The competent authority, the Lithuanian Ministry of Environment, is responsible for the coordination of the EIA procedure.

Different stakeholder groups were consulted when needed during the preparation of the EIA Report and the supporting reviews.

The EIA Report will be available for public display. The motivated (justified) proposals, that will be received, will be registered, evaluated and attached as appendixes to the approved EIA Report. Public information and discussion events will be organized in the countries concerned.

The review of the EIA Report by relevant parties, including governmental institutions, responsible for health protection, fire-prevention, protection of cultural assets, development of economy and agriculture, and municipal administrations, has an important role in ensuring the quality of the EIA procedure.

Environmental impact assessment in a transboundary context is regulated by the Law on the Assessment of the Impact on the Environment of the Planned Economic Activities and by the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention*). The Ministry of Environment is responsible for the practical organization of the environmental assessment procedures in a transboundary context. The Ministry of Environment has informed the respective authorities of Latvia, Estonia, Poland, Belarus, Finland, Sweden and Russia about the commenced environmental assessment process of the new nuclear power plant in Lithuania and inquired about their intent to take part in the environmental assessment procedure. Austria, Belarus, Estonia, Finland, Latvia and Sweden gave their comments on the environmental impact assessment of the new NPP. The comments have been taken into account in the preparation of the EIA Report and the supporting reviews.

Information about the EIA procedure is provided at Lietuvos Energija AB's website - http://www.le.lt and the new NPP project website http://www.vae.lt. The websites provide up-to-date information on the progress of the EIA procedure. The EIA Program and EIA Report are available in the Lithuanian, English and Russian languages on the website.

1 GENERAL INFORMATION

Lietuvos Energija AB has initiated the environmental impact assessment procedure concerning a new nuclear power plant in Lithuania. The power plant would be located in the near vicinity of the current Ignalina nuclear power plant (INPP). The net electrical output of new nuclear power plant (NNPP) would be at most 3 400 MW and it would replace the current INPP Unit 1, which was closed on December 31, 2004 and Unit 2, which is scheduled to be shut down at the end of 2009.

Lithuania has no primary energy sources of its own. From the late 1980s, the Ignalina nuclear power plant (INPP) has produced a large percentage of Lithuania's electricity. The Lithuanian electricity and gas networks are closely interrelated to the north-west power sectors of the Russian Federation.

The meeting of the finance ministers from the group of seven industrialized nations of the world in Munich in 1992 was crucial to Lithuania and operation at INPP. The political decision was made that its RBMK reactors should be closed, as the reactors were judged incapable of being upgraded to western safety levels.

Presently the INPP is the only nuclear power plant in Lithuania. About 70 % of the total domestic electricity production was generated by the INPP in 2005. The current Lithuanian electricity generating capacities, including small capacity combined heat and power plants that are planned to be constructed, will be sufficient to meet the national demand until 2013. After the shutdown of INPP Unit 2 the new nuclear power plant would become the major electricity generating source in Lithuania.

The planned new NPP would meet the aims of the National Energy Strategy (*State Journal, 2007, No. 11-430*). According to the strategy, one of the identified main tasks is "to ensure the continuity and development of safe nuclear energy; to put into operation a new regional nuclear power plant not later than by 2015 in order to satisfy the needs of the Baltic countries and the region".

According to the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity (*State Journal, 2005, No. 84-3105*) construction, shutdown or decommissioning of nuclear power plants or other nuclear facilities are such economic activities for which an environmental impact assessment (EIA) procedure must be carried out. The objectives of the EIA are defined in the Article 4 of the named law and shall be as follows:

- to identify, characterize and assess potential direct and indirect impacts of the proposed economic activity on human beings, fauna and flora; soil, surface and entrails of the earth; air, water, climate, landscape and biodiversity; material assets and the immovable cultural heritage, and interaction among these factors;
- to reduce or avoid negative impacts of the proposed economic activity on human beings and other components of the environment, referred to in paragraph above; and
- to determine, if the proposed economic activity, by virtue of its nature and environmental impacts, may be allowed to be carried out in the chosen site.

The content and structure of this EIA Report meet the requirements of the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity (*State Journal, 2005, No. 84-3105*) and consider the requirements of the Regulations on Preparation of Environmental Impact Assessment Program and Report (*State Journal, 2006, No. 6-225*).

1.1 ORGANIZER OF THE PROPOSED ECONOMIC ACTIVITY

The organizer of the proposed economic activity is Lietuvos Energija AB.

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Telephone	+370 5 278 2589
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E-mail	tadas.matulionis@lpc.lt

1.2 DEVELOPERS OF THE EIA REPORT

The developer of the EIA Report is Consortium Pöyry Energy Oy (Finland) and Lithuanian Energy Institute (Lithuania). Pöyry Energy Oy is the leader of the Consortium.

Organization	**Pöyry Energy Oy**	**Lithuanian Energy Institute, Nuclear Engineering Laboratory**
Address	Tekniikantie 4 A, P.O. Box 93 FI-02151 Espoo Finland	Breslaujos 3, LT-44403 Kaunas Lithuania
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E-mail	mika.pohjonen@poyry.com	poskas@mail.lei.lt

1.3 NAME AND CONCEPT OF THE PROPOSED ECONOMIC ACTIVITY

The proposed economic activity is named as the “New Nuclear Power Plant in Lithuania”.

By this proposed economic activity a new nuclear power plant will be constructed in the vicinity of the existing Ignalina NPP. Total capacity of electricity production of the new NPP will not exceed 3 400 MW.

The new nuclear power plant will consist of one to five units. In some parts of this assessment the impacts are assessed for one or two reactors of about the size of 1600-1700 MW. In these cases the impacts of three to five units with smaller reactor size are assumed to be the same as for the two units with greater reactor size.

In the new NPP, electricity will be generated in accordance with the principles and regulations concerning the internal energy market of the European Union (EU). In accordance with sustainable development, the EU aims to reduce harmful environmental impacts of energy production and use. Another objective is to increase the EU’s competitiveness, which requires investments in the energy production and transmission capacity. It is estimated that investments of EUR 900 billion in new electricity generation capacity will be needed in the EU area during the next 20 years. To secure the reliability of energy supply, the EU focuses particular attention on curbing the increase of the need for importing oil and natural gas. (*European Commission, 2007*)

Lithuania needs new carbon dioxide emission-free electricity production capacity to meet the challenges posed by climate change, competitiveness and reliability of operation, and to ensure economic growth and the Lithuanians' standard of living. The objective is to reduce the dependence on fossil fuels. The measures proposed by the European Commission in January 2008 with a view to curb climate change require that carbon dioxide emissions will be reduced by 20 % from the 1990 level in the EU area by 2020. The long-term target is to cut carbon dioxide emissions by 60–80 % in the developed countries by 2050. (*European Commission, 2008*)

1.4 STAGES OF ACTIVITY AND SCHEDULES

The proposed economic activity can be divided into three main stages:

1. Construction and commissioning
2. Operation
3. Decommissioning.

It is planned that at least the first unit of the new nuclear power plant is in operation not later than 2015. Typical construction time of a new NPP unit is 5–7 years (Figure 1.4-1). Operation time is approximately 60 years or even more. Decommissioning time depends on the decommissioning strategy and can last from 20 to 100 years.

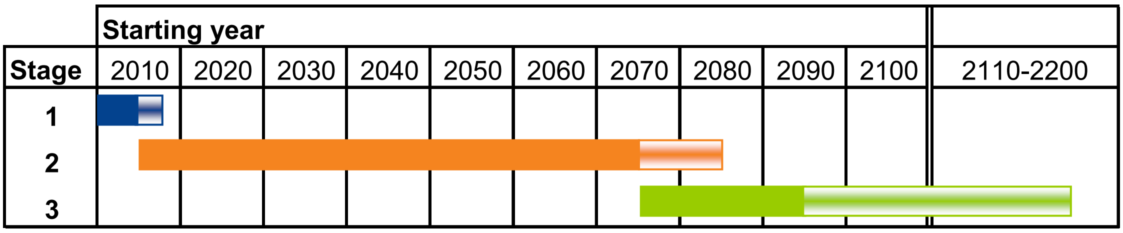


Figure 1.4-1. The estimated durations of the three main stages of the NPP project in case of one reactor.

In case of two or more reactors, it is assumed that construction work for the reactors would start two years after the previous one. In case of two reactors this would mean two years delay in all the different stages of the project.

The construction and commissioning stage of a reactor can be further divided into three stages: design adaptation and site preparation, actual construction time and start-up tests. Depending on the chosen reactor type, the durations of these stages vary so that total duration of the construction and commissioning is about 5–7 years (Figure 1.4-2).

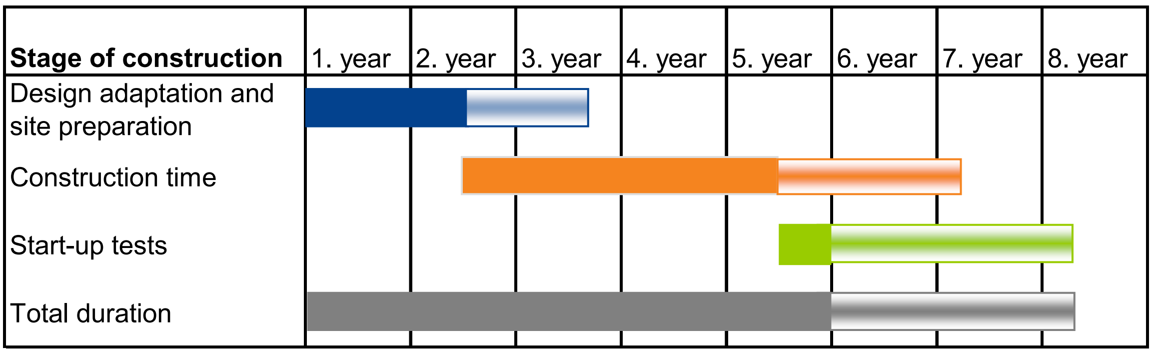


Figure 1.4-2. The durations of the different stages of the construction and commissioning of the new NPP.

1.5 ENERGY PRODUCTION

Information on planned production of energy is presented in Table 1.5-1.

Table 1.5-1. Energy production.

Energy type	Planned annual amount (output 1700 MW)	Planned annual amount (output 3400 MW)
Electrical energy, TWh/year	13	26
Thermal energy, TWh/year	0.4*	0.7*

* If heat for district heating of Visaginas will be produced.

1.6 DEMAND FOR RESOURCES AND MATERIAL

Demand for resources and materials during construction and operation of the new NPP is summarised in Table 1.6-1, Table 1.6-2, Table 1.6-3 and Table 1.6-4.

The estimations about the maximum consumption of main raw materials during the construction of the new NPP are presented in Table 1.6-1.

Table 1.6-1. Information about consumption of raw materials during construction of the new NPP (amounts are for 2 units 1700 MW each).

Material	Quantity
Earthworks (excavation)	1 400 000 m^3
Earthworks (fill materials)	1 300 000 m^3
Concrete; reinforced	640 000 m^3
Concrete; infill	60 000 m^3
Liner (skin and sleeves)	1 800 t
Turbine building (metal structures)	10 000 t + 46 000 m^2 metal cladding
Pools (Inox)	600 t
Steel reinforcement	90 500 t
Pre-stressing	3 970 t

Estimations on the fuel and energy consumption during the operation of the new nuclear power plant are presented in Table 1.6-2. The consumption of nuclear fuel will depend on the chosen reactor type.

Table 1.6-2. Information about fuel and energy consumption during operation of the new NPP.

Energy and technological resources	Measurement unit	Annual consumption amount (1 reactor)	Annual consumption amount (2 reactors)	Source
House load	MW	100	200	NNPP
Natural gas (if used for both reserve heat boilers and back-up power engines)	m^3	156 000	312 000	Lietuvos Dujos AB
Diesel fuel (if used for both reserve heat boilers and back-up power engines)	l	143 000	286 000	Fuel providers
Nuclear fuel (Uranium Dioxide UO_2)	t	29	58	Not defined yet
Nuclear fuel (Uranium Dioxide UO_2) "CANDU reactors"	t	102	204	Not defined yet

Table 1.6-3 presents information about chemical substances and preparations containing dissolvents that are possibly used during the operation of the new nuclear power plant.

Boric acid is used in the primary coolant of EPR reactors. It can possibly also be used in some support systems at the used fuel storage areas. Hydrazine is used in the component intermediate cooling system for deoxidization and corrosion prevention. Ammonia is used in the feed water system to control the pH value of the water. Lithium hydroxide is used in the primary circuit to control the pH value. Sulphuric acid (H_2SO_4) is used in demineralization as a recovery chemical of the ion exchangers. Sodium hydroxide is used as different solutions. It is used in the demineralization as a recovery chemical of the ion exchangers and in the feed water system to control the pH value of the water. Some lubricating oil will also be used.

Table 1.6-3. Information about chemical substances and preparations containing dissolvents possibly used during operation of the new NPP.

Name of the chemical substance and preparation containing dissolvents	Annual amount (1 reactor)	Annual amount (2 reactors)	Classification and labelling of the chemical substance or preparation [1]		
			Category	Hazard reference	Risk phrases
Boric acid (in EPR)	8 000 kg	16 000 kg	Xi	Irritant	R36/37/38
Hydrazine	22 m^3	44 m^3	R10; Carc. Cat. (2)	Flammable; Carcinogenic	R45 T; R23/24/25 C; R34 R43 N; R50-53
Ammonia	1 200 l	2 400 l	R10; T	Flammable; Toxic	R23 C; R34 N; R50
Lithium hydroxide	40 kg	80 kg	T	Toxic	R22 R23 R34
H_2SO_4	11 000 kg	22 000 kg	C	Corrosive	R35
NaOH (50 %)	3 200 kg	6 400 kg	C	Corrosive	R35
NaOH (10 %)	*dilution*	*dilution*	C	Corrosive	R35
NaOH (30 %)	*dilution*	*dilution*	C	Corrosive	R35
Lubricating oil (Addinol CLP 460 S)	0.5 m^3	1 m^3	T; Xn; Xi; N	Toxic; Harmful; Irritant; Dangerous for the environment	R22 R23 R24 R34 R38 R41 R43 R48 R50 R51 R53

Comment: 1 – According to the Law on Chemical Substances and Preparations (*State Journal, 2000, No. 36-987*) and Order of Classification and Labelling of Dangerous Chemical Substances and Preparations (*State Journal, 2001, No. 16-509; 2002, No. 81-3501*)

All the chemicals at the site will be handled and stored in appropriate manner to minimize the risk of environmental impact (Table 1.6-4).

Table 1.6-4. Storage of chemical substances and preparations containing dissolvents.

Name of the raw material, chemical substance or preparation	Amount for storage at site (1 reactor)	Amount for storage at site (2 reactors)	Storage manner [1]
Boric acid (in EPR)	10 t	20 t	Chemical storage facility, stored in separate tanks in containment basin
Hydrazine	17 t	30 t	
Ammonium	2 000 l	4 000 l	
Lithium hydroxide	0.01 t	0.02 t	Chemical storage facility, stored in purchase package
H_2SO_4	2 m^3	4 m^3	Chemical storage facility, stored in separate tanks in containment basin
NaOH (50 %)	2 m^3	4 m^3	
NaOH (10 %)	0.5 m^3	1 m^3	
NaOH (30 %)	0.2 m^3	1 m^3	
Lubricating oil	140 m^3	280 m^3	Stored in separate tank in containment basin

Comment: 1 – Underground tankage, tanks, structures, fuel storage areas covered with concrete for minimization of risk to environmental impact

1.7 SITE STATUS AND TERRITORY PLANNING DOCUMENTS

The considered sites for the new NPP (see Figure 1.7-1) are within an industrial land area allocated for State Enterprise Ignalina NPP (land parcel No. 4535/0002:5 and No. 4535/0003:2) (*Utena region governor order No. 14-293, dated June 20, 2003, On permission of State land usage at Ignalina region*). In accordance with land usage specialty (*State land usage specialty No. PN 45/03-0071 and No. PN 45/03-0072, Ignalina, July 2, 2003*) State Enterprise Ignalina NPP is allowed to use the site for unlimited time period.

The land usage purpose is defined as "of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)". Due to the proposed economic activity the land usage will not need to be changed. The special land usage conditions will be considered also.

On December 12, 2006 Director of Visaginas municipality administration by the order No. IV-652 "Concerning to approval of detailed plan" has approved the new revision of a detailed plan for the land parcel No. 4535/0002:5, which was prepared by UAB "Urbanistika" and coordinated by the State Enterprise Ignalina NPP. The main goal was to optimize land usage. The changes in the new revision of the detailed plan will not affect the status of the proposed sites for the new NPP.

The proposed sites for the new NPP are within the existing INPP industrial site. A 3 km radius sanitary protection zone (SPZ) is defined for Ignalina NPP site. There is no permanently living population within the existing sanitary protection zone and the economic activity is limited as well. The proposed economical activity is distant from residential areas. The sanitary protection zone for the new NPP is proposed in Section 7.10.2 of this EIA Report.

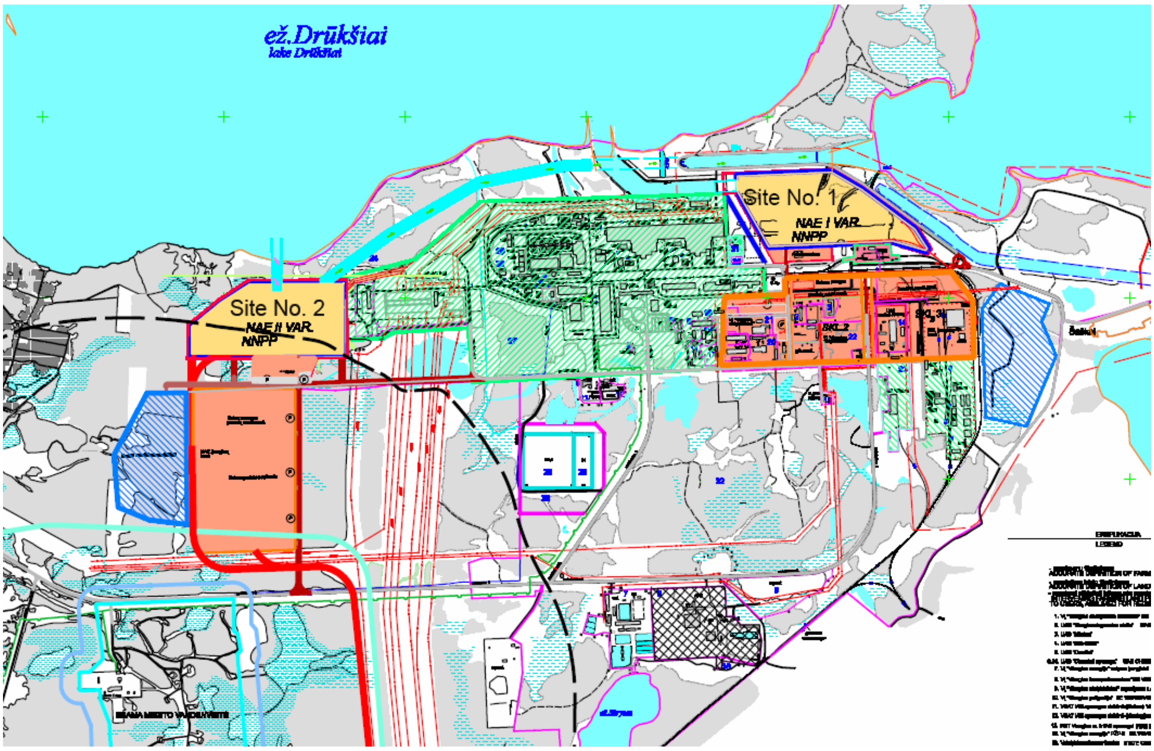


Figure 1.7-1. The proposed sites for the new NPP.

Alternative site 1 (see Figure 1.7-1 and Figure 1.7-2) is situated east of Unit 2 of the present power plant and comprises the area, which was previously planned for Units 3 and 4. The site area is approximately 0.493 km^2 and ends at its northern side (length 0.6 km) directly at the cooling water discharge channel common for existing Ignalina NPP Units 1 and 2. South of Units 1 and 2 the area is limited by the road from west to east. The eastern part of this area is triangular shape due to the existing railways at its eastern border from north-west to south-east. At this eastern border there are digs filled with water, which are the partially constructed new cooling water channels for the previously planned Unit 4. The length of the western border is approximately 0.58 km. The perimeter of this site is approximately 3.5 km. At its southern border (length of 1.255 km) the interim spent nuclear fuel storage facility for Units 1 and 2 (buildings 192, 193 and 194) is located. Also a buffer storage facility for very low level waste (LLW) and a free release facility for the existing INPP are planned to be built at the southern border of alternative site 1. Construction of the free release building and security fence surrounding all the above mentioned objects has already started.

Figure 1.7-2. A view of alternative site 1 (east of current unit 2).

Alternative site 2 (see Figure 1.7-1 and Figure 1.7-3) is situated in an area west of the existing switchyard and is currently an unbuilt area (swamp, bushes). Its size is approximately 0.424 km^2. Its northern border is the shoreline of Lake Druksiai (length approximately 0.75 km). The other three borders are straight, forming a rectangular area, the eastern side of which is 1.1 km and the western 0.66 km long. The existing Building No. 108 (administrative building of State Enterprise “Visagino Energetikos Remontas“) is in the area. Better road connection and new railway connection have to be built to the site.

Figure 1.7-3. A view of alternative site 2 (west of the existing switchyard).

Present status of territorial planning documents in the area is as follows:

- Lithuanian territory general plan. The analyses of Lithuanian territory general plan and NNPP territory planning correlation issues have been made. Therefore, on the 7th of May in 2008 the Government of the Republic of Lithuania approved the resolution on addition of Lithuanian territory general plan's measures implementation plan concerning NNPP preparatory works.
- Utena county plan. It has been agreed and approved that the NNPP will be included in the Utena county plan. It is estimated that Utena county plan will be prepared and approved by the end of 2008.
- Visaginas, Zarasai and Ignalina municipalities plan. It has been agreed and approved (by the Visaginas municipality common council decision) that the NNPP will be included in the Visaginas, Zarasai and Ignalina municipalities plan. It is estimated that this plan will be prepared and approved by the end of 2008.
- NNPP detailed plan. The legal analyses of all sites, which may be needed for a NNPP construction, are under preparation. After analyses are ready, the changes and amendments of legal acts will be done and detailed planning will be initiated. It is estimated that the NNPP detailed plan preparation procedures will be completed in 2009.

1.8 UTILIZATION OF THE EXISTING INFRASTRUCTURE

After the present Ignalina NPP will be closed, some of the existing infrastructure in the area will be available for the new NPP. The possibilities to reuse parts of the existing infrastructure and equipment have to be examined as to its age, integration possibilities, interfacing of old and new infrastructure, requalification requirements, economic savings and various other aspects to assure the right selection. In this Section a preliminary evaluation of the existing infrastructure, which probably may be integrated into the new NPP, is presented. A more detailed examination will be done during the design stage of the new NPP. Since the compatibility of the existing infrastructure and equipment with the new NPP systems and the management of interfacing old and new infrastructure are some of the key issues to be examined, the supplier of the new NPP has to approve the integration of some of the existing infrastructure.

1.8.1 Hydraulic structures of Lake Druksiai

1.8.1.1 Regulation of the level of water

The level of water in Lake Druksiai is regulated to its present level. It is assumed that this regulation will continue also during the operation of the new NPP.

A blind earth dam was built in 1953 at the place of junction of the Apyvarde River to close the channel and the flood plain of the Druksa (called Drisvyata in Belarus) River (for a map, see Section 7.1). This dam secures the flow from the Apvardai Lake trough the Apyvarde River into Lake Druksiai. The crest and the slopes of the earth dam are lined with concrete on the side of the Apyvarde River and the slope is additionally strengthened with reinforced concrete plates. Also on the other side of the dam slope an additional embankment has been constructed. (*Ignalina Nuclear Power Plant, 2003*)

Also in 1953 a run-off regulation sluice, called "Object 500", was built on the River Prorva to regulate the level of Lake Druksiai. Downstream from this a hydroelectric power plant (HPP), called "Tautu Draugyste", was built between the Lakes Stavokas and Abaliai. The HPP building and the water intake openings are combined in one concrete block. The concrete block has three openings, two for turbine operation and a third one for discharge of excess water. Both Object 500 and the HPP are located in the area of the Republic of Belarus.

The HPP was taken out of operation in 1982 and the turbines have been disassembled. However, the level of Lake Druksiai is still regulated by the gates of the HPP. The Object 500 currently functions only as a transit structure. The radial gates of it are currently lifted to the maximum to secure full discharge. The water from Lake Druksiai flows into Lake Stavokas where from the water is discharged via the stop logs of the water regulating hydraulic structure based on the former HPP.

Under an agreement (signed on February 6th, 1995) concerning Object 500 and HPP "Tautu Draugyste" between the Governments of the Republic of Lithuania and the Republic of Belarus, responsibility for Object 500 has been transferred to the Republic of Lithuania, whereas any agreement concerning the proprietary rights of the HPP has not been signed till now.

In case the HPP and the earth dam of the diversion channel of the HPP are damaged for some reason, the level of the Lake Druksiai can be regulated with the Object 500.

1.8.1.2 Cooling water channels

The shape of the Lake Druksiai shore with its peninsula leads to an ideal arrangement for the cooling water inlet and outlet of the existing INPP. Lake Druksiai has the biggest depth close to the shore at the site of the water inlet. The water inlet is located at 6.6 meters depth (near the bottom) and is designed as an open channel with embankments in the lake part. From the power plant the water is let out through a closed reinforced concrete channel that then goes into an open channel. The channels are conjugated by a siphon structure.

The cooling water inlet and outlet were designed for four units, of which the two first units were realized. The channels are already partially excavated for the remaining, but not realised units. The outlet channel is designed for a maximum discharge of 170 m^3/s with 4 m filling level (*Ignalina Nuclear Power Plant, 2003*).

Cooling water inlet and outlet channels of the present INPP may be reused after renovation especially for alternative site 1 of the NNPP. The inlet channel would have to be somewhat extended. The maximum discharge from the new NPP would be 160 m^3/s. The distance from site 2 of the new NPP might be too long for the existing cooling water inlet channel to be used.

The renovation work can be carried out only after INPP Unit 2 is totally defueled. Modifications for avoiding crossing of old and new intake and outlet connections will have to be studied in detail during the design stage of the NNPP.

1.8.2 Water supply

Potable water is used for household and process water purposes in the new NPP. Potable water supply for the present INPP is outsourced to the State Enterprise "Visagino Energija", which also serves the town of Visaginas. Ground water is used as the source of raw water and it requires only a simple treatment of aeration and filtration to remove excessive iron. The total water production capacity is 31 000 m^3/d, but as one of the INPP units has already been closed and a drastic water consumption reduction has taken place in Lithuania, the present capacity in use is only about 10 000 m^3/d, and the daily average output is about 6 900 m^3/d. The treated water storage tanks have a capacity of 12 000 m^3, which provides for adequate stand-by supply volume. Continuous supply to the INPP is secured with a 500 kVA stand-by diesel generator. The plant instrumentation and automation will be upgraded in a project started in May 2008.

The maximum potable water demand of the new NPP is 1300 m^3/d (for more detail, see Section 7.1). "Visagino Energija", or its municipal successor, will thus have adequate capacity to supply all the needed potable water for the new NPP. Water demand in the town of Visaginas is still in decline, which also deallocates capacity for use in the NNPP.

Some of the potable water needs to be demineralised before it is used as process water. The inactive part of the existing demineralised water system of the INPP has a maximum capacity of 1080 m^3/d. The need for demineralised process water for the new NPP will be maximum 1000 m^3/d. Thus the existing system may be reused for the purposes of the new NPP.

1.8.3 Waste water treatment

"Visagino Energija" operates also the municipal wastewater treatment plant of the region. The non-radioactive wastewater of the INPP is lead to this plant to be treated. The plant has a capacity of 21 000 m^3/d, but it is in need of rehabilitation. A reconstruction project has been planned and its implementation was started in May 2008 by signing the construction contract. The new plant will have a capacity of 5 500 m^3/d. It will be based on an activated sludge biological process. The new plant will be able to meet the current Lithuanian and EU effluent standards. After the rehabilitation project has been finalized, the existing municipal wastewater treatment plant can be used to serve the new NPP. The present wastewater flow from the town of Visaginas is about 4 000 m^3/d and is decreasing. The new NPP will need a maximum of 600 m^3/d of household wastewater treatment capacity. The maximum capacity is needed during the construction stage of the NNPP. During normal operation the needed capacity will be about half of this (see Section 7.1).

For liquid radioactive waste, a new treatment facility will be built. The existing treatment facility will be decommissioned and with the building of a new one, total compatibility with the new NPP can be assured.

The surface water run-off system at the INPP site is designed to remove rain water from buildings' roofs and all the impermeable areas like roads, parking areas etc. Run-off water contains particles and can also be contaminated with hydrocarbons. The surface water run-off system is equipped with grease/oil separators (*Ignalina NPP Decommissioning Service, 2007*). This system may be reused when the run-off system following the surface relief of the new site fits to the old run-off system. The connection to the old wastewater pipes might be possible.

1.8.4 Waste management

The waste produced in the Visaginas area and in the INPP noncontrolled zone is placed in different landfills managed by different Lithuanian companies specialized in waste management. The amounts of conventional waste produced during the construction and during the operation stage of the new NPP (see Chapter 6) will be disposed of partially in the present infrastructures located in the area, and, because of the significant amounts of waste produced, part of this amount will have to be placed in new (or enlarged) landfills.

Within the frame of INPP decommissioning a new solid waste management and storage facility (SWMSF) has been contracted and its commissioning is scheduled for 2010 (*NUKEM Technologies GmbH and LEI, 2008*). Treatment of the INPP operational radioactive waste is expected to last until 2020. After 2020, and up to the end of the solid waste treatment facility's (SWTF) 30 years design life, the facility will be used to process INPP decommissioning waste. Technically a simultaneous treatment of both the INPP decommissioning waste and the NNPP operational waste could be viable. The design lifetime of the new solid waste storage facilities (SWSF) for short-lived and long-lived waste will be 50 years (until 2060). A new project for construction and commissioning of near surface repository (NSR) for short-lived low and intermediate level waste (LILW-SL) is underway. The site of the NSR has been confirmed at Stabatiske, in the vicinity of the INPP (*Resolution No. 1227 of the Government of the Republic of Lithuania, dated November 21, 2007*). When NSR will be commissioned and storage/disposal containers with LILW-SL from SWSF are transferred to the NSR, the containers with LILW-SL from NNPP can be temporary stored at SWSF until 2060. The more detail analysis of possibilities to reuse existing treatment and storage facilities for NNPP radioactive waste is presented in Section 6.2.2.

1.8.5 Electrical systems

The open power distribution system of the INPP will remain without changes during the decommissioning of the INPP and there will be no need to install a new electrical network. The condition of the existing power transmission lines depends on many factors and it should be checked before the start of the operation of the new NPP. Because of the importance of the transmission lines for the whole operation of the plant, it is economically viable to ensure the good condition of the transmission system and renew the parts of it that might be close to the end of their life span.

The 330/110 kV outdoor switchyard of the INPP has been in operation for nearly 25 years. By 2015 the major components will reach about 80 % of their expected life span. Due to the importance of the switchyard for the grid connection of the new NPP, it is suggested to replace the technology of the switchyard completely after the shutdown of the INPP. Following its rehabilitation, the switchyard may be reused. However, the location of it is relatively far from the site 1. In case site 1 is chosen for the implementation of the project, it should be studied, if it would be more convenient to build a completely new switchyard.

If the main transformers of the INPP should be reused, they would have to be relocated close to the turbine hall of the new NPP. The existing rail system of the INPP site area would make this operation manageable. However, the condition of the technology and its environmental feasibility should be studied more in detail before a decision on the reuse can be made.

1.8.6 Logistics

The main road connection from Visaginas to the INPP area can be used for the traffic also to the new NPP area. New access roads to the NNPP and to the relating facilities will have to be built when the site has been confirmed.

The site rail system of the INPP can be completely taken over and reused. Some smaller adaptations might be required.

1.8.7 Heat and steam sources

It is possible to use the existing heat only and steam only boilers of the INPP area for the purposes of the new NPP.

1.8.8 Monitoring systems

The existing monitoring systems and equipment will be used to the appropriate extent. However, they will be renewed according to the recent regulations and standards (see Chapter 9).

A seismic alarm and monitoring system of the INPP has been installed only recently. It comprises sensors located at distances of up to 30 km from the INPP which enables alerting prior to arrival of earthquake shock waves at the site. It identifies seismic events, does not interfere with other systems and its integration does not involve any risk for the NNPP supplier.

Also the INPP off-site radiological monitoring system could be reused. However, renovation of it should be considered within the first two decades of the operation of the NNPP.

1.8.9 Other

The old construction storage and lay down area from the early site construction days equipped with rails connecting several storage halls and parts of the area is still suitable for use during the NNPP construction phase in case site 1 is chosen for the implementation of the project. The existing buildings of this area need to be renovated.

The pressurized air supply system of the INPP could technically be integrated into the new NPP. However, the simultaneous use of pressurized air for dismantling Units 1 and 2 of the INPP and for the operation of the new NPP would create a need for some changes in the system.

The N_2-supply system of the INPP has been used for heat removal of the RBMK graphite core. The system can be reused in case the new nuclear power plant is a BWR.

The hydrogen electrolysis plant of the INPP could be reused for the same purpose as now, i.e. cooling of the stator coils of the electric generator. Its capacity should be sufficient.

The fire fighting hydrant system is a part of a safety system and this is why reuse of the pumping station only should be considered. If the pumping station would need to be disassembled and reassembled, the reuse of it should not be considered.

The pipelines that have been used to supply hot water to the Visaginas district heating system have been renovated and may be used if the NNPP will be used to produce heat for the district heating.

The storage hall of INPP for new fuel is not suitable to be reused for the NNPP. Reasons for this are the hall’s location and building design, which might not comply with recent requirements.

New back-up diesel engines will be built for the NNPP.

The communication system of the INPP has been newly installed. However, it will most likely be outdated when the operation of the new plant starts and it might be economically more viable to build a totally new system than reuse the existing one.

2 DESCRIPTION OF THE EIA PROCEDURE

2.1 GENERAL

Environmental Impact Assessment (EIA) is a process that predicts, examines and evaluates potential environmental impacts of a proposed economic activity and ensures that the decision makers know the public opinion before giving development consent and are provided with information about negative environmental effects, which might arise from development actions.

According to Lithuanian legislation, the EIA should be performed only for activities that have the potential for significantly affecting the environment due to the nature, size or proposed location of the activity. The activity of construction of nuclear power plants and other nuclear installations is included in the List of the Types of Proposed Economic Activities that shall be Subject to the Environmental Impact Assessment (*Annex 1 of the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity, State Journal, 2005, No. 84-3105*). Therefore performance of EIA for this proposed economic activity is obligatory. The planned schedule of the EIA procedure for this proposed economic activity is presented in the following figure (Figure 2.1-1).

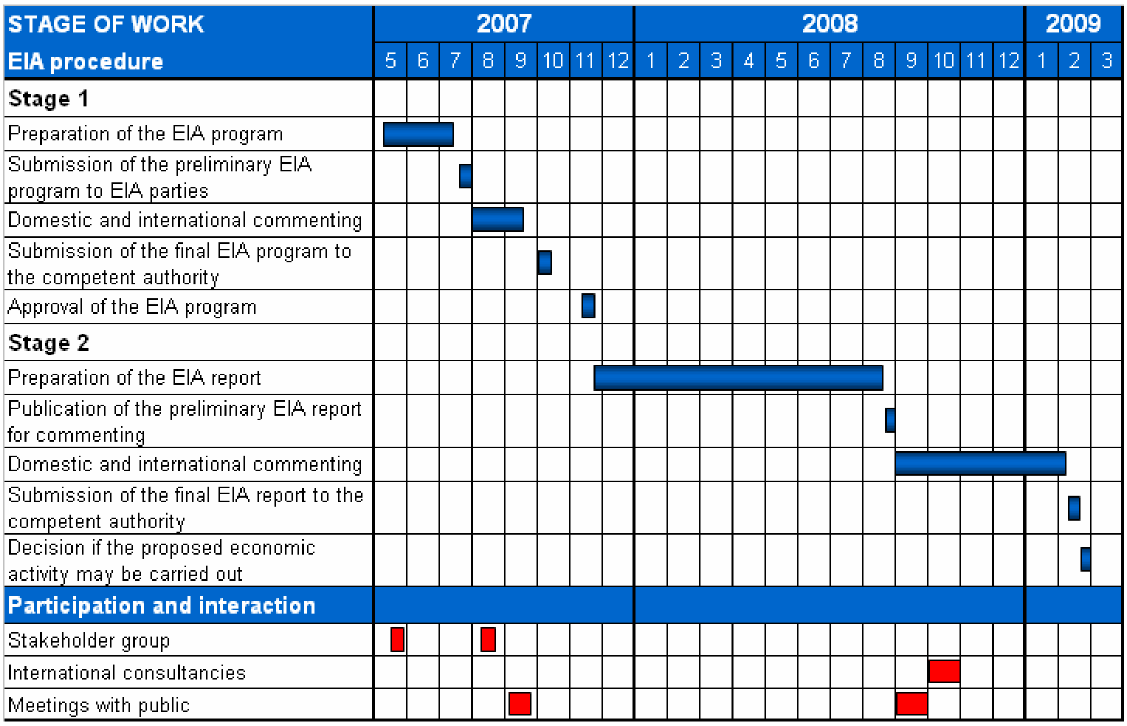


Figure 2.1-1. Planned schedule for the EIA procedure.

2.2 EIA PROCEDURE

The Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)* and regulations supporting the law define the legal requirements for the EIA procedure. The EIA is performed in two subsequent stages (Figure 2.2-1). In the first stage, the EIA program has been prepared and presented to the authorities and public for a review. The EIA program defines the scope and content of the EIA Report and has already been approved by the competent authority (Ministry of Environment of Lithuania). In the second stage, the EIA Report is prepared based on the approved EIA program and the opinions and statements. Before the competent authority decides if the proposed economic activity is permitted on the chosen site, the EIA Report is reviewed by the EIA Relevant Parties and public.

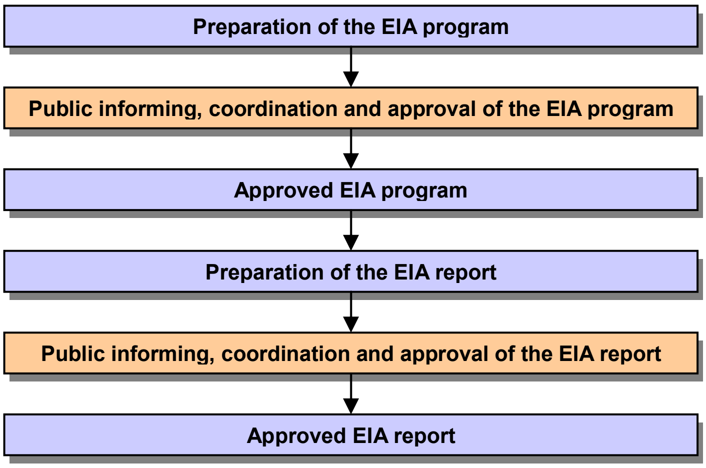


Figure 2.2-1. General overview of the EIA procedure.

2.3 PREPARATION OF THE EIA REPORT

The Environmental Impact Assessment Report is prepared by the Developer of the Environmental Impact Assessment documents according to the program, approved by the Competent Authority. All the issues, foreseen in the program, are thoroughly analyzed in this Report. Implementation of procedures for the EIA Report is presented in Figure 2.3-1.

The Organizer of the Proposed Economic Activity according to the order, established by the Ministry of Environment, organizes the presentation of the Report to the public. The Developer of the Environmental Impact Assessment documents, according to the motivated suggestions made by the interested public, presents the updated Report to the Relevant Parties. The Relevant Parties check whether the Report thoroughly analyzes issues in their competence, foreseen in the program.

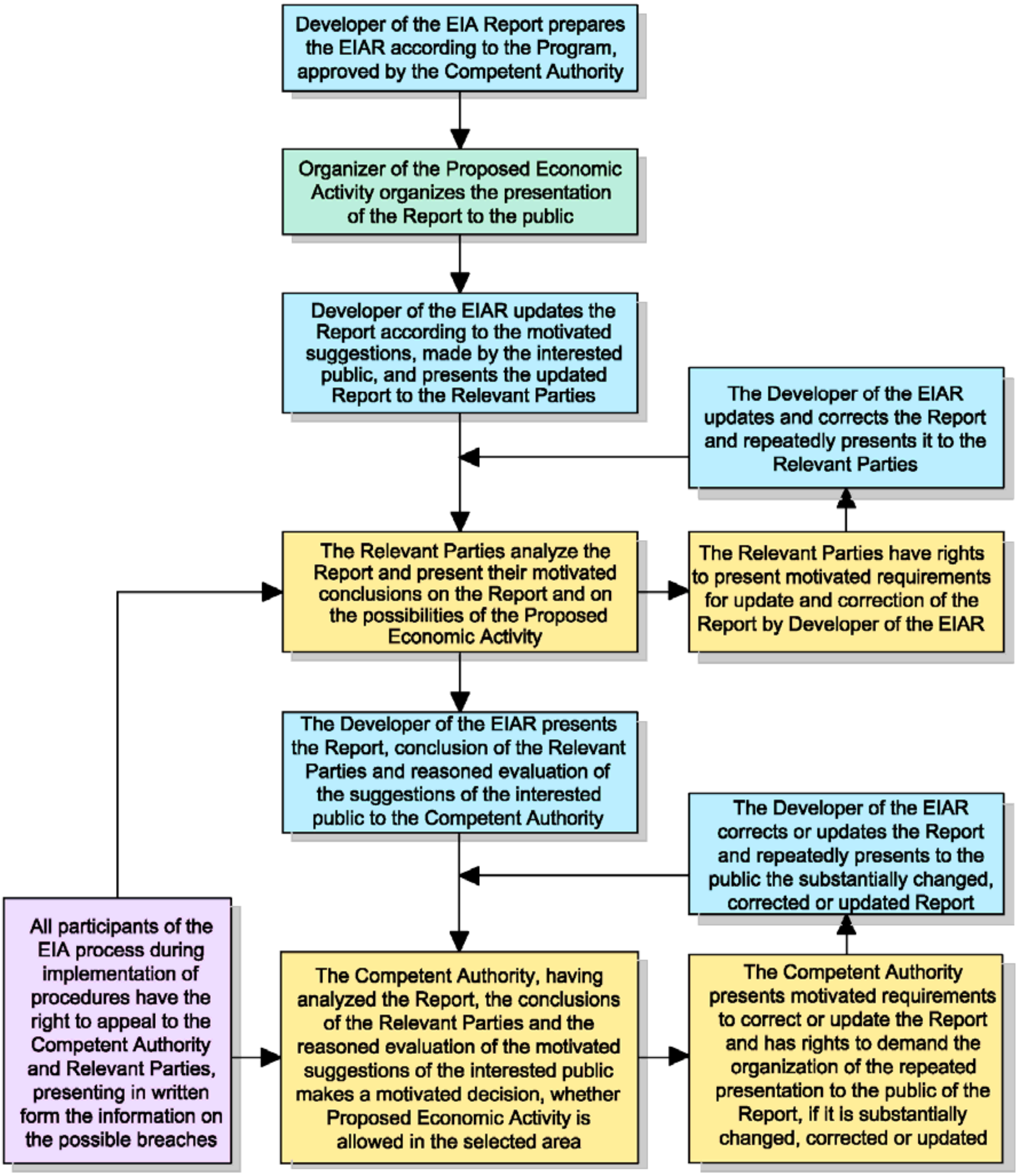


Figure 2.3-1. Implementation of procedures for EIA Report.

The Relevant Parties analyze the Report, and within 20 working days from its reception present their motivated conclusions on the Report and on the possibilities of the Proposed Economic Activity to the Developer of the Environmental Impact Assessment documents. The Relevant Parties have the right to present motivated requirements for update and correction of the Report by the Developer of the Environmental Impact Assessment documents. The Developer of the Environmental Impact Assessment documents has to update and correct the Report and present it again to the Relevant Parties. The Parties analyze the Report and within ten working days from its reception present motivated conclusions on the Report and on the possibilities of the Proposed Economic Activity to the Developer of the Environmental Impact Assessment documents.

The Developer of the Environmental Impact Assessment documents presents the Report, conclusion of the Relevant Parties on the Report and the possibilities of the Proposed Economic Activity, and reasoned evaluation of the suggestions of the interested public to the Competent Authority. The Competent Authority has the right to demand the organization for a repeated public introduction of the Report, if, after the public introduction of the Report, it has been substantially changed, corrected or updated (for instance, new locations, technological alternatives, impact mitigating measures, etc. are suggested) due to motivated conclusions, received from Relevant Parties and motivated requirements by the Competent Authority to correct or update the Report.

All the participants of the EIA process during the implementation of procedures on the Environmental Impact Assessment of the Proposed Economic Activity have the right to appeal to the Competent Authority and Relevant Parties on the issues of their competence, until the Competent Authority makes a decision. In their appeal the participants need to present in written form the information on the possible breaches establishing, characterizing and assessing the possible environmental impact due to Proposed Economic Activity or when implementing Environmental Impact Assessment procedures.

2.4 INFORMING THE PUBLIC

An EIA process ensures effective and well-timed public participation and consultation. All interested citizens and interest groups have the right to express their opinions at virtually every stage of the EIA process. The reasons why the public must be involved in the EIA process include:

- local inhabitants may provide local expertise and knowledge;
- public participation may help to identify the important issues or concerns determining the scope of the EIA;
- local inhabitants may propose additional project alternatives;
- public participation ensures that possible later conflicts will be avoided;
- positive public opinion might serve as a useful additional argument when requesting development consent;
- public participation ensures the openness of the EIA and the acceptability and credibility of EIA decision-making.

Non-governmental organizations (NGOs) and community groups might significantly contribute at the practical and policy levels of EIA process. They can provide a point of contact and organize public and informal meetings. In addition, NGOs can often provide considerable expertise and experience which is unavailable to consultants, developers or public authorities. They usually have links with other NGOs, international specialists and advisers as well as a network of volunteers and staff with direct and often extensive EIA experience in dealing with policy and decision makers.

The Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)* defines the rights and functions of the public, ensuring public participation throughout the whole process of Environmental Impact Assessment. Procedural details of public participation are provided in the Order of Informing the Public and Public Participation in the Process of Environmental Impact Assessment, approved by the Ministry of Environment (*State Journal, 2005, No. 93-3472)*.

2.5 ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT

In cases when an economic activity that is proposed to be carried out in the territory of the Republic of Lithuania may cause a significant negative impact on the environment of any other State that has signed the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention, 1991. State Journal, 1999, No. 92-2688*), or upon request of such a State, the public is participating in the process of environmental impact assessment in accordance with the requirements of the above mentioned Convention, international agreements between relevant States and the Republic of Lithuania, the Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)*, and other relevant legal acts.

The EIA process is performed in compliance with the Espoo Convention. The Competent Authority has to inform the countries which might suffer the detrimental environmental impacts of the proposed economic activity. After the Competent Authority gets the responses from the countries concerned and their comments on the EIA Report, it delivers them to the organizer of the proposed economic activity.

2.6 DECISION ON THE POSSIBILITIES OF THE PROPOSED ECONOMIC ACTIVITY

After analyzing the Report, the conclusions of the Relevant Parties on the possibilities for the Proposed Economic Activity, the reasoned evaluation of the motivated suggestions of the interested public and motivated suggestions, presented in a written form by the interested public, within 25 working days from the reception of the Report the Competent Authority

1) presents motivated requirements to correct or update the Report;
2) makes a motivated decision, whether the Proposed Economic Activity, with the respect to requirements of relevant laws and regulations, the character of activity and (or) environmental impact, is allowed in the selected area.

The Competent Authority presents a motivated decision in a written form to the Relevant Parties and to the Organizer of the Proposed Economic Activity or to the Developer of the Environmental Impact Assessment documents.

When the conclusions of the Relevant Parties on the possibilities of the Proposed Economic Activity contradict one another, the Competent Authority, before making a decision, invites the Relevant Parties to participate in the process of discussion of their conclusions. It also invites the representatives from public, who had presented motivated suggestions.

If it is determined that the implementation of the Proposed Economic Activity causes significant negative effects to the areas of the European Ecological Network "Natura 2000," and there are no alternative ways of decision for activities, the Proposed Economic Activity may be allowed only in those cases, when its decisions are related to public health, preservation of certain environmental components or taking into consideration the opinion of the European Commission, and for other significant reasons. In such cases, all possible compensating measures, necessary for preservation of integrity of the areas of the European Ecological Network "Natura 2000," have to be foreseen and implemented. The authority in charge of the organisation of the security and management of protected areas (the State Service for Protected Areas) informs the European Commission about these compensation measures, following the Order on Strategic Evaluation of Environmental Results of Plans and Programs, approved by the Ministry of Environment (*State Journal, 2004, No. 130-4650)*.

If the Competent Authority makes a decision that the Proposed Economic Activity due to breaking of requirements of relevant laws and regulations and (or) possible negative impact to the environment is not allowed in the selected area, the Proposed Economic Activity may not be implemented.

The Competent Authority and the Organizer of the Proposed Economic Activity, according to the requirements of the Order of Informing the Public and Public Participation in the Process of Environmental Impact Assessment (*State Journal, 2005, No. 93-3472),* present the motivated decision to the public on whether Proposed Economic Activity, taking into consideration requirements of the relevant laws and regulations, the nature of activity and impact to the environment, is allowed in a selected area, and give the opportunity to get acquainted with it.

The positive decision made by the Competent Authority on the opportunities of the Proposed Economic Activity is valid for five years from the public notification day.

3 COMMUNICATION AND PARTICIPATION

One of the objectives of the EIA procedure is to increase availability of information of the proposed economic activity and improve the opportunities for citizens' participation. In the following the means of communication and interaction in the EIA procedure of the new nuclear power plant are described. Parties involved in the EIA procedure are presented in the following figure (Figure 3-1).

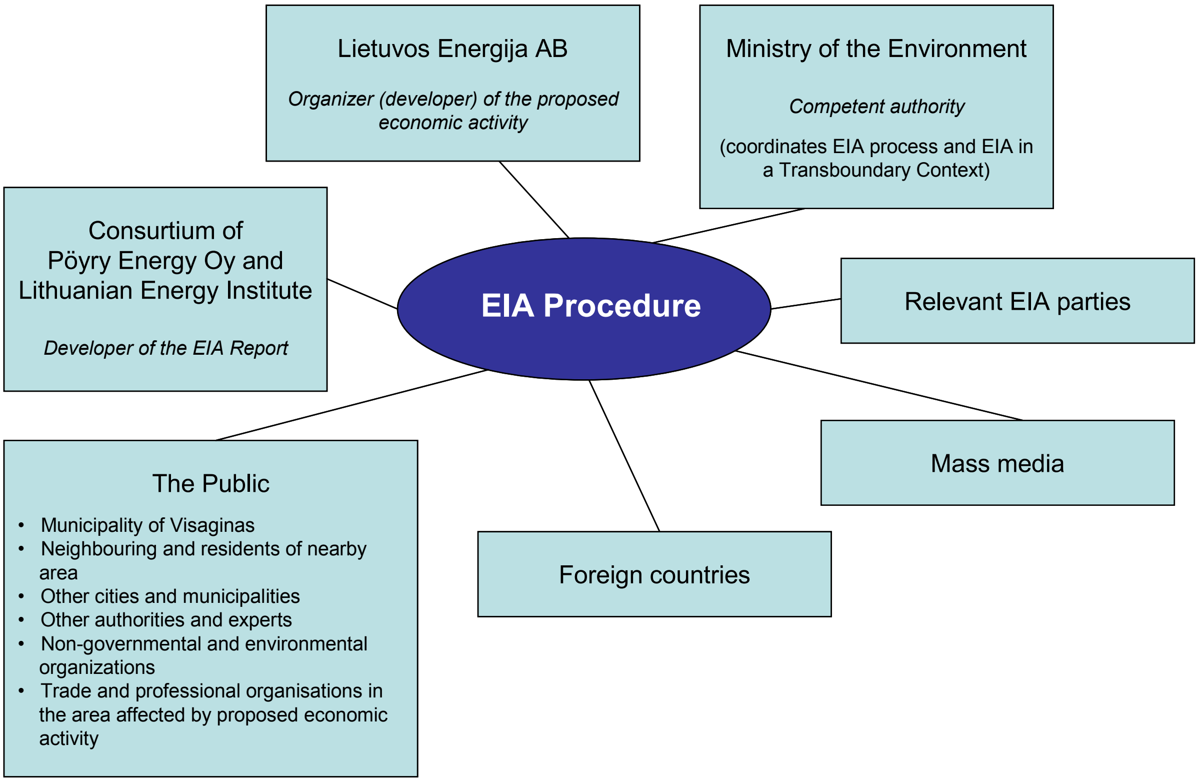


Figure 3-1. Parties involved in the EIA procedure.

3.1 STAKEHOLDER GROUP

In the EIA Program stage, a Stakeholder Group was organized. The purpose of the Stakeholder Group was to promote the exchange of information between the organisation responsible for the project, the authorities and other interest groups. Based on the letter of the Ministry of Environment, the following parties were invited to the Stakeholder Group:

- Competent Authority
  - Ministry of Environment;
- EIA parties
  - State Nuclear Power Safety Inspectorate,
  - Radiation Protection Centre,
  - Fire and Rescue Department ,
  - Utena Public Health Service,
  - Utena Region Environmental Protection Department,
  - Cultural Heritage Protection Department,
  - Utena County Governor's administration,
  - Administration of Visaginas Municipality,
  - Administration of Ignalina district Municipality,
  - Administration of Zarasai district Municipality.

The parties of the Stakeholder Group act as experts in their particular fields. The opinions expressed as part of the Stakeholder Group work do not oblige the parties giving the official statements.

At its meetings the Stakeholder Group discussed the progress of the environmental impact assessment and presented opinions on the preparation of the EIA Program, the EIA Report and the supporting reviews. In the first meeting of the Stakeholder Group in May 2007 the project, the EIA procedure, interaction and the planned main content of the EIA Program were presented to and discussed with the Stakeholder Group.

Comments and clarifications received during and after the meeting were taken into account in the preparation of the EIA Program to the widest possible extent as far as they concerned the EIA Program. Otherwise, any comments have been taken into account in the implementation of the EIA procedure and in the preparation of the EIA Report.

The Stakeholder Group convened for the second time on August 14, 2007 after the EIA Program had been submitted for EIA parties and public review. In the meeting the contents of EIA Program and the impacts to be assessed in the process were presented to and discussed with the Stakeholder Group.

During the EIA Report stage no meeting of the Stakeholder Group was organized. However the different parties of the Group were consulted when needed during the preparation of the EIA Report and the supporting reviews. One of these consultation meetings was organized with State Nuclear Power Safety Inspectorate and Radiation Protection Centre to discuss the methods and contents of the risk analysis and assessment more in detail.

3.2 INFORMATION AND DISCUSSION EVENTS

Information and discussion events open to the public are arranged during the preparation of the Environmental Impact Assessment Program and Report. At the events the general public has the opportunity to discuss and express their opinions on the EIA work and its sufficiency and to receive information about the new nuclear power plant project and the EIA procedure from Lietuvos Energija AB and the developers of the EIA Program and the EIA Report.

The EIA Program for the new NPP was presented to the public of Lithuania and the neighbouring countries in three public meetings during the autumn of 2007.

On September 3rd, 2007 a public discussion event was organized on the EIA Program in Daugavpils, Latvia. The discussion was attended by Lietuvos Energija AB, the developers of the EIA Program, the representatives from the Ministry of Environment of Lithuania, representative from the Ministry of Environment of Latvia and representatives from the Latvian Radiation Security Centre and the Latvian Hazardous Waste Management Agency in addition to the Latvian residents of the region.

On September 14th, 2007 a presentation of the EIA Program and a discussion with the members of the municipal communities of Visaginas, Ignalina and Zarasai regions took place in Visaginas.

On September 26th, 2007 a meeting with representatives of various scientific organizations was organized in Vilnius.

On September 27th, 2007 a public discussion between the organizers of the EIA and the Estonian public was also organized in Tallinn, Estonia. The event was attended by Lietuvos Energija AB, the developers of the EIA Program, representatives from the

Ministry of Environment of Estonia, members of the Estonian Parliament as well as public organizations and communities.

The next public meetings will be organized during the autumn of 2008 after the preliminary EIA Report will be completed. The preliminary EIA Report will be made public in August 2008. Local and international presentations of the EIA Report will be organized during September and October 2008.

3.3 PUBLIC DISPLAY OF THE EIA PROGRAM AND EIA REPORT

In the both EIA Program and EIA Report stage the organiser (or developer of EIA documents) of the proposed economic activity informs the public about the EIA Program and the EIA Report in accordance with requirements of the Order of Informing the Public and the Public Participation in the Process of Environment Impact Assessment (*State Journal, 2005, No. 93-3472*). The public has the right to examine the EIA Program and the EIA Report and express their opinions about them. The developer of EIA must perform the registration of received motivated (justified) proposals, reasonably evaluate them and attach them as appendixes to the approved EIA Program or the approved EIA Report.

The residents of the nearby area were able to get acquainted with the EIA Program from July 30th to August 20th, 2007 in Lithuanian Energy Museum, in the administration of the municipalities of Visaginas town, Ignalina and Zarasai regions, and in the lobby of Lietuvos Energija AB. The presentation took place for 15 working days. The advertisement for the presentation of the EIA Program to the public was published in all the republican daily newspapers: the Lietuvos Rytas, the Respublika (in the Lithuanian and Russian languages), the Lietuvos Žinios, the Kauno Žinios, the Versio Žinios, the Valstiečių Laikraštis and the regional newspapers of Visaginas, Ignalina and Zarasai.

The proposals by the public concerned for example the usability of the existing infrastructure of the INPP, the impacts of the project on Lake Druksiai and the possibilities to use indirect cooling. Some proposals concerned issues that are not in the scope of the EIA process, like technical and economical aspects that are evaluated in separate feasibility studies. The proposals and responses have been attached as appendix to the approved EIA Program (in the original Program in Lithuanian language).

The EIA Report will also be available for public display. The motivated (justified) proposals, that will be received, will be registered, evaluated and attached as appendixes to the approved EIA Report.

3.4 REVIEW OF EIA PROGRAM AND EIA REPORT BY RELEVANT PARTIES

Relevant parties of the environmental impact assessment assess the EIA Program and Report and have a right to give their conclusions to the organiser (developer), who has to take them into account. The relevant parties include governmental institutions, responsible for health protection, fire-prevention, protection of cultural assets, development of economy and agriculture, and municipal administrations. Their review has an important role in ensuring the quality of the EIA process.

The procedure of the review by the relevant parties is described more in detail in Section 2.3.

3.5 COORDINATION OF EIA PROCESS BY COMPETENT AUTHORITY

The competent authority, the Lithuanian Ministry of Environment, is responsible for the coordination of the EIA process and fulfils its functions set out in the Law on the Assessment of the Impact on the Environment of the Planned Economic Activity (*State Journal 2005 No. 84-3105*).

The EIA Program was first submitted to the Ministry of Environment for comments and approval on October 4, 2007. Lietuvos Energija AB received comments and proposals (47 comments) for the EIA Program from the Ministry of Environment on October 19, 2007. The EIA Program was revised and supplemented accordingly and submitted for approval on October 29, 2007. The EIA Program was approved by the Ministry of Environment on November 15, 2007.

Within 25 working days since the EIA Report is presented, the competent authority can give justified request to revise and/or amend the Report or make a justified decision that this activity, taking into account the requirements of the relevant legislation and regulations, by virtue of its nature and environmental impacts can be carried out in the chosen site. More detailed information is presented in Section 2.6.

3.6 OTHER COMMUNICATION

Lietuvos Energija AB provides information on the project through press releases or press briefings. Also summary brochures have and will be prepared for communication. The first brochure was prepared in early 2008 once the EIA Program was completed. It describes the project, the EIA procedure and summarizes the contents of the EIA Program. The second summary will be prepared once the EIA Report is completed. It will describe the project and the most important results of the environmental impact assessment.

Information about the EIA procedure is also provided at Lietuvos Energija AB's website - http://www.le.lt and at the new NPP project website http://www.vae.lt. The websites provide up-to-date information on the progress of the EIA procedure. The EIA Program is available in the Lithuanian, English and Russian language on the website. The website also has the EIA Program summaries available in the Lithuanian, English, Russian, Latvian, Estonian and Polish languages. The EIA Report will also be available on the same website.

3.7 ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT

Environmental impact assessment in a transboundary context is regulated by the Law on the Assessment of the Impact on the Environment of the Planned Economic Activity (*State Journal 2005 No. 84-3105*) and by the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention*).

The parties to the Convention are entitled to participate in an environmental impact assessment procedure carried out in Lithuania if the detrimental environmental impacts of the project could potentially affect the country in question. Correspondingly, Lithuania is entitled to participate in an environmental impact assessment procedure concerning a project located in the area of another country if the impacts of the project could potentially affect Lithuania.

The Ministry of Environment is responsible for the practical organization of the environmental assessment procedures in a transboundary context. The Ministry of Environment has informed the respective authorities of Latvia, Estonia, Poland, Belarus, Finland, Sweden and Russia about the commenced environmental assessment process of the new nuclear power plant in Lithuania and inquired about their intent to take part in the environmental assessment procedure. The information letter was supplemented with the EIA Program in English or Russian and a comprehensive summary in each country's official language was attached. The above mentioned countries had an opportunity to present their suggestions and comments on the EIA Program, which were taken into account by the developer of the EIA documents.

Austria, Belarus, Estonia, Finland, Latvia and Sweden gave their comments on the environmental impact assessment of the new NPP. The comments have been taken into account in the preparation of the EIA Report and the supporting reviews. In Table 3.7-1 the comments and responses to them are presented. The comments mainly concern transboundary impacts, which are assessed separately in Chapter 8.

Table 3.7-1. International comments given and related responses (the references in the comments are references to the chapters or sections of the EIA Program).

	Comment	Response
AUSTRIA	Apart from providing us with the EIA Report you could assist our assessment by informing us on legal requirements applicable to this project providing clear evidence that no project will be licensed which is capable of causing significant adverse transboundary impacts (considering effects of design basis and beyond design basis accidents), e.g. by effectively excluding: ▪ emergency protection action or long term action beyond 800 meter from the reactor, and ▪ delayed action at any time beyond 3 km from the reactor. If the Lithuanian authorities could confirm to the Austrian authorities in writing that these objectives will be met, either by an irrevocable decision of the owner/operator, supported by convincing technical evidence pertaining to the type reactor selected, or - preferably - in compliance with a condition encoded in legally binding requirements or set by the Lithuanian Nuclear Regulatory Authority in a legally binding way, Austria in return could consider not to be affected by significant adverse transboundary impacts on Austria's environment. Please let us know in due course, if Lithuania is able to provide such evidence.	Emergency protection action or long term action beyond 800 meter from the reactor, and delayed action at any time beyond 3 km from the reactor are safety requirements extracted from “European Utility Requirements for LWR Nuclear Power Plants, 2001”. In general EUR provides guidance for the safety justification of NPPs and these issues shall be considered in the Safety Analysis Report. The purpose of EIA is to demonstrate that proposed economic activity by virtue of its nature and environmental impacts may be carried out in the chosen sites. After EIA process, other stages of the project will be implemented: tendering process, technical design, safety justification, licensing, etc. EUR will be considered in these subsequent stages.
	Potential interferences of simultaneous activities at the site as decommissioning of the old units, construction and later operation of the new NPP should be analysed in the EIA Report (including timetables for both activities). The total inventory of radioactive material at the site should be estimated for the different phases of the activity at the site.	The simultaneous activities at the site are taken into account in the parts of the assessment where potential interference might be expected, for example the impacts from traffic. The potential radioactive emissions from the new NPP and other existing and planned objects in the same area are evaluated in Section 7.10.
	Considering the influence of thermal pollution due to the NPP's waste water release into the lake, the alternative to construct smaller co-generation heat and power plants fuelled either by gas or biomass should be analysed in the EIA Report. Such plants could be constructed near villages and provide effectively electricity and heat which both could be used locationally.	Section 4.5 describes the options excluded from the investigation and gives the explanation to the exclusion of these options.
	Concerning development and prognoses of demand and generation of electricity more detailed information should be provided by the EIA Report, including data on export and import of electricity. The EIA Report should provide a serious discussion of the prognoses for electricity demand, as well as an assessment of the potential for efficiency enhancement and demand side management.	The electricity generation and demand forecast for Lithuania is presented in Section 4.4 to the extent included in the scope of the EIA process.

	In order to analyse the differences in impacts from other electricity generating sources and nuclear power plants on air quality, the emissions of greenhouse gases and other pollutants caused by use of different fuels we recommend to include demand side efficiency improvements and energy saving and demand side management, as well as different renewable energy forms. The comparison of the environmental impact has to include the total life cycle of all considered alternatives.	In Section 4.5 it is explained why energy saving is not a relevant option for this EIA Report. Emissions from different burning fuels will be compared in sections related to the impacts of non-implementation and impacts on air quality.
	If the EIA is performed in order to prepare a decision about the reactor type a detailed comparison of emissions, waste and fuel requirements. However a more detailed assessment will be required for the safety and risk assessment of the plant.	The EIA is not performed in order to make a decision about the reactor type to be chosen. The purpose of EIA is to evaluate whether the proposed economic activity by virtue of its nature and environmental impacts may be carried out in the chosen sites. Risk analysis and assessment is presented in Chapter 10 to the extent needed to fulfil the objectives of the EIA.
	The EIA Report should contain more concrete information about the reactors considered to be constructed for Lithuania.	The considered plant type options are described in Chapter 5.
	The following information corresponding to the reactor type should be given by the EIA Report: ▪ a description of the plant and its safety an control systems ▪ the number of reactor units, ▪ the description of common facilities and structures ▪ allocation of all facilities at the NPP site, ▪ refuelling cycle, and maximum fuel burn-up, ▪ radioactive core inventory ▪ Safety targets, safety standards and requirements, (IAEA guidelines, Euratom directives etc.) ▪ PSA results including source terms for DBA and BDBA should be given in the EIA Report.	Chapter 5 describes the operational principles of a nuclear power plant, the plant type options and the fundamentals of nuclear safety. It includes the description of relevant safety targets, safety standards and requirements to the extent included in the scope of the EIA. The number of reactors will be from one to five. In general, requested information is more relevant to Technical Design and Safety Analysis Report. EIA contains all necessary information to the extent needed to assess the impacts of the new NPP during normal operation and possible accidents.
	The EIA Report should include a preliminary estimation of cost for long-term treatment of SNF and radioactive waste, just as it is required in the EIA Program for decommissioning in order to establish and collect appropriate funds for these activities during operation of the plant.	Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report. In EIA Program (Section 6.3) it is stated, that during the design stage of the new NPP an initial decommissioning plan should be prepared before the operating licence is issued. The initial decommissioning plan must specify the likely quantity of waste and provide an estimate of decommissioning costs.
	Monitoring results should give the detection limits instead of zero-values. Monitoring results should be completed by the description of the sampling (location and frequencies) and the measurement methods.	The proposal for the monitoring program for the new NPP is described in Chapter 9. In the program the sampling and the measurement methods are described.
	For the dose assessment the calculation method including the dispersion model used, the considered exposure pathways and a specification of the critical group have to be presented in the EIA Report.	The methods of the dispersion modelling, the dose assessment and the considered exposure pathways are presented in Sections 7.10 and 10 and more in detail in the study that is referred to.

	Since INPP is operating since 30 years a time series of measurement data should be given. We recommend to provide time series of data not only concerning the radiation monitoring but also concerning the public health in order to allow a serious discussion of the impact of radioactive emissions.	The history of the INPP radiation monitoring program is described in Chapter 9. The present state of public health and impacts on it are assessed in Section 7.10.
	The EIA Report should present the estimation of the air pollution emissions of the planned new NPP and their impact.	The assessment of impacts on the air quality is presented in Section 7.2.
	Why are no environmental and societal NGOs invited to send their experts to the stakeholder group? Who are the “relevant EIA parties”? The difference between “relevant EIA parties” and “stakeholders” should be clearly defined.	The environmental and societal NGOs have the opportunity to express their opinion about the EIA Report (as well as the EIA program) as part of the public participation (Section 3.3). The relevant parties include governmental institutions, responsible for health protection, fire-prevention, protection of cultural assets, development of economy and agriculture, and municipal administrations (Section 3.4).Stakeholders include all the persons, groups and organizations who effect or can be affected by the economic activity assessed in this EIA.
	The EIA Report should present a serious discussion of the prognoses for electricity demand and analyse options for efficiency enhancement and demand side management is necessary.	The electricity generation and demand forecast for Lithuania is presented in Section 4.4 to the extent included in the scope of the EIA process.
BELARUS	Taking into consideration an already substantial number of radiation-dangerous installations in the vicinity of the boarder with Belarus and planned installation of new NPP units, we consider it appropriate to carry out a long term complex environment impact assessment of induced load, including in the Republic of Belarus.	The impacts caused by the NNPP together with other activities in the region are taken into account where necessary (for example traffic, radioactive releases).
	“Alternative sites” may not be excluded from clause 4.3 “Alternatives excluded from investigation”, in the view of the absence in the world practice of similar instances of location of NPP in the immediate vicinity of the state boarder with the contiguous state. Therefore, we suggest analysing other possible sites for installation of the New NPP at the territory of Lithuania.	The reasons why alternative locations of other places in Lithuania are excluded from the investigation are described in Section 4.5.
	For clause 6.2.2 “Radioactive Waste”, we assume that in the EIA for the New NPP it is necessary to provide a concept of the disposal of spent nuclear fuel (SNF) and the program for handling of SNF for the period of 100 years. What concerns the issue of propagation of radioactive substances, it is necessary to take into consideration not only the area of sanitary protection zone but also surveillance area (30 km area), as a part of this area is on the territory of the Republic of Belarus.	The different SNF management options are described in Chapter 6 based on existing experience. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report. The dispersion of radioactive releases is assessed to the extent where impacts occur. Impacts of radioactive releases during normal operation of new NPP on water are assessed in Section 7.1 and impacts of radioactive emissions on air quality in Section 7.2. The transboundary impacts are assessed in Chapter 8 and dispersion modelling for long distances in case of accident is provided in Chapter 10.

	For clause 7.1.2 “Water impact assessment”, we suggest analysing scenarios of the radioactive waste transfer by water in different accident situations, and during normal NPP operational mode, as due to the existing hydrographical and hydrological conditions surface water discharge in the region of the proposed construction of the NPP from the territory of Lithuania goes to the territory of Belarus. In case of radionuclide releases to the environment in particular by water the major contamination of waterways of the Republic of Belarus may occur.	The radioactive releases in water during normal operation are described and assessed in Section 7.1. The transboundary impacts are assessed in Chapter 8. The cross border transfer of radioactive effluents from the new NPP via hydrological pathway to Belarus is estimated in this chapter.
	For clause 7.1.3 “Impact mitigation measures”, we consider appropriate analysing issues of rehabilitation of objects of the environment more profoundly in the surveillance area, for example due to prevalence of west winds (c.7.2.1.1).	EIA considers possible impacts and describes measures that are available to mitigate these impacts. Rehabilitation issues are not a subject of EIA.
	To broaden clause 7.3.2 “Impact assessment on the groundwater”, by considering scenarios of radioactive waste penetration into groundwater and its transfer to the territory of the contiguous states.	The impacts on groundwater are assessed in Section 7.3.
	To supplement clauses 7.8 “Cultural heritage” and 7.9.1.1 “Population and demography” with the information about numbers of population and objects of cultural and environmental importance, located in the surveillance area at the territory of the Republic of Belarus.	Objects of environmental importance, located in the surveillance area at the territory of the Republic of Belarus, are discussed in Section 7.6 and population in Section 7.9.
	In clause 7.9.1.3 “Transport and noise”, to perform an additional analysis of the air route Minsk–Riga.	Information about air route Minsk-Riga is included.
	In clause 7.10 “Abnormal and accident situations”, we consider it necessary to present a list of abnormal and accident situations and then to assess such potential emergency situations as: aircraft crash onto the NPP, fire, terrorist attack, and earthquake. As they may cause significant radiological consequences not only for the Republic of Lithuania but for the neighbouring states as well.	In Chapter 10 plant internal faults as well as external natural and human events are taken into account.
	Chapter 8 “Potential Impact on the Neighbouring States”. We recommend broadening this chapter by analysing it following the same clauses of the Program as for the territory of Lithuania.	The transboundary impacts are assessed in Chapter 8. The assessment of these impacts is done similarly as the assessment of the impacts that concern the territory of Lithuania.
	During preparation of the EIA Report, when analysing potential impact from specific technological processes, we recommend taking as a base maximal safety standards, also based on the recommendations of IAEA.	The safety standards, including the recommendations of IAEA, are taken as a base when assessing the potential impacts of the nuclear power plant where applicable.
	For more complete information and forming of the opinion of the people in the Republic of Belarus on the planned construction of the New NPP in Lithuania we suggest preparation and distribution of pamphlets, brochures at the territory of the Republic of Belarus as well as management of the Internet web page in Russian.	The summary of the environmental assessment program is available in Russian on the Website of Lietuvos Energija (http://www.le.lt).

ESTONIA	The EIA Report should also assess impact of construction of the new power plant just for Lithuanian domestic electricity needs.	EIA is done for the proposed economic activity. This activity is a new NPP with total electrical power of no more than 3 400 MW. Analysis of economical issues and domestic needs are not within the scope of EIA.
	2. In case of the “zero-alternative” the EIA Report should include the different alternatives: How is it possible to produce energy from other sources (in planned amount and only for domestic needs): the production of electricity using co-general ion plants based on combination of coal, fuel oil and natural gas; the production of electricity as decentralized production in many small co-generation plants on combination of bio mass, natural gas and wind powers. Non-implementation should foresee common conventional power production options used in the region as well implementation of the energy efficiency measures. The EIA experts should also analyse whether it is possible to export electricity from other states.	The zero-option and its impacts are described in Section 4.4.
	The EIA Report should give information about why the two locational alternatives have been chosen.	The choice of the location alternatives is explained in Section 4.1.
	The EIA documentation has to set up how the proposed project may impact the energy production in surrounding states (for example it may decrease the production of electricity from green sources)	Analysis of economical issues and energy production in surrounding states are not within the scope of EIA.
	The EIA Report has to give information about the possibility of the accidents with transboundary implications ("worst-case scenario") and describe the potential consequences associated with these situations (spatial extent; impacts, thereof, e.g. air and water pollution, radiation level, external hazards - taking into account prevailing wind directions and wind speeds etc). While radioactive material (in case of emergency) may cross Estonian border, it is necessary to set out all circumstances what Estonia has to take into account to guarantee radiation safety. It is also essential to describe how it is planned to inform other states and the public about increasing of radiation level in Lithuania	Different types of accident situations are described and assessed in Chapter 10. Also the potential consequences associated with these situations are described in this chapter. The assessment is done for Lithuania as well as other countries that might be affected by the impacts of accidental situations.
	The international regulations specific requirements for transport, storage, loading and handling of nuclear fuel have to be described in the report.	Fundamental safety principles of NPPs are described in Chapter 5. The international regulations, specific requirements for transport and storage of nuclear fuel and compliance to them are subjects of Safety Analysis Report.
	The EIA Report has to give description how storage of spent nuclear fuel is regulated and done in practice so far. An overview about how and where the final disposing of spent nuclear fuel shall take place should be given. It is necessary to give information about the principles to finance the final disposal. The different phases of spent nuclear fuel generation and potential impacts of spent fuel storage and disposal should be described in detail.	The different SNF management options are described in Chapter 6 based on existing experience. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report.

	It is necessary to set up how the waste management during normal operation should be carried out.	The waste management during operation is described in Chapter 6.
	A description of the current and planned monitoring system of the radioactive emissions should be given.	The monitoring plan for the new NPP is described in Chapter 9.
	The EIA Report has to assess how the proposed project may impact emissions of CO_2 in other states taking into account that according to the program the purpose of the project is to satisfy the energy consumption in all Baltic countries.	CO_2 emissions in case of zero-option are provided in Section 7.2. Predictions for what power plants will be built in foreign countries and estimation their CO_2 emissions are not within the scope of this EIA.
	The EIA Report should assess how taking the cooling water from Lake Druksiai will affect the water and living nature of the lake.	The possible impacts on water and biodiversity of Lake Druksiai are assessed in Sections 7.1 and 7.6, respectively.
	The EIA experts should analyse whether Lithuania has enough workers for the new power plant in the future and which skills they have to have.	The impacts on the employment are assessed in Section 7.9, which also includes description of the existing INPP staff prequalification and reuse possibilities.
	The EIA documentation has to provide the description of cumulative impacts (taking also into account impacts of decommissioning of the present plant).	Cumulative impacts are taken into account where necessary (for example traffic, radioactive releases).
FINLAND	The long range transport and potential impacts of radioactive emissions should be assessed in the EIA to an adequate extent covering an area of 1000 kilometres from the nuclear power plant.	The dispersion of radioactive releases in an accident situation has been modelled and the results are presented in Chapter 10. The assessment covers the whole area where significant impacts might occur.
	The EIA should point out the structural problems and safety solutions connected with different technical alternatives, e.g. what are the differences between the reactor types in the case of exceptional situations.	The plant type options and technological differences are described in Section 5.2. The exceptional situations are discussed in Chapter 10 and are based on "worst-case" scenario.
	It should be indicated whether the solutions for the transportation of spent nuclear fuel and for final disposal of the spent fuel may include the need to transport spent fuel on the Baltic Sea or transport it in the vicinity of Finland.	The different SNF management options are described in Chapter 6. According to present Lithuanian legislation, transportation of SNF from Lithuanian territory is forbidden. The more detailed description of the long-term storage and disposal of SNF and the activities related to these will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report.
	The treatment, interim storage and final disposal of spent nuclear fuel, and accidents should be assessed and discussed in a precise manner.	The different SNF management options are described in Chapter 6 based on existing experience. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report. Possible accidents and bounding consequences are presented in Chapter 10.
	The risk assessment of and preparation to prevent negative impacts are central issues.	Chapter 10 deals with risk analysis and assessment to the extent needed to fulfil the purpose of the EIA.
	It is important to include life-cycle analysis (e.g. source of raw materials, the use of the power plant, decommissioning, waste management and final disposal of spent nuclear fuel) and monitoring of safety in the EIA.	The life-cycle of the nuclear power plant, from procurement of fuel to decommissioning and management of spent nuclear fuel, is described in this EIA Report. The fundamentals of nuclear safety are described in Section 5.3.
	The impact on Finland in the case of an accident should be assessed with the help of wind models.	The impacts of an accident have been modelled based on existing weather data. The results are presented in Chapter 10.

	The possibility that contaminated water may be discharged into and have an impact on the Baltic Sea should be assessed (current models).	The transboundary impacts are assessed in Chapter 8.
	There also may be indirect impacts on nature in Finland, e.g. through migratory birds and aquatic species.	The impacts on vegetation, animals and protected areas are assessed in Section 7.6.2.
	The impacts of operation should also be investigated: ▪ If cooling water is discharged into Riga Bay, the temperature of the Baltic Sea may rise. ▪ Adjustments in response to changes in demand of electricity, and on reserve power, and their impacts on the environment should be assessed.	The impacts of cooling water on the temperature of the Lake Druksiai are assessed in Section 7.1. The outflows of the lake Druksiai enters the Baltic Sea via hydrographic net which makes about 550 km, therefore increase of temperature of the Baltic Sea due to the cooling water is not expected. Analysis of electricity demand, reserve power is not within the scope of EIA.
	The likely transboundary environmental impacts in exceptional situations and in the case of an accident should be assessed and reported adequately.	The impacts of accidental situations are assessed also for other countries that may be affected. The results are presented in Chapter 10. All the transboundary impacts are summarized in Chapter 8.
LATVIA	A clear picture of all kinds of possible impacts and especially about safety issues and risks in the Latvian territory should be given.	Safety issues and risks are assessed regardless of the territory being affected.
	The project has to be evaluated taking into account existing baseline conditions as well as foreseen changes during next years related to the closure of Ignalina NPP and activities related to that.	The assessment of the impacts is based on the present state of the environment. The foreseen changes related to the closure of the INPP are taken into account where needed to assess the impacts of the new NPP.
	The number of reactors will have to be defined.	Possible technological alternatives (reactor types) are described in Chapter 5. Exact reactor type and number of reactors will be identified during tendering process where different aspects will be considered. EIA considers different type of reactors and number of units varies from 1 to 5 based on planned total capacity of electricity production (maximum 3400 MW) of the new NPP.
	It has to be defined that assessment will be done only for generation III and III+, more over only reactors which are somewhere already built and used.	The assessment has been done for generation III and III+ reactors. The plant type options are described in Section 5.2.
	If there will be no changes regarding alternatives (pressurized water reactor, boiling water reactor and pressurized water reactor), then EIA should be done also for production of heavy water because experiences from other countries, which use heavy water reactors, confirms, that earlier or later state starts production of heavy water, but relevant facilities also have impact to the environment.	Supply of heavy water on the worldwide market is sufficient and if HWR is chosen as a new NPP, heavy water will be imported. In case if it is decided to produce heavy water locally in Lithuanian, this will be another economical activity and separate EIA will be performed.
	In the assessment of impacts from different types of reactors it is necessary to analyse also generation of radioactive waste (amount and radioactivity) for the same electrical power of different reactors.	The generation of radioactive waste is described for different reactor types in Chapter 6.
	Necessity of additional electrical lines and other infrastructural objects has to be evaluated and characterized to ensure possibility to utilize produced electricity as well as heat.	The possibilities to use the existing infrastructure are described in Section 1.8.

	As the new power plant is planned as base load power plant, maintenance period and other periods, when plant will not be operated, have to be assessed with a view of possibility to ensure alternative sources of electricity as well as issues and circumstances necessary to be taken into consideration during these periods.	Assessment of alternative sources of electricity is not within the scope of this EIA Report.
	Issues concerning possible solutions dealing with safe handling of spent fuel and all kinds of radioactive waste have to be evaluated, including possible alternatives and liability options during operation, decommissioning and aftercare period. Geological, hydrogeological, hydrological and seismic issues as well as proximity of borders and security issues have to be taken into consideration.	Management of radioactive waste is described in Chapter 6. The different SNF management options are described in this chapter based on existing experience. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report. Detailed assessment and safety justification of radioactive waste and SNF management will be performed later in Technical Design and Safety Analysis Report.
	Possible impacts to Latvian water objects, air quality, nature values and land use during normal operation as well as during emergency situations have to be evaluated.	The transboundary impacts are assessed in Chapter 8.
	Particular importance has to be devoted for the risk assessment for nearest municipalities and Daugavpils city, including monitoring and early warning system, as well as cooperation with Lithuanian institutions.	The risk analysis and assessment (Chapter 10) includes all the areas that might be affected. Nuclear safety and emergency response arrangements are discussed in Section 10.4. Cooperation agreements between Latvian and Lithuanian institutions in the field of environmental protection are described in Chapter 8.
	Possible emergency situations, including characteristics of worst case scenario have to be assessed and necessary safety measures and possibilities to ensure them have to be explained in detail.	Possible emergency and accident situations are described and their impacts assessed in Chapter 10. The fundamental of nuclear safety are described in Section 5.2.
	Necessary additional measures in the territories around the NPP for monitoring and control issues (e.g. in Latvia) as well as other necessary activities, equipment, elaboration of safety plans, or other issues relevant for planned activity have to be assessed.	The proposal for the monitoring program for the new NPP is described in Chapter 9. Nuclear safety and emergency response arrangements are discussed in Section 10.4. Control issues, other equipment, safety plans are not within the scope of EIA. These issues will be considered in Technical Design and Safety Analysis Report.
	"Early warning system" based on advanced technologies has to be elaborated.	Existing emergency response arrangements are discussed in general in Section 10.4. More detailed discussion is out of the scope of the EIA.
	Scope of investigations have to include collection of representatives base line date about existing situation in Latvian side, as well as argued prognosis based on proposed technologies and safety issues including health issues, social issues and possible long term effects on the land use.	In Sections 7.9 and 7.10 general information about the present state of health and social issues is presented. The situation of Latvia is included also. Information is based on the responses provided by Latvian institutions. The transboundary impacts are assessed in Chapter 8.

	Other direct and non-direct impacts caused by new nuclear power plant together with associated or other known activities in this region (e.g. decommissioning of existing Ignalina NPP and activities associated with that, necessity of building of new electrical lines, necessity for alternative sources of energy and contingency arrangements) have to be assessed.	The impacts caused by the NNPP together with other activities in the region are taken into account where necessary (for example traffic, radioactive releases).
	Full EIA documentation in this particular case should be prepared also in Latvian language to ensure Latvian society with complete and fully understandable information about this project.	The full EIA documentation will be available in English, Lithuanian and Russian. The summary of the EIA Program is, and the summary of the EIA Report will be available in Latvian language.
SWEDEN	The EIA documents need to be supplemented in respect of the requirements to be placed on the new operation as regards reactor safety and waste management	The regulations concerning nuclear safety and risk assessment are taken into account in Section 5.3 and Chapter 10. The requirements for waste management are described in Chapter 6 to the extent needed to fulfil the purpose of the EIA.
	Further description in the EIA of how waste from the nuclear power plant will be managed is needed. This relates to the management of operational waste, to the management of demolition waste from decommissioning and to the final disposal of spent fuel.	The management of SNF, operational and decommissioning waste from the new NPP is described in Chapter 6 to the extent needed to fulfil the purpose of this EIA. More detailed information on decommissioning waste and final disposal of SNF will be provided in separate EIAs in the future.
	It would be desirable to have descriptions of the environmental impact of the three different technical alternatives for the production of nuclear power presented in the program as well as the zero alternative.	The environmental impacts of the different technical alternatives are assessed separately in those parts where the impacts might differ. The impacts of the zero alternative in the climate and air quality are assessed in Section 7.2.
	In order to facilitate comparison of environmental impacts, a more transparent description of the alternative ways to produce the equivalent amount of electrical energy (including the zero alternative) would be desirable.	The zero-option is assessed in Section 4.4.
	More light should be shed on how the project may affect fish species, fish stocks and fisheries as far as Sweden is concerned.	The transboundary impacts are assessed in Chapter 8.
	The zero alternative should be more explicitly based on a comprehensive picture of a tentative energy system.	The zero-option is described in Section 4.4.
	The potential for enhanced energy efficiency should be taken into account in the energy system of the zero alternative	The potential for enhanced energy efficiency is considered in Sections 4.4 and 4.5 about the zero-option and the options excluded from the investigation.
	The environmental impacts which might arise in the overall system of electricity supply if unplanned emergency shutdowns of the reactor in question were to occur should be discussed.	No such environmental impacts that would be included in the scope of this EIA are expected.
	The description in the EIA Program is somewhat unclear as regards the names of the faults, the age of the neotectonics and the location of the faults in relation to the planned nuclear power plant.	More detailed information about the geology of the sites is provided in Section 7.5.
	Both the zero alternative, alternative locations and alternative designs must be included in the environmental impact assessment, and they must be analysed and evaluated on the basis of safety aspects and the assessment of risks.	The alternatives being assessed are described in Chapter 4. These alternatives are considered separately in the parts of the assessment where it is needed based on difference in the impacts.

	Safety aspects and risk assessments should take into account expected future climate change, and they should analyse what may happen in the case of accidents.	The nuclear power plant safety issues are described in Section 5.3. The plant will be designed to withstand external threats like natural phenomena. The risk assessment in Chapter 10 also takes into account the expected climate change.
	The uncertainties in the development of the Swedish nuclear waste program need to be taken into account in an environmental impact assessment.	The description of the SNF management options is based on exiting experience.
	The EIA should contain a description of the location and method that will be used for the final disposal of spent nuclear fuel as well as the capacity of the facilities for final disposal.	The different SNF management options are described in Chapter 6 based on existing experience. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report.
	The EIA should contain information about any environmental impacts that may arise in Sweden.	All the transboundary impacts are assessed in Chapter 8.

4 ALTERNATIVES

The proposed economic activity is the construction of a new nuclear power plant (NNPP) in the vicinity of the existing Ignalina NPP. The total electricity production capacity of the new NPP will not exceed 3 400 MW. The new NPP will consist of one to five units depending on the plant size and reactor type to be chosen.

In this chapter the alternatives for executing the proposed economic activity are presented and compared. However, also the options excluded from the investigation as well as the non-implementation alternative are presented. The evaluated alternatives include the following:

- location alternatives;
- cooling alternatives (direct and indirect (cooling towers) cooling; alternative scenarios for electricity production levels; location of the cooling water inlet and outlet channels);
- technological alternatives (types of reactors);
- non-implementation alternative;
- options excluded from the investigation.

4.1 LOCATION ALTERNATIVES

There are two options for the location of the new NPP. The alternative sites are located in the territory of the existing Ignalina NPP (Figure 4.1-1):

- Site No. 1: location east of the Ignalina NPP unit 2,
- Site No. 2: location west of the switchyard.

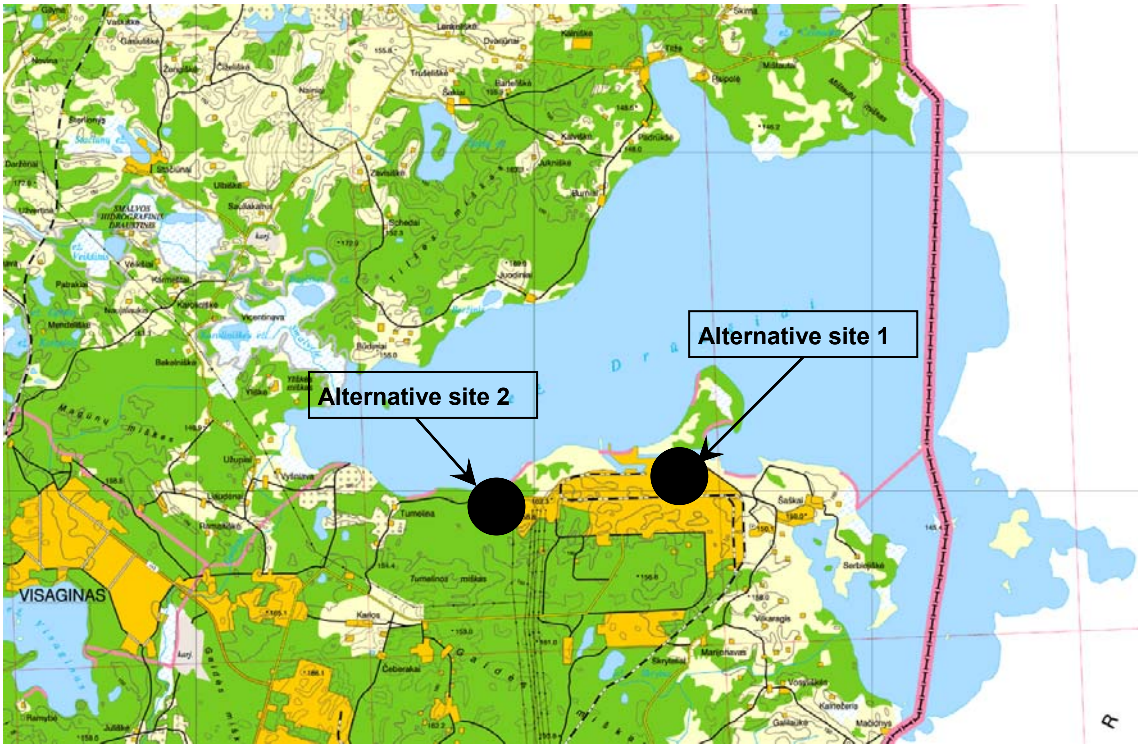


Figure 4.1-1. Location of Site alternatives No. 1 and No. 2.

The construction of the nuclear facilities in the territory was started in 1974. Ignalina NPP has been in operation since 1983, using Lake Druksiai for cooling. The first INPP unit was shut down in 2004. In 2009 also the second INPP unit will be closed. The decommissioning process will continue at least until 2030. Therefore the purpose of the site, to produce electricity by nuclear power, will remain the same also after the new nuclear power plant is constructed.

The current territory of the INPP is the only territory in the Republic of Lithuania, with existing electricity transmission, cooling water, transportation roads and auxiliary facilities, which are necessary for the operation of the nuclear power plant. In addition there are other nuclear facilities planned as well as under construction including the facilities for radioactive waste management and disposal facilities.

4.2 COOLING ALTERNATIVES

4.2.1 Inlet and outlet locations

Three alternative inlet and two alternative outlet locations have been studied with a 3D-flow model. Alternative inlet locations were the present location, a location about 2 km to the west from the present location and a tunnel from the deep part of the lake. Alternative outlet locations were the present outlet location in the middle of the lake and an outlet to a bay in the southern part of the lake. Additionally, an outlet alternative where the cooling water flow was divided into these two outlets was studied. The locations are shown in Figure 4.2-1.

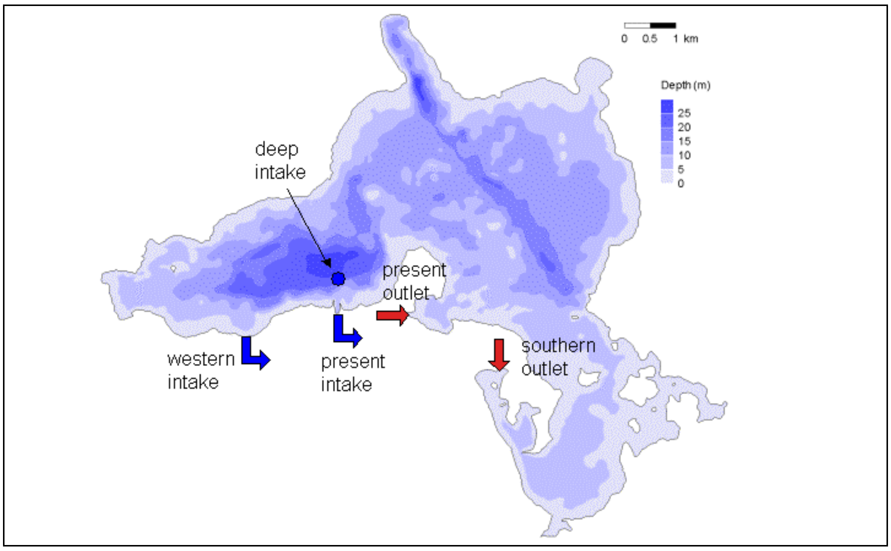


Figure 4.2-1. Alternative inlet and outlet locations.

Present inlet and present outlet were chosen for modelling since the existing infrastructure would be adequate also for the new NPP. Additional locations were chosen based on expert estimate on how to assess in the modelling as wide a variety of thermal impacts as possible.

The deep inlet option was selected to assess the possible advantages of obtaining cooler water from the deep water layers. The western inlet is located close to the alternative site No. 2 and additionally the distance to the outlet locations is longer than from the present inlet. It was estimated that longer distance between inlet and outlet might give a different thermal impact. Furthermore, it might decrease recirculation of cooling water which in turn would benefit electricity production. Also the southern alternative was selected since it would increase the distance between the inlet and outlet areas. The divided alternative was selected to assess the possible benefits of dividing the thermal load to two areas.

To investigate the effect of NNPP inlet and outlet locations on lake temperatures, six alternative NNPP inlet and outlet location combinations were computed (see Section 7.1.2 for modelling description and results).

4.2.2 Cooling water systems

The main duty of a power plant cooling system is to condense low pressure steam exiting from a steam turbine. The lower the cooling fluid temperature is, the greater the condenser vacuum and efficiency of the plant are. Selection of the cooling system has a substantial effect on this. Finding the most suitable system requires examination of many parameters related to equipment and plant location.

Once-through system (OTC), later referred as direct cooling, and wet cooling tower (WCT) are considered as wet cooling methods due to the fact that both use water as the primary cooling substance. Both systems have a high cooling efficiency and therefore they are the most commonly used cooling systems in power plants for energy production. Wet cooling tower can be either natural or forced draft type. Dry cooling systems can be direct, such as air-cooled condenser (ACC), which uses air as a primary cooling substance or indirect, such as Heller, where water is used as a primary and air as a secondary coolant. In the dry-cooling systems the cooling efficiency is lower than in the wet cooling systems but also the demand of water is lower. In the sections below, cooling systems are examined in more detail.

4.2.2.1 Direct cooling

In direct cooling the cooling water is taken e.g. from a lake or a sea, led through screening and directed to the condenser. Also an indirect construction of a direct cooling system is possible, where the primary cooling water (from the water base) is led through a separate heat exchanger which cools down the secondary (closed) cooling water flow that is used at the condenser. The primary cooling water will be returned to its origin.

The cooling water has to be pumped from the water base, which causes some power demand, but as there are no other power demands as fans, the power consumption is lower when compared with WCT. The investment cost of a direct cooling system is typically low, since no tower has to be constructed. However, it is essential that there is a water system with adequate water resources in the vicinity of the NPP.

4.2.2.2 Wet cooling tower

In WCT the cooling water is led to a cooling tower by spraying. Large amount of small droplets form a vast heat transfer area between water and cool air. The latent heat absorbed to the evaporating water, together with convection and radiation, creates the cooling effect. After contact with the air the cooled water trickles down the fill structure to a basin from where it is pumped back to the condenser.

The cooling tower can be either natural or forced draft type. Natural draft tower utilizes buoyancy via a tall chimney to create a current of air through the tower. Warm moist air in the tower is less dense than drier outside air at the same pressure. The air naturally rises due to the density difference, which creates a current trough the tower. A forced draft tower utilizes power driven fan motors to force air through the tower. A natural draft type cooling tower is typically a large construction, but does not require power to operate blowing fans. Forced draft cooling tower is significantly smaller in size, but requires electricity.

Especially in cool and moist climate conditions a visible plume is formed above the tower due to saturation of the exiting air. At freezing conditions special attention must be paid to the operation of the tower to avoid icing, as it reduces the heat transfer efficiency and might break the structures of the cooling tower. Anti-fouling chemicals have to be added to the water circulating within the cooling tower.

Wet cooling towers can also be used as a part of the direct cooling system to decrease thermal discharge to water base. With this solution, condenser cooling water discharge is led (entirely or partly) through this so called "helper cooler" which cools down the exiting water. This arrangement basically moves a part of the thermal discharge from water base to atmosphere.

4.2.2.3 Dry cooling methods

Specific features of an air-cooled condenser (ACC) and Heller system are insignificant make-up water consumption but also rather ineffective cooling. However, under circumstances where water is not available these cooling methods can be a reasonable solution despite the greater investment costs and the demand of large area.

ACC uses air as the cooling substance. The low-pressure steam from the turbine is led to the condenser, which consists of numerous finned tubes, usually mounted to an A-form. The steam condenses to water inside the tubes and cools down to the design temperature. The cooling occurs with convection and radiation. The air circulates through the condenser by fans, which require electricity. Because of the large diameter of the low pressure steam pipelines, the condenser must be located near the steam turbine. Due to relatively low heat transfer efficiency, ACC also requires a large area to be placed.

Heller is an indirect dry cooling method. There's a closed circulation between the condenser and the dry cooling tower whose structure is very similar to ACC's. The condenser is jet type which sprays the cooled water directly to the boiler water circulation. Therefore the cooling water has to be demineralised water. As the condenser is at vacuum, the cooled water from the tower is expanded at a regeneration turbine which regenerates a part of the pumping power needed for cooling water circulation.

4.2.2.4 Hybrid cooling tower

Hybrid cooling tower combines the features of both wet and dry cooling. The construction of a hybrid tower may vary significantly along the various manufacturers. The basic idea is, however, that the wet cooling part is located at the bottom of the tower and the dry cooling at the top. Typically the basic design criteria are to diminish the use of water under certain conditions and prevent the formation of a plume.

4.2.2.5 Cooling system comparison

The most essential factor in the cooling system selection process is the availability of a sufficiently large body of water. Other aspects include e.g. the effects on the plant efficiency and availability of required land area.

In the following Table 4.2-1 the examined cooling systems are roughly compared with each other. The wet cooling tower is set as a base system (evaluation factor 1 for all parameters) to which the other systems are compared. All the towers are presumed to be of forced draft type.

Table 4.2-1. Relative comparison of the cooling systems.

Parameter	WCT[1]	DC[2]	ACC[3]	Heller[4]	Hybr.[5]
Investment costs	1	<1	>1	>1	>1
Internal power consumption	1	<1	>1	>1	~1
Water demand	1	>1	0*	<1	<1
Chemical additions	1	<1	<1	<1	~1
Condenser pressure	1	<1	>1	>1	~1
Noise	1	<1	>1	>1	~1
Plume	1	<1	0	0	0
Required area	1	<1	>1	>1	>1

* If finned tubes are not sprayed (However, even with spraying <1)
[1] WCT – Wet cooling tower; forced draft
[2] DC – Direct cooling system
[3] ACC – Dry cooling system; air-cooled condenser
[4] Heller – Dry cooling system; heller
[5] Hybr. – Hybrid tower

The direct cooling system is the most efficient cooling system but it requires a water system with large capacity. Its advantages are the usually lower investment costs and higher plant efficiency. In the once-trough cooling the receiving water body acts as a heat sink from where the heat is transferred to air by evaporation. The discharge of heated water can have negative environmental impacts in the receiving water body. However, in once-trough cooling the cooling water does not necessarily need any other treatment than mechanical removal of larger solids whereas the cooling towers usually need treatment for biofouling, scaling and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

Wet cooling tower is the commonly used system at locations with finite water resources. It is the second most efficient cooling system after the once-trough system. It also has higher investment costs. Its power consumption as well as demand for area depend on the design type. The natural draft towers consume less energy but demand more space than the forced draft towers. A common feature of the wet cooling towers is the formation of a visible plume especially during colder months. Since most of the heat is evaporated to the atmosphere and not discharged to the water system, the effects on the surrounding water system remain smaller than with the direct cooling.

With the helper cooler solution the thermal discharge to a water base can be decreased. The efficiency of this system is highly dependent on the temperature difference between air (wet bulb) and cooling water discharge. As long as the air wet bulb temperature is 5 degrees or less lower than the exiting cooling water, helper cooler has no significant effect. E.g. with low cooling water temperatures, air wet bulb temperature must be zero or less to justify the helper cooler. With cooler air (or warmer cooling water discharge) the effect can be reasonable. The helper cooler can be a good solution for a secondary supporting cooling system, which can be used only during the warmest summer months.

The dry cooling systems are not regularly used as a primary cooling system in large (> 1000 MW) power plants since they demand a relatively large area (up to ten times as large as for wet cooling towers) and decrease the plant efficiency significantly. The electricity demand is also higher than in direct cooling due to the fans, which are required for air circulation. The investment costs of dry cooling systems are substantially higher than those for wet cooling. Also, the dry tower system alone can be unable to produce the needed performance required during periods of ambient high temperature. The advantage of the dry cooling systems is that they barely consume water at all, thus there are typically no evaporation losses. Since it does not produce any thermal discharges it does not cause any heat impacts on the surrounding water systems.

In conditions when water can be a limiting factor for some time periods it can be favourable to combine both dry and wet cooling methods. It is possible to use separate wet and dry towers or to incorporate both wet and dry cooling sections in the same tower design (hybrid). The cooling system can be operated based on the prevailing conditions. When sufficient amounts of water are available the dry cooling, which consumes more electricity, would be turned off and heat removal would rely on wet towers. During times of limited water resources the heat or, depending of the design, some proportion of it would be removed by the dry towers.

For comparison of the different cooling systems some central parameters for a plant with a gross production of 1700 MW are presented (Table 4.2-2). The gross production is set to be 1700 MW for a plant using once-trough cooling. The gross production for the other cooling systems is calculated by taking into account the efficiency losses due to the higher condenser pressure. The net production is calculated by deducting the internal consumption of the cooling systems (pumps, fans etc.).

Table 4.2-2. Indicative comparison of the different cooling systems.

Parameter	DC[1]	WCT (nf)[2]	WCT (forced)[3]	ACC[4]	Hybr.[5]
Electricity production (gross, MWe)	1 700	1680	1680	1642	1680
Electricity production (nett, MWe)	1678	1663	1646	1614	1644
Condenser pressure (bar)	0.032	0.04	0.04	0.062	0.04
Cooling water flow (m^3/s)	80	70	70	0	70
Evaporation (m^3/s)	0.75	0.75	0.75	0	0.73
Discharge to lake (m^3/s)	80	0.25	0.25	0	0.24
Required area (m^2)	na*	23 000	15 000	33 000	22 000

[1]DC – Direct cooling system
[2]WTC (nf) – Wet cooling tower; natural draft
[3]WTC (forced) – Wet cooling tower; forced draft
[4]DCS (ACC) – Dry cooling system; air-cooled condenser
[5]Hybr. – Hybrid tower
*Not applicable

The values clearly indicate that the direct cooling system is the best option when it comes to the electricity production. It also consumes less water compared to the wet cooling towers. The dry cooling option is clearly the most consuming system in terms of electricity and area. Wet cooling towers consume more energy than direct cooling, but are still significantly more efficient than the dry options. The estimated values for the hybrid tower are strongly dependent on the design and the amount of heat rejected by the dry cooling system. The ecological and hydrological effects and criteria affecting the selection of the cooling system are further discussed in Section 7.1.

4.3 TECHNOLOGICAL ALTERNATIVES FOR NUCLEAR POWER REACTORS

Nuclear power plants were first developed during the 1950's and 1960's. In the early days several different types were studied and built, but only a few designs ended up in wide commercial use. The first test and prototype reactors represent the first generation of nuclear power plants, created for the development of nuclear power in industry today. Most of the current operating nuclear power plants are Generation II (including the existing Ignalina NPP), constructed in the 1970's having evolved from Generation I technologies. These units have been found to be safe and reliable, but are being superseded by better designs.

Generation III reactors were developed during the later 1980s and 1990s. Generation III+ refers to the most advanced new power plant types currently available, remaining based upon the original concepts for fuel and plant design, operating at modest temperatures and pressures. Generation IV units are at the concept/ early development stage and are not expected to be viable as a commercial offering before 2015–2020. Their operating principles are very different, generally operating at high temperatures (and improved efficiency), requiring new fuels and special coolants.

All current marketed commercial nuclear power reactors use water to remove heat from the reactor core. Most of the nuclear reactors around the world are so-called Light-Water Reactors (PWR, BWR). In addition to light-water reactors, there are heavy-water moderated reactors (CANDU). Other less common reactors in commercial use include graphite moderated and gas cooled tube reactors. Ignalina nuclear power station in Lithuania currently employs the RMBK-1500, a water-cooled and graphite-moderated reactor.

Generation III (Advanced LWR) and III+ (Evolutionary Designs) have a number of characteristic features for future nuclear power plant programs:

- A standardised design for each type to expedite licensing, reduce capital cost and construction time;
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets;
- Higher availability and longer operating life – typically 60 years (cf. 30–40 years for present designs);
- Reduced possibility of core melt accidents by design and additional protection systems;
- Resistance to serious damage that would allow radiological release from external impact and terrorist activity;
- Higher burn up fuel to reduce fuel use and the amount of radioactive waste
- Special “burnable” absorbers to extend fuel life.

The greatest enhancement from Generation II designs is that many incorporate passive or inherent safety features which require fewer or no active controls or urgent operator intervention to avoid accidents in the event of a malfunction. They are not only intrinsically safer, but also have optimised features giving higher availability and better economics than their predecessors.

The possible technical alternatives for nuclear reactors being considered for the new nuclear power plant in Lithuania are all generation III or III+ reactors of the following types:

- pressurized water reactor (PWR);
- boiling water reactor (BWR);
- pressurized heavy water reactor (PHWR).

Specific details of Generation III design alternatives for construction in Lithuania are provided in Section 5.2.

Figure 4.3-1 shows the evolution of nuclear power.

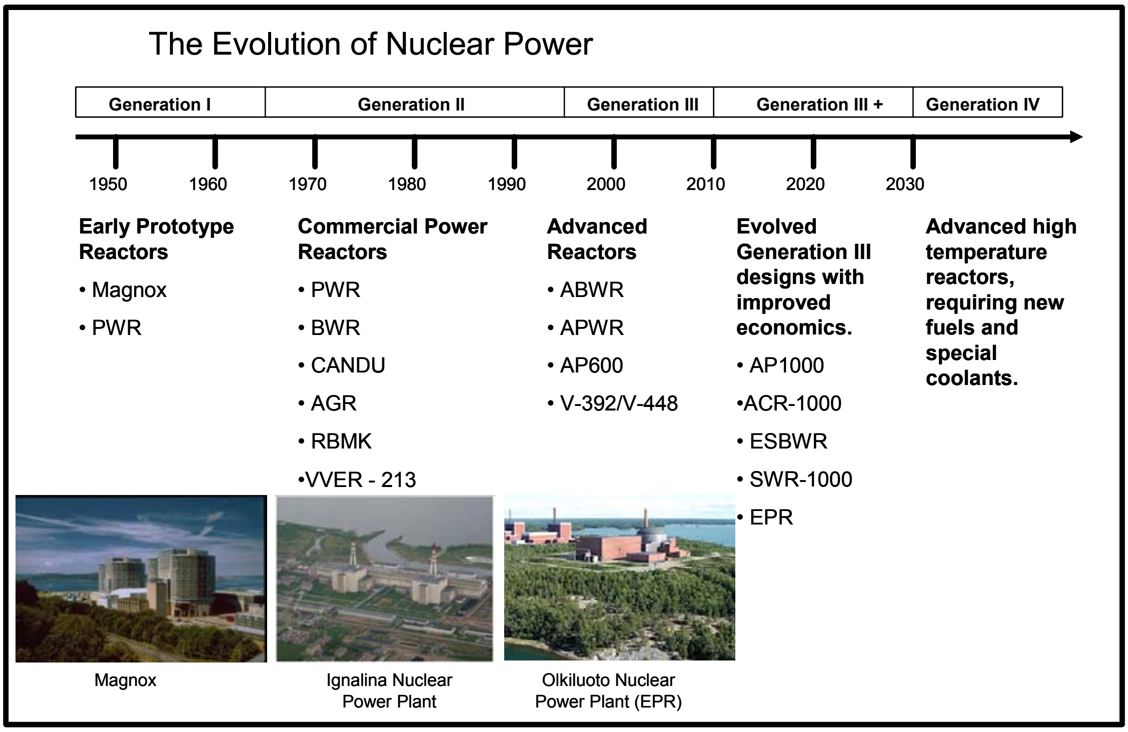


Figure 4.3-1. The evolution of nuclear power.

4.4 NON-IMPLEMENTATION

According to a so called non-implementation, or zero option, no new nuclear power plant unit will be constructed in Lithuania. In this case the supply of energy from diverse, secure, sustainable energy sources which do not emit greenhouse gases and other pollutants will not be secured and the country's energy security will not be ensured.

4.4.1 Electricity demand forecast

Since 2000 the Lithuanian gross domestic product (GDP) has been growing very fast – on average by 7.9 % per year. It is foreseen that the rapid rate of economic growth will persist in the coming two decades. In the National Energy Strategy approved by the Lithuanian Parliament in 2007 (*State Journal, 2007, No. 11-430*) three possible economic development scenarios have been chosen for future forecasts: 1) fast economic growth scenario (the annual rate of 6 % during the period from 2005 to 2025), 2) basic scenario (the growth rate of 4.5 %), and 3) slow economic growth scenario (the annual rate of 4 %). The basic scenario is based on the most likely economic development trends, assuming that the Lithuanian economy will attain the current economic level of the EU states within the next 15 years.

Fast growth of the national economy is one of the most important factors that increases energy consumption, in particular, electricity demand. During the period of 2000–2006 final electricity consumption by end user grew by 5.3 % per year. However, gross electricity consumption increased only by 3 % per year because the power plants' own needs in 2006 were 27 % lower than the 2000 level due to the closure of Unit 1 at Ignalina NPP, and because electricity transmission and distribution losses also decreased during that period.

Although electricity consumption over the period of 2000–2006 showed the most rapid increase compared to the consumption of other energy forms, Lithuania is lagging considerably behind developed European countries in terms of the comparative indicator of final electricity consumption per capita by economic sector (2336 kWh per capita). In 2005, the average electricity consumption per capita in the EU-27 countries was 2.4 times as high as in Lithuania (in Finland 6.6 times, in Germany 2.7 times, even in new member states about 2 times). Therefore, the energy demand forecast was based on the assumption that the modernization of the Lithuanian economy would require the rapid growth of the electricity demand.

An increase in electricity demand will be considerably influenced by the dynamics of macroeconomic indicators (GDP growth, structure of branches of the economy, etc.), rising fuel and energy prices, consumer response to rising income and higher energy prices, energy efficiency enhancement and other factors. With a view to estimate the uncertainty of economic growth and other factors, uncertainty analysis methodology was applied for forecasting. It allows analysing changes in energy consumption in economic sectors, taking into account interrelationship between the factors determining consumption, as well as assessing tendencies of their changes.

To have consistent modelling framework for analysis of the energy sector development, projections of electricity demand (net electricity generation), presented in Figure 4.4-1, take into account final energy consumption, electricity consumption by energy transformation system (including needs of petroleum refinery, oil extraction, heat plants and other energy sector activities) and losses of electricity transmission and distribution. The mathematical MESSAGE model (*Messner et al, 1995, 2000*) which from a set of existing and new technologies selects the optimum mix of generating capacities produces a forecast of electricity consumption for power plants' own use. As is shown in Figure 4.4-1, by the end of planning period electricity generation for the country's internal demand in the fast economic growth scenario will increase 2 times, basic scenario – 1.8 times, and slow economic growth scenario – 1.5 times.

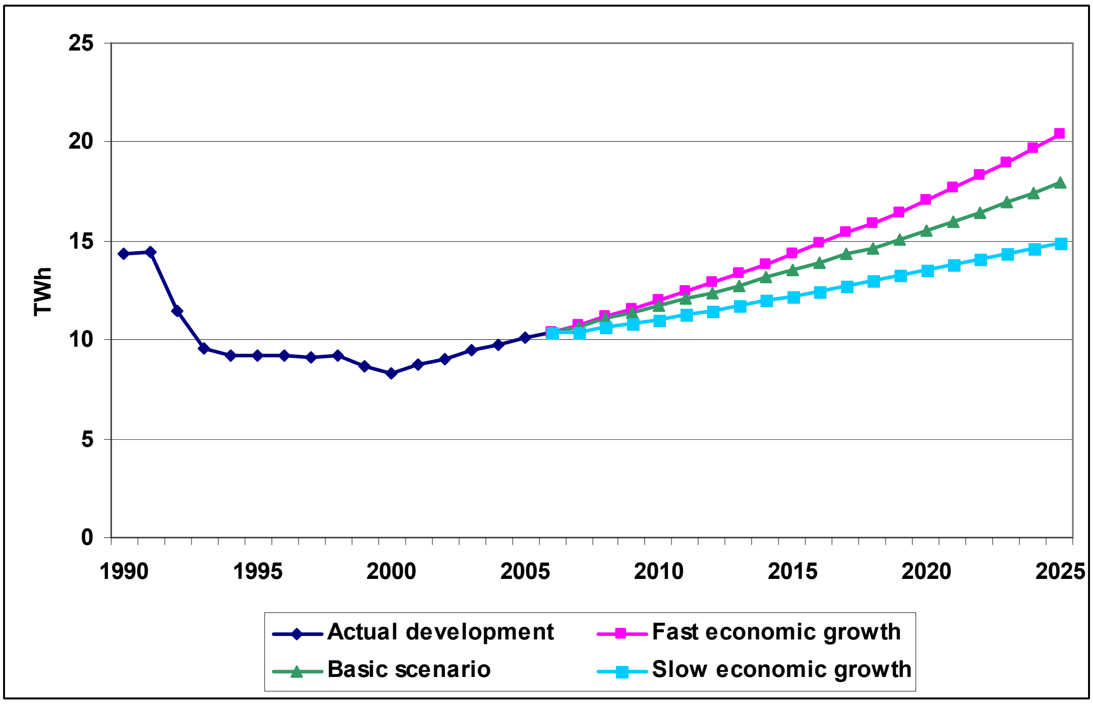


Figure 4.4-1. Electricity demand by scenario.

Disaggregated forecast of electricity demand for the basic scenario by sector is presented in Figure 4.4-2. According to the forecast, the final electricity demand in the branches of economy would reach and exceed the level of 1990 by the year 2017.

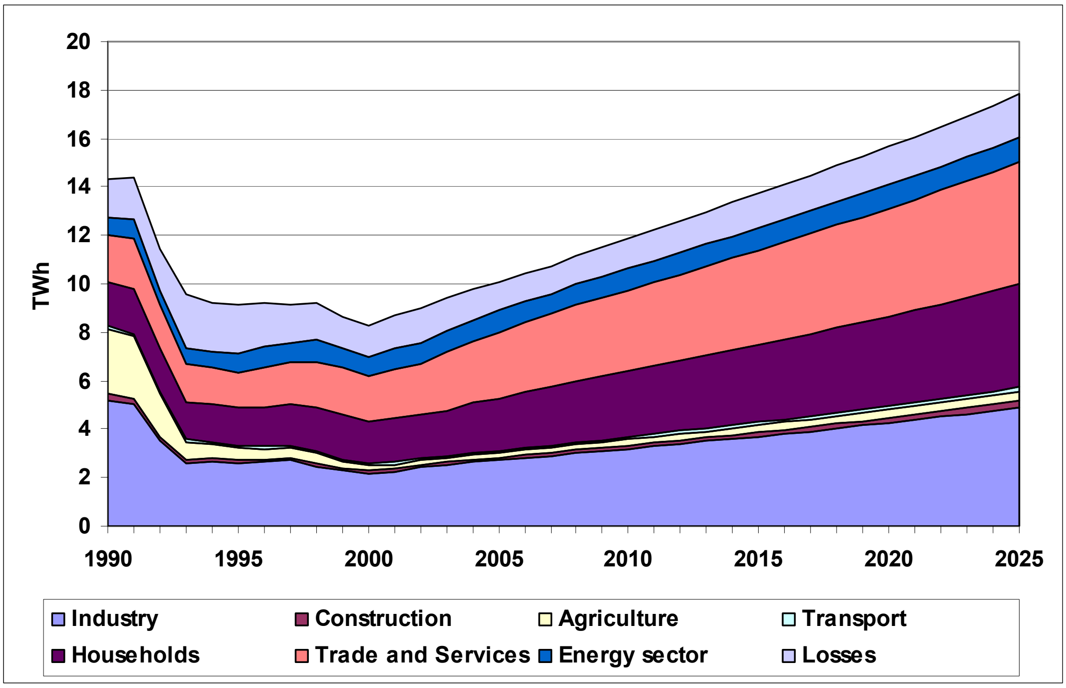


Figure 4.4-2. Electricity demand by sector.

Currently, the Ignalina NPP is dominating in electricity generation – in 2007 its share was 72.6 %. The share of electricity from renewable sources increased up to 4.4 %, and the rest (13 %) was generated by the power plants using natural gas and heavy fuel oil. Lithuania will comply with the EU requirements on the use of renewable energy resources for generating electricity. Renewable energy resources like wind power plants, small hydropower plants and biofuel burning CHP plants being constructed within the next few years will account for over 7 % in the total electricity generation balance in 2010. In 2025 their contribution should increase up to 10 %. Thus, after the closure of the Ignalina NPP more than 90 % of electricity will come from fossil fuels, unless a new nuclear power plant is constructed. In the analysed zero-option, it is assumed that the amount of electricity equal to the production of the new NPP would be partly produced in Lithuania in thermal power plants and part of it would be imported.

Evaluation of the economic effectiveness of utilisation of various energy resources, construction of new energy generating capacities, modernization of existing energy technologies and implementation of appropriate environmental protection measures causes a complex problem, which should be solved by analysing future development of the country’s energy sector during a comparatively long period of time. Without such analysis only preliminary assessment could be presented.

Dependence on the energy import from Russia and the risk of energy supply disruptions will increase significantly. The cost of electricity production will increase dramatically – more than three times due to very high prices for gas and oil and comparatively low efficiency of existing generating units at the Lithuanian TPP. In addition, the replacement of nuclear energy by fossil fuel will significantly increase CO_2 emissions.

4.4.2 Environmental impact of zero-option

In a case when future electricity generation is based mostly on fossil fuel, existing units at the Lithuanian TPP should produce more than 50 % of electricity necessary to meet the country’s internal demand. In addition, the construction of new CHP plants and combined cycle gas turbine units is required. Natural gas will become the major source of primary energy. As there are targets in the Lithuanian Energy Strategy to increase the use of biomass, also biomass-based electricity production is assumed to be included in the zero-option. Imported electricity is assumed to be produced in thermal power plants using coal and oil as a fuel and in hydro and nuclear power plants as well.

Flue gas and green house gas emissions avoided thanks to the new NPP are estimated and the estimated emissions in the zero-option are presented in Section 7.2.2.2.

4.5 OPTIONS EXCLUDED FROM THE INVESTIGATION

Alternative locations in Lithuania

There are no other realistic options for the location of a new nuclear power plant in Lithuania than the proposed sites close to the existing Ignalina NPP. It is essential for the project to utilise existing land use plans and infrastructure. The suitability of the chosen locations is described more in detail in Section 4.1.

Energy saving

The organisation responsible for the project, Lietuvos Energija AB, does not have means to save energy in Lithuania so that the new nuclear power plant or corresponding amount of electricity would not be needed. Thus energy saving will not be investigated as an alternative to the new NPP.

Alternative ways to produce energy

Other options to generate the electricity would be by using other energy sources such as oil products, coal, natural gas, peat, biofuels, hydropower or wind power. However, the nuclear power plant project organisation, and later project company, has been established for constructing and operating a new nuclear power plant in Lithuania and therefore does not have a mandate or possibilities to construct any other kind of power plants. If another company or organisation should begin to develop such power plants, the environmental impacts of them would be assessed as a part of those projects. The purpose and justification of the nuclear power plant project is described more in detail in Chapter 1.

Thus impacts of alternative forms of electricity production in Lithuania have not been assessed in this EIA process. However, the differences between the impacts from other energy generating sources and nuclear power plants on air quality, the emissions of greenhouse gases and other pollutants caused by producing the corresponding amount of energy with other fuels are demonstrated in Section 7.2.2.

5 TECHNOLOGICAL PROCESSES

5.1 OPERATIONAL PRINCIPLES OF A NUCLEAR POWER PLANT

5.1.1 Introduction to nuclear power reactors

Nuclear energy is a way of creating heat through the controlled release of energy from splitting the atoms (fission) of elements such as uranium and plutonium. The energy released from continuous fission in the fuel is used to make steam, which is used to drive the turbine-generator to produce electricity (as in most large thermal power plants).

Nuclear power plants do not use oxygen, therefore they do not directly produce sulphur dioxide, nitrogen oxides, fine particles, mercury or other pollutants, that are produced in the combustion of fossil fuels and cause e.g. health impacts, ground-level ozone formation and acid rain. Nor does operation of a nuclear power plant produce carbon dioxide or other greenhouse gases causing global warming of the climate.

Nothing is burned or exploded in a nuclear power plant, the fuel (many tonnes of uranium) is carefully contained in fuel rods, which are arranged into fuel assemblies for insertion and removal from the reactor. Some reactor types replace the fuel at discrete intervals, other designs utilise continuous refuelling. The fuel core can be thought of as a reservoir from which energy can be extracted through the fission chain process.

There are several components common to most types of reactors used or available for commercial operation today:

Fuel: Usually pellets of uranium dioxide (UO_2) arranged in gas tight metal tubes to form fuel rods. The rods are arranged into fuel assemblies (also called "bundles" in some designs) in the reactor core. The fuel core for a large reactor may have up to 1100 fuel assemblies, more typically between 150 and 260, held in place by end plates and supported by metal spacer grids to brace the rods and maintain proper distances between them (for cooling). During operation of the reactor the concentration of useful (fissionable) atoms in the fuel decreases as those atoms are used to create heat energy. The products created by the fission reactions are retained within the fuel pellets and build up to affect the effective utilisation of the remaining fissionable fuel. Eventually a point is reached where it is necessary to replace some of the fuel, either "at power" or during a temporary reactor shutdown (typically a few weeks), depending on the reactor design. The amount of energy extracted from nuclear fuel is called its "burn up", which is expressed in terms of the energy produced per initial unit of fuel weight (commonly MWd(th)/TeU).

Discharged fuel contains the waste products of fission many of which are radioactive and through a process of radioactive decay continue to generate heat for significant periods after shutdown and removal. Spent fuel is initially stored at the reactor site in water in special cooling ponds – large concrete vaults lined with stainless steel in a dedicated building. These ponds provide both cooling (of the fuel rods) and shielding to protect people and the environment from residual ionising radiation.

Control Rods: These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the reactor core to control the rate of the fission chain reaction, or halt it. As a means of increasing safety (in case some event prevents successful operation of the control rods) reactor designs include secondary shutdown systems which involve adding other neutron absorbers usually into the primary cooling system.

Coolant/ Moderator: A liquid or gas circulating through the reactor core is used to transfer heat from the fuel rods to the turbine-generator, either in a direct cycle (such as Boiling Water Reactor, see below) or indirect cycle via a steam generator (other water reactors and current commercially operating gas reactors). The circulating coolant also provides a moderating function to improve the efficiency of the neutron fission process in current commercial power reactors. In some reactors a separate moderator is used (e.g. CANDU (heavy water in a tank surrounding the primary coolant/ fuel channels) or RBMK (graphite)). The choice of moderator influences the design of the reactor core and fuel cycle, particularly the amount of enhancement (enrichment) of fissile Uranium during the fuel rod production process, the amount of energy that can be extracted from each fuel rod and the size (power density) of the reactor core.

Pressure Vessel or Pressure Tubes: Usually a robust steel vessel over 20 cm thick containing the reactor core and moderator/ coolant, but it may also be a series of tubes holding the fuel and conveying coolant through the moderator (e.g. as CANDU and RBMK).

Primary Circuit: The system which conveys coolant containing heat from the reactor core either directly to the turbine-generator or to a steam generator. After transfer of energy the cooled coolant is returned to the reactor core in a closed cycle, either by use of pumps or natural circulation processes. Attached to the primary circuit are a number of auxiliary “primary systems” which are used for chemistry (corrosion) and volume control of the coolant.

Some reactor designs are based on prevention of phase change (boiling) in the primary circuit and incorporate a pressurizer to suppress boiling. This allows the circulating water and steam at the turbine to hold more energy per unit volume and increase the overall efficiency of the nuclear power plant. These designs are those that have an intermediate steam generator and separate secondary (steam-feedwater) circuit supplying steam to the turbine-generator.

Turbine-Generator: The turbine (one or several) converts the steam into rotational energy which drives an electricity generator. Roughly a third of the generated heat energy can be converted to electrical energy. The excess heat is usually released into the environment. From the turbine, the steam is led to the condensers, where the cold intake water from the lake cools and condenses it back into water for reheating in the reactor core. The water used for cooling in the condensers warms up by a few degrees Celsius and is either discharged to a body of water or led to cooling towers. Water which circulates inside the reactor primary circuit may contain small quantities of fission and activation products, but this water is not mixed with the condenser cooling water at any time.

Containment: The enclosure or structure around the reactor core which is designed to protect it from outside intrusion and by providing a major barrier, to protect those outside from the effects of radiation or the release of radioactivity. The containment structure is typically a metre-thick pre-stressed concrete structure lined with steel, in modern designs designed to withstand the impact of a crashing aircraft, for example. Some designs incorporate two containment shells.

It can be seen that there are a number of features that affect the design of nuclear power plant reactor systems, and each design incorporates benefits and compromises. It is noted here that the evolution of reactor designs has produced increasing levels of safety and for the present worldwide commercial development is focused on water-based reactors. These are described below in general terms; detail of candidate designs under consideration for the new NPP in Lithuania is provided in Section 5.2.

5.1.2 Plant type options for Lithuania

Most of the nuclear reactors in the world are so-called light water reactors (LWR). LWR uses regular water to transfer the heat away from the reactor core. It also acts as a moderator. There are two types of LWR designs: 1) the pressurized water reactor (PWR) and 2) the boiling water reactor (BWR). In addition, PHWR (pressurized heavy water reactors) reactor types are included in the options being considered.

Pressurized Water Reactor (PWR)

This is the most common type of commercial reactor and was originally developed in the USA for submarine propulsion. Roughly 60 % of the world's commercial reactors are PWRs.

The uranium dioxide fuel is enriched to about 4–5 % and contained in zirconium alloy tubes, typically 3.5–4 m in length. Pressurised water acts as both moderator and coolant and heats water in a secondary circuit via a steam generator to produce steam which is used to drive the turbine(s) (Figure 5.1-1).

The PWR operates under a high pressure; this acts to increase the boiling point of the coolant, enabling more efficient heat transfer. The coolant in the primary circuit is kept at operating pressures of typically 120–155 bar. A pressurised water reactor plant has two separate circulation systems; the primary system, which circulates the water pumped through the core to the steam generator (heat exchanger), which transfers heat to the secondary circuit and produces saturated steam. Pressurised water in the primary circuit is heated up to 300–330 ºC. The water in the secondary circuit is heated up to 260–290 ºC and kept at a lower pressure (45–78 bar), this allows the water to boil and generate the steam required to drive the turbine. A PWR's thermal efficiency is 32–37 %.

The reactor is encased in a concrete containment which is designed to withstand internal pressures resulting from a sudden rupture of the pressurised primary water circuit, and external impacts such as aircraft crash.

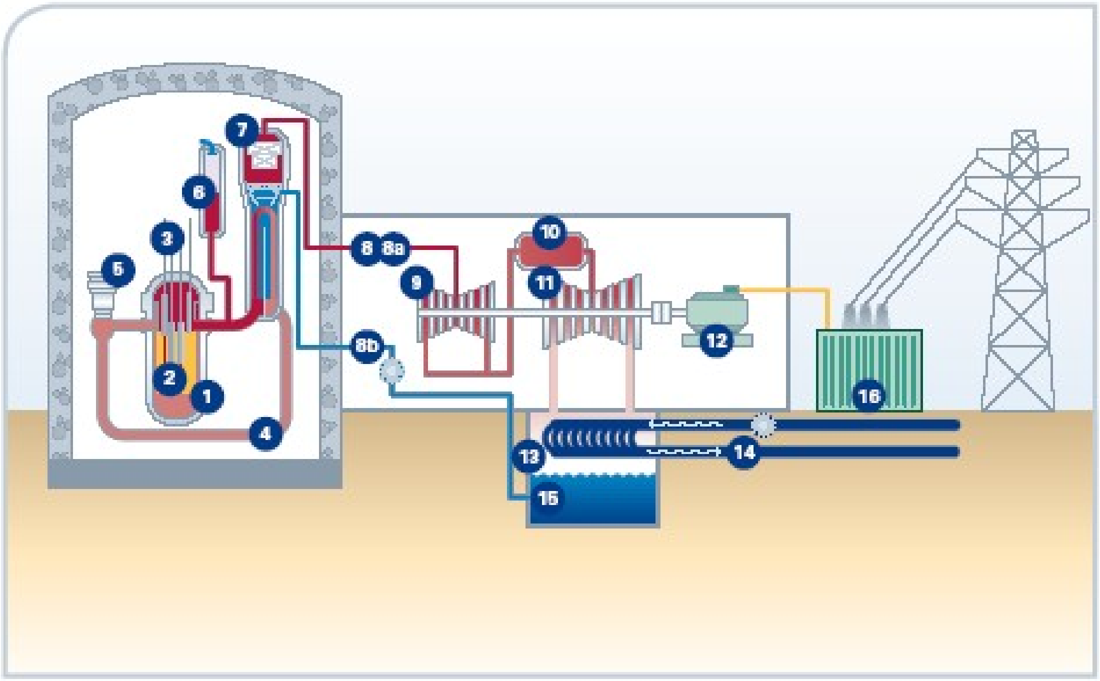


Figure 5.1-1. Key Features of a Pressurised Water Reactor: (1) Reactor, (2) Core, (3) Control rods, (4) Primary circuit (water circuit), (5) Main reactor coolant pump, (6) Pressurizer, (7) Steam generator, (8) Secondary circuit (steam), (8a) Steam for the turbine, (8b) Water for the steam generators, (9) High pressure turbine, (10) Reheater, (11) Low pressure turbine, (12) Generator, (13) Condenser, (14) Cooling circuit, (15) Condensation water, (16) Transformer.

Boiling Water Reactor (BWR)

A BWR is effectively a PWR without the steam generator (Figure 5.1-2). Water is circulated through the core again acting as both moderator and coolant, inside a pressure vessel. This heats the water to a temperature of approximately 300 °C, which makes it boil and generate steam at a pressure of approximately 70 bar. About 10 % of the water is converted to steam and passed to steam turbines. After condensing it returns to the pressure vessel to complete the circuit. The fuel is similar to that of a PWR, but the power density (energy per unit volume of core) is about half, with lower temperatures and pressures. This means that for equivalent heat output BWR pressure vessels are larger than for PWR, but the absence of steam generators and lower system pressures means the reactor containment may be smaller.

The cost advantage of a single circuit (i.e. not having steam generators) is offset by potential radioactive contamination throughout the steam plant in the rare case of fuel failures. With lower pressures (70 bar) and temperatures the thermal efficiency of BWR is slightly less than a PWR.

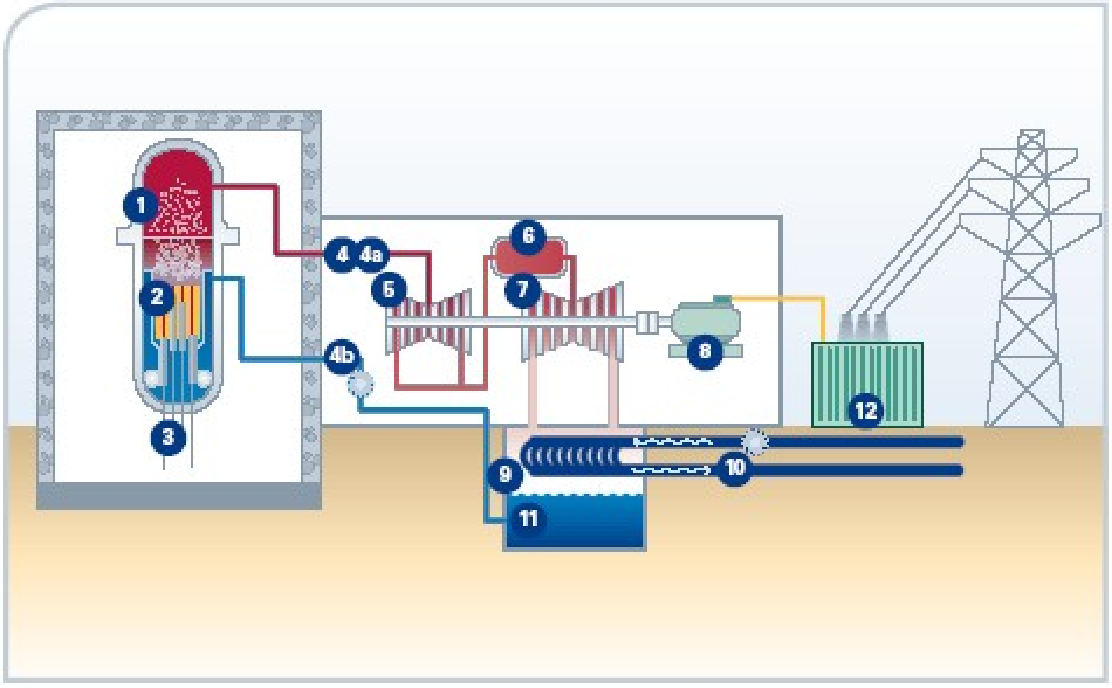


Figure 5.1-2. Key Features of a Boiling Water Reactor: (1) Reactor, (2) Core, (3) Control rods, (4) Primary circuit, (4a) Steam for the turbine, (4b) Water for the reactor, (5) High pressure turbine, (6) Reheater, (7) Low pressure turbine, (8) Generator, (9) Condenser, (10) Cooling water circuit, (11) Condensation water, (12) Transformer.

Pressurized heavy water reactors (CANDU)

The CANDU (CANadian Deuterium Uranium) reactor, as the name implies, uses deuterium oxide (a special form of water) as both coolant and moderator. This permits the use of natural or low enriched uranium dioxide fuel contained in zircaloy tubes. The CANDU reactor design is similar to the PWR, but instead of a large pressure vessel, the uranium fuel is placed in hundreds of horizontal pressure tubes (called channels). These are cooled by heavy water, which removes heat from the core in the same way as the PWR. The pressure tubes sit in a large vessel, or calandria, containing a separate heavy water moderator at low pressure (Figure 5.1-3).

The average power density is about one-tenth that of a PWR, which means that for a comparable output the reactor and its containment are correspondingly larger in size.

CANDU fuel differs from PWR/ BWR fuel, being much shorter in length, with several fuel bundles (typically 12, each 50 cm long) placed end to end in a fuel channel. The fuel tube/ bundle arrangement means that CANDU reactors can be refuelled at power, which increases potential availability. The primary circuit typically operates at 120 bar and 285 °C, leading to a thermal efficiency of about 30 %.

The Advanced CANDU Reactor, ACR, see section 5.2, is a hybrid of PWR and CANDU technology, using slightly enriched fuel with a light water primary coolant to increase the power density and extend the burn up of the fuel, resulting in reduction in size and spent fuel arisings compared to its natural uranium equivalent.

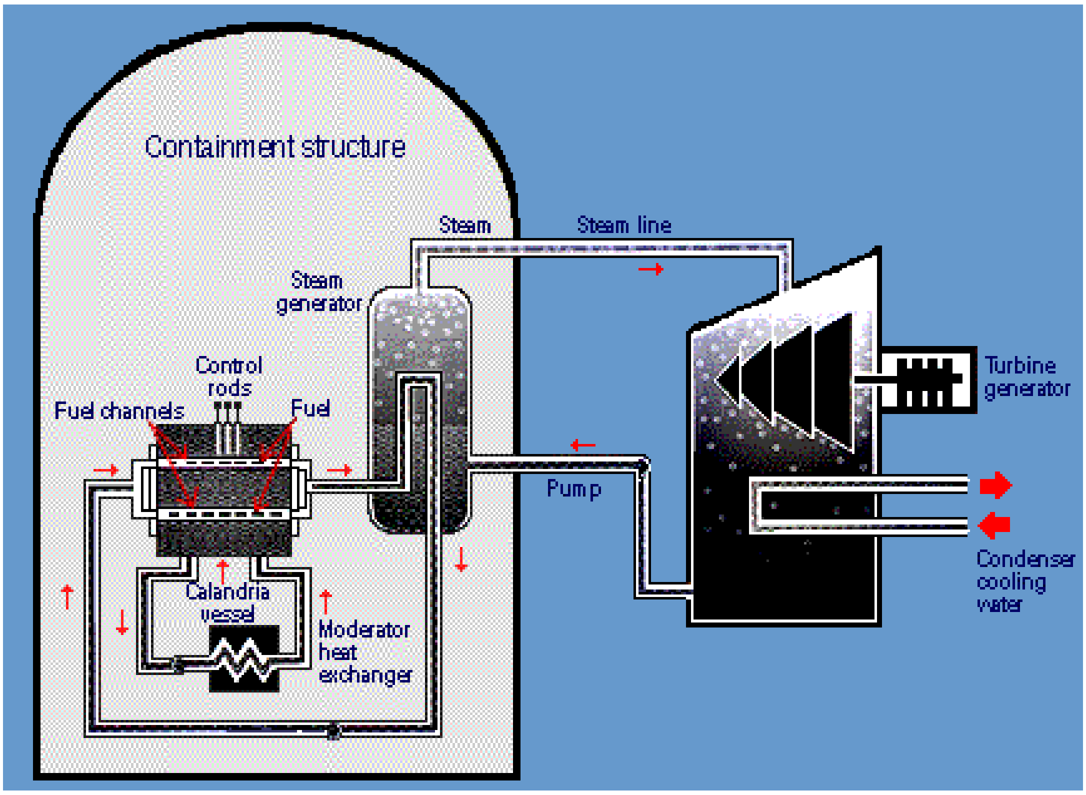


Figure 5.1-3. Key Features of a pressurized heavy water reactor (CANDU, ACR type).

5.1.3 Technical requirements of new nuclear power plant

Detailed specification of technical requirements for the new nuclear power plant will be developed under a separate work package as the project proceeds, hence cannot be stated in this EIAR. Plant output considerations are described elsewhere in this report; this section identifies a principal source of technical requirements for the new nuclear power project.

The major European electricity producers have worked on a common requirement document (European Utilities Requirements document, EUR) for future LWR plants since 1992 to get specifications acceptable to potential owners and operators, the public and the safety authorities. Production of a common requirements document would enable designers to develop standard LWR designs that could be acceptable across Europe and the utilities could open consultations with vendors on a common basis. Communication with the public and regulatory authorities should also be improved. The EUR promoters are a group of organizations that represent the major Western Europe electricity producers. It is likely that the EUR will form a major input to the specification for a new NPP in Lithuania.

The major objectives of the EUR document have been to develop requirements addressed to the LWR plant designers and vendors. It is a tool for promoting the harmonization of the most important plant features that historically were often country specific. The main items considered in this convergence process are the safety approaches, targets, criteria and assessment methods, the standardised environmental design conditions and design methods, the performance targets, the design features of the main systems and equipment, and – at a lower level – the equipment specifications and standards.

The EUR document is structured in 4 volumes (see www.europeanutilityrequirements.org). The whole document includes about forty chapters and some 4000 individual requirements covering a variety of plant design, performance and safety related topics:

- Volume 1: Main policies and top tier requirements; It is guidance on the safety policies and it defines the major design objectives that are implemented in the EUR document;
- Volume 2: Generic nuclear island detailed requirements; it contains all the generic requirements and preferences of the EUR utilities for the nuclear islands. It deals with matters applicable for all designs such as size, performance, safety approach and objectives, grid requirements, fuel cycle, component technology and functional requirements for systems;
- Volume 3: Design specific nuclear island requirements; It contains a subset specific to each nuclear power plant design of interest to the participating utilities. Part 1 of this subset includes a plant description, Part 2 presents the results of the conformance assessment of the design versus the generic EUR requirements of Volume 2 and Part 3 contains the specific requirements, if any, that have been placed by EUR for the particular design;
- Volume 4: Power generation plant requirements; It contains the generic detailed requirements for the Balance of Plant.

The EUR promoters are producing evaluations of selected LWR designs, the results of which are included in Vol. 3 of the EUR document. Presently seven subsets dedicated to GE's ABWR, Westinghouse BWR90, EPP and AP1000, Areva's EPR and SWR1000, and Russian WWER AES92 projects have been published and a further subset dedicated to the Mitsubishi APWR is undergoing preliminary compliance assessment. The requirements are also being employed for the design of the ESBWR. It is expected that further designs may be sponsored by EUR promoters for assessment in the future. Formal assessment of a design for compliance with the EUR can take 18 months.

It is to be noted that the EUR document is a reference user's document for LWR plants to be built in Europe, but it is not a document for licensing the plants. The plant designs will always need to duly comply with the national licensing regulations and laws.

It is necessary to register to EUR to obtain access to the main requirements sections of the EUR. However, the following key safety requirements (based on open literature, e.g. *Scherrer Institute paper and INTERNATIONAL ATOMIC ENERGY AGENCY, "Status of advanced light water cooled reactor designs 1996", IAEA Report, IAEA-TECDOC-968, September 1997*) are highlighted as the key safety related aspects of EUR compliant reactor systems:

- Application of "As low as reasonably achievable (ALARA)" principle;
- Forgiving design characterized by simplicity and passive safety features where appropriate;
- Safety classification based on: Design Basis Condition (DBC) and Design Extension Conditions (DEC);
- Redundancy and independence of safety systems performing DBC and some DEC functions to ensure prevention of common cause failure;
- For DBC's reaching a safe shutdown state within 24 hours from the accident initiation and in any case within 72 hours. For DEC a safe shutdown state should be reached within one week as a goal and before 30 days in any case; The confinement of fission products and protection against external events in normal operation, DBC

and DEC's. The containment should not experience early failure under DEC conditions;

- The containment design has to exclude hydrogen detonation;
- If in-vessel coolability can not be demonstrated, then ex-vessel coolability and non-criticality features must be provided;
- The leakage rate from the containment should not exceed 0.5-1.0 V%/day for a pre-stressed concrete shell without a liner, 0.1-0.5 V%/day with a liner or for a metal shell;
- On-line monitoring of containment leak-tightness during operation;
- The containment should not remain at elevated pressure after the accident. The pressure should be reduced at least to 50 % of its peak value in the worst DBC;
- Requirement for a secondary containment, for example by a partial solution of enclosing all penetrations;
- Secondary bypass leakage should not exceed 10 % of the primary containment leakage;
- Next generation of NPP's will be safer by increasing design robustness, better operation and maintenance (preventive means) rather than through protective actions;
- If possible, public evacuation planning should not be necessary (for a site boundary of 800 m);
- For accident prevention – simplification of the safety systems, elimination of common mode failures by physical separation and diverse back-up systems, less sensitivity to human errors by designing components with larger inventories of water, optimized man-machine interface by digital instrumentation and control systems, use of probabilistic risk assessment to limit the residual risk due to total loss of safety grade systems;
- Target frequency of:
    - core damage accidents (No action necessary beyond 800 m from the damaged plant, very limited economic impact out of the plant), with containment intact: $< 10^{-5}$/ reactor year;
    - criteria for limited impact (No immediate Emergency Protection Action beyond 800 m from the reactor; no delayed action at any time beyond about 3 km from the reactor; no long term action at any distance beyond 800 m from the reactor; limited economic impact out of the plant): $<10^{-6}$/ reactor year;
    - Sequences potentially involving either the early failure of the Primary Containment or very large releases: $< 10^{-7}$/ reactor year.

5.2 PLANT TYPE OPTIONS

A general description of the design and key safety features for those reactor designs being considered for the new NPP in Lithuania is given in this section. Reactor designs being considered are presented in Table 5.2-1.

Table 5.2-1. Reactor designs being considered for the new NPP.

Output, MW_e	Reactor Type	Model	Supplier	Generation	Website[1]
600	PWR	AP-600	Westinghouse-Toshiba	III+	www.ap600.westinghousenuclear.com
700	PHWR	Enhanced CANDU-6	Atomic Energy of Canada Limited	III	www.aecl.ca/reactors/
1006	PWR	V-392	Atomstroyexport	III	www.gidropress.podolsk.ru/english/razrab_e.html
1085	PHWR	ACR-1000	Atomic Energy of Canada Limited	III+	www.aecl.ca/reactors/
1100	PWR	AP-1000	Westinghouse-Toshiba	III+	www.ap1000.westinghousenuclear.com
1254	BWR	SWR-1000	Areva NP	III+	www.areva-np.com
1300	BWR	ABWR	GE-Hitachi	III	www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm
1500	PWR	V-448	Atomstroyexport	III	www.gidropress.podolsk.ru/english/razrab_e.html
1535	BWR	ESBWR	GE-Hitachi	III+	www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm
1660	PWR	EPR	Areva NP	III+	www.areva-np.com
1700	PWR	APWR	Mitsubishi Heavy Industries	III	http://www.mhi.co.jp/en/nuclear/

1 – Information on reactor systems has been taken from published sources with particular emphasis given to the web sites of the Vendor organisations as listed in this table. Additional information is taken from publicly available documents provided by reactor suppliers in support of regulatory review or assessment, for example the web sites of the US NRC and UK HSE.

The sections that follow provide further information on these reactors, highlighting key features of the design and comments regarding the status of the design in terms of interest by electricity utilities and licensing. This information is at time of writing subject to continuous change. This information is provided to indicate the possible type of nuclear power plant that may be constructed in Lithuania, not to indicate or imply any selection at this time. Selection of the preferred plant design and licensing acceptance will be undertaken at a later stage in the NPP development program.

For ease of presentation, information below is by vendor, rather than ordered by power output.

Areva NP

European Pressurised Reactor (EPR)

The EPR is an evolutionary PWR manufactured by Areva/Framatome ANP. This generation III+ reactor is designed to generate up to 1600 MW of electricity. The EPR has been developed from the Framatome N4 units and the Siemens/KWU Konvoi plants, currently operational in France and Germany. Several utilities companies have participated in the design, including EDF, E.ON, RWE, and EnBW. The reactor design follows an evolutionary approach where safety relies on active safety systems based on conventional engineering as opposed to passive safety features of Generation III+ designs.

The EPR is based on 4-loop PWR technology with a single large turbine-generator and incorporates 4 train safety systems to protect against plant malfunctions. The reactor containment building has two walls, the first, an inner pre-stressed concrete housing with a metallic liner, encapsulated by the second wall comprised of a reinforced concrete shell. The containment building has a specially-designed corium spreading area. In the event of core meltdown, this is where any molten core escaping from the reactor vessel would be collected, retained and cooled. The diesel building contains four emergency diesel generators and their support systems to supply electricity to the safeguard trains in the event of a power blackout. The calculated core damage frequency is <3.9 x 10^{-7}/ reactor year, and the frequency of significant release of radioactivity from the plant of <6 x 10^{-8}/ reactor year.

The EPR design is shown in Figure 5.2-1.

Figure 5.2-1. Schematic of the principal buildings of an EPR (*www.areva-np.com*).

The efficiency of the plant is between 36 % and 37 % depending on site conditions. Fuel cycle lengths are between 12 and 24 months. The reactor can be fuelled with either, 5 % enriched Uranium or up to 100 % MOX fuel. The reactor fuel cycle has a burnup of 65 GW·d/tU, resulting in 27.7 Te of spent nuclear fuel/ year for an 24 month refuel cycle.

The EPR is designed to achieve the highest unit power to date, mainly due to economies of scale. Other factors such as shortened construction times, high thermal efficiency due to raised steam pressures in the secondary circuit, and improved reliability resulting from on-line maintenance for components out side of the reactor building, help achieve this.

The EPR is certified as EUR compliant (December 1999) and is also undergoing Generic Design Assessment in the UK and NRC Design Certification in the USA.

Construction time of the NPP is approximately 45 months. The first EPR is currently under construction in Olkiluoto, Finland. Operation was originally scheduled for 2009, but TVO have recently announced that construction problems have resulted in a delay of around 18 months; operation is now expected in 2010/2011. Construction of an EPR reactor at Flammanville, France has commenced and orders have been placed for China and the USA.

Siede Wasser Reaktor (SWR-1000)

The SWR 1000 is a generation III+ advanced boiling water reactor, originally designed by Siemens (now part of Areva) and generates up to 1254 MW of electricity. The design is based on German boiling water reactor technologies, modified to include integral recirculating pumps for the primary circuit, simplifying the design. Passive safety systems have been introduced into the design, alongside proven active safety systems. The design has also been simplified; features include the adoption of a single-train feedwater heating system, and the removal of the feedwater tank and the re-heaters.

A schematic of the reactor part of the SWR 1000 is given in Figure 5.2-2.

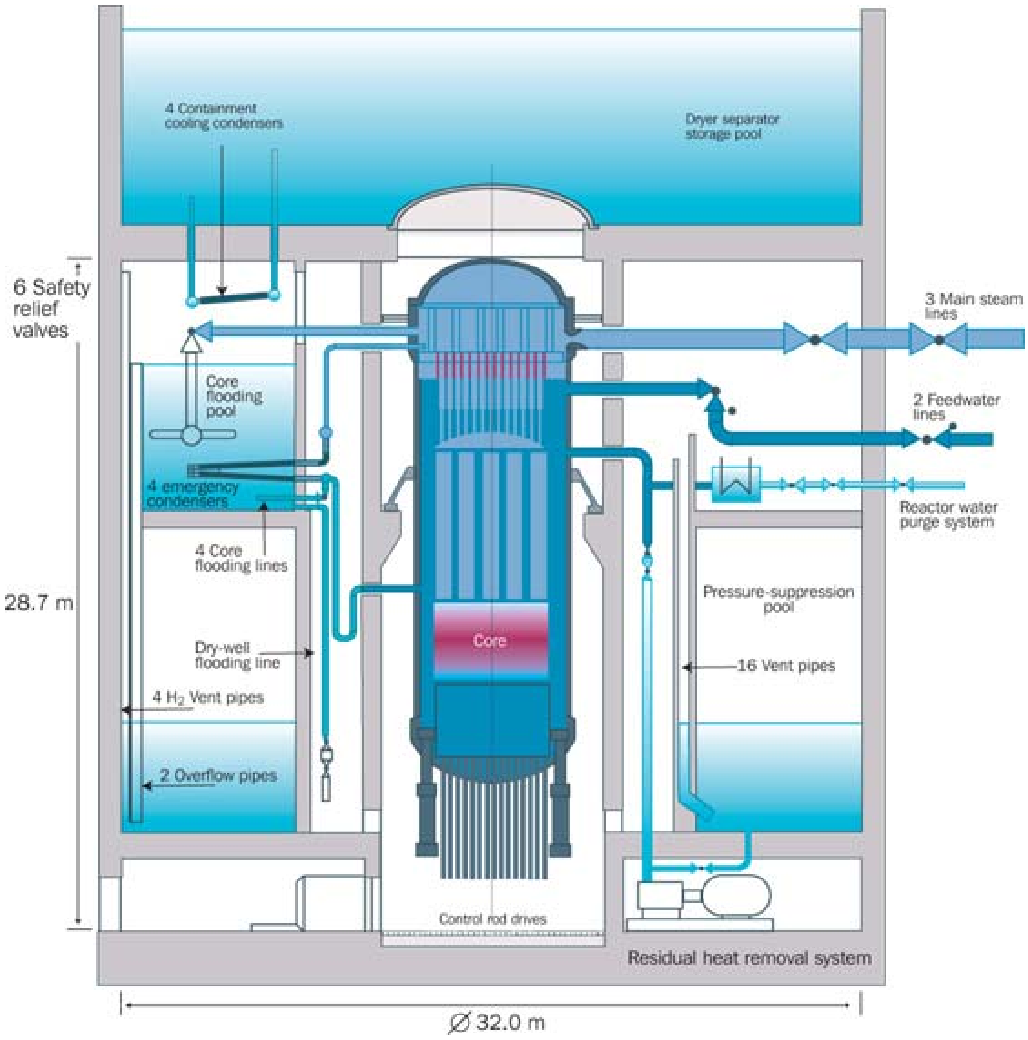


Figure 5.2-2. A Schematic of the Reactor part of the SWR 1000 (*www.areva-np.com*).

Safety design features include: an increased water inventory in the reactor pressure vessel which completely covers the core with water during de-pressurisation, lengthening the time available to provide additional makeup water before fuel overheating, addition of core flooding pools inside the containment provide a large storage capacity for the accommodating system, and a passive heat removal system via the containment cooling condensers. The safety analysis estimates a core damage frequency of <8.4 x 10^{-8}/ reactor year, and a frequency of significant release of radioactivity from the plant of <8.4 x 10^{-9}/ reactor year.

The plant has an efficiency of 37 %. The reactor fuel has a design burn-up of 65 GW·d/tU, producing an extended fuel cycle, giving approx 24.6 TeU/ year as spent fuel requiring storage and replacement.

A construction schedule of less than 48 months is stated.

The SWR-1000 was certified as EUR compliant in Feb 2002. The SWR-1000 is one of three nuclear power plants being considered by Fennovoima for its planned nuclear power plant in Finland.

<u>General Electric-Hitachi</u>

Advanced Boiling Water Reactor (ABWR)

The ABWR is a large, forced circulation, direct-cycle BWR reactor. It is of Generation III reactor design, capable of generating 1300 MW of electricity. The design is based on GE's long history of BWR development. The ABWR is one of the designs produced under the USA's joint EPRI/DOE Advanced Light Water Reactor Development Program, initiated in 1987.

In the direct-cycle BWR system the cooling water is allowed to boil as it passes upward through the reactor core, producing steam. A schematic of the reactor core is shown in Figure 5.2-3. The steam is dried and passed directly to power the turbines. After which the steam is condensed and returned to the core.

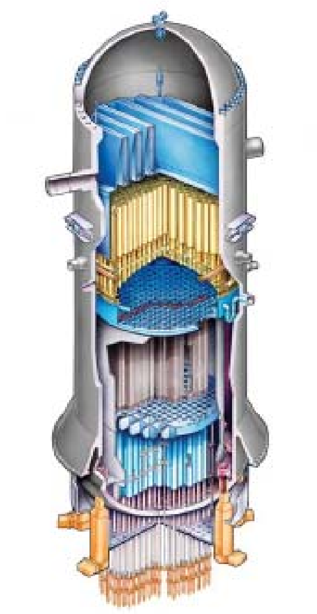


Figure 5.2-3. Schematic of the reactor core of the ABWR (*www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm*).

Enhancements to the design improve safety, reliability and economic performance. These include the replacement of the external recirculation pumps with internal ones, to allow the elimination of large diameter nozzles below the top of the core. This, along with a reduced number of forgings, has greatly reduced the need for both welds and primary circuit piping. This simplifies construction and reduces occupational radiation exposure by reducing the need for in-service inspection. The reactor building encapsulating the core allows for secondary containment. Both the reactor pressure vessel and the reactor building are integrated to improve the overall seismic response. A fully digital instrumental and control system provides enhanced reliability and accuracy. Lower operator doses are achieved through the use of improved fuel materials and coolant chemistry control and a reduction in the use of cobalt bearing alloys. The calculated core damage frequency is <1.6 x 10^{-7}/ reactor year, and the frequency of significant release of radioactivity from the plant <1 x 10^{-6}/ reactor year.

The plant layout is very similar to the EBWR reactors, as shown in Figure 5.2-4. The ABWR has an efficiency of 33 %. The design allows for modular construction, within 39 months. The ABWR is certified as EUR compliant (2000) and is also undergoing Generic Design Assessment in the UK and has been issued NRC Design Certification in the USA (March 2008).

The ABWR design is licensed in three countries, the United States, Japan and Taiwan. The first ABWR to be built was Unit 6 at Kashiwazaki in Japan, and has been operational since 1996. Four further ABWR units are operational in Japan, with more under construction and planned.

The reactor produces 28,7 TeU/ year as spent fuel requiring storage and replacement. Fuel cycles last up to 24 months.

Economic Simplified Boiling Water Reactor (ESBWR)

The ESBWR is a generation III+ plant, manufactured by General Electric-Hitachi Nuclear Energy (GEH) and has evolved from the direct-cycle BWR system. In designing the ESBWR, GE have simplified the design and reduced costs, allowing for faster construction, lower operating costs and enhanced safety. This has been achieved by employing a natural circulation system in the core and passive safety systems. The ESBWR has been designed to produce 1550 MW of electricity.

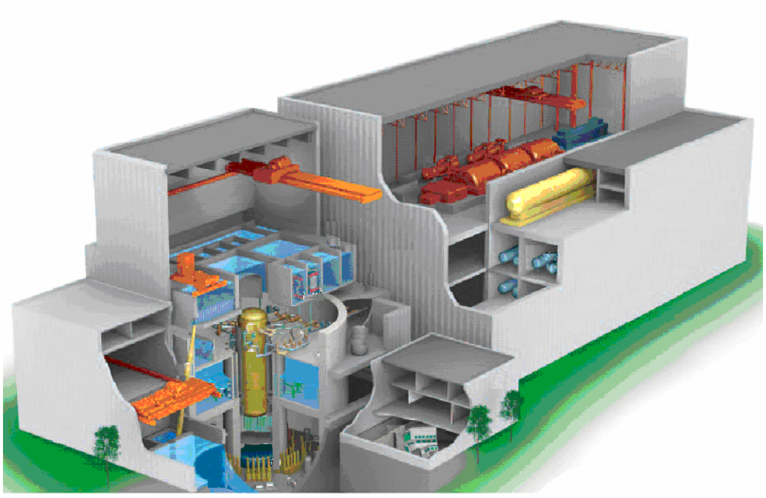


Figure 5.2-4. A schematic of the ESBWR plant design (*ESBWR fact-sheet, 2007*).

The ESBWR incorporates an advanced natural circulation system and passive safety systems, which rely on natural forces such as gravity, evaporation and condensation for plant operations, instead of the large numbers of active pumps and valves used by existing reactors. A total of 11 systems have been removed from previous designs, resulting in a 25 % fewer valves, pumps and motors.

Heat produced in the core is converted directly to steam, circulation of water occurs naturally in the core, as the water is heated it rises and forms steam, which is then diverted to the turbine. This natural circulation eliminates the need to use recirculation pumps, simplifying the design. Although present in all BWR's, natural circulation is enhanced in the ESBWR by extending the chimney region above the core, improving the steam separator, and by providing a clearer flow path between the down-comer and the lower plenum.

The ESBWR reactor core, illustrating the natural circulation system, is presented in Figure 5.2-5.

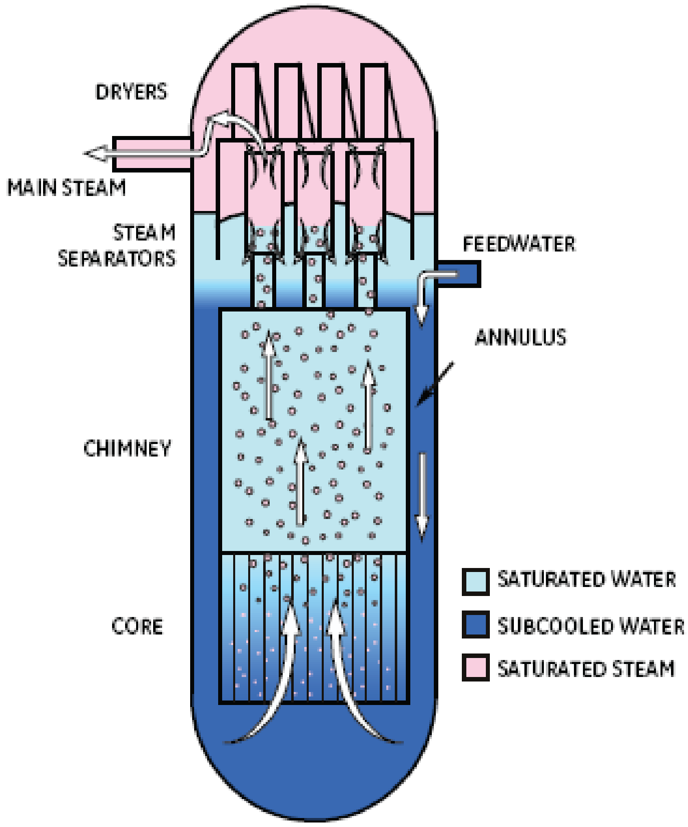


Figure 5.2-5. The ESBWR reactor core, illustrating the natural circulation system (*ESBWR fact-sheet, 2007*).

Passive safety features have been favoured in the ESBWR design. Active components such as pumps, motorized valves, and other powered devices are replaced by systems whose operation is independent of external power. The Emergency Core Cooling System consists of passive safety features, as follows (*General Electric Fact Sheet*):

- An Automatic Depressurisation System (ADS), which employs safety relief valves on the main steam lines that discharge steam to the suppression pool and drywell in the event of a system over pressure.
- A Gravity Driven Cooling System (GDCS), which uses gravity to provide makeup water following a depressurization vent.

Other passive features include:

- The Isolation Condenser System (ICS). The ICS removes decay heat from the reactor following transient events involving reactor scram, including station blackout. The ICS consists of four independent high pressure loops, each containing a heat exchanger that condenses steam on the tube side, this system uses natural circulation to remove decay heat.
- The Passive Containment Cooling System (PCCS). The PCCS removes heat from inside containment following a LOCA. The system consists of four safety-related low-pressure loops. Each loop has a heat exchanger open to the containment, a condensate drain line and a vent discharge line submerged in the suppression pool. The four heat exchangers, similar in design to the isolation condensers, are located in cooling pools external to the containment.

The reactor uses 4.2 % enriched UO_2 (for a 24 month cycle). Plant efficiency is expected to be about 34.7 %. The average fuel burnup at discharge is 50 GW·d/tU resulting in 30.2 TeU /year spent fuel.

Entergy Corp, Dominion and the utility consortium NuStart Energy Development, have each selected the ESBWR for several potential nuclear projects in the United States. The ESBWR is currently undergoing NRC design certification in the USA, design approval is expected at the end of 2008, with formal certification 12 months later. It is favoured for early US construction and could be operational in 2014. Construction time is quoted as approximately 36 months.

The ESBWR is also being considered for construction by utilities in a number of other countries and is undergoing Generic Design Assessment in the UK.

Westinghouse-Toshiba

AP600

The AP600 is an advanced pressurised water reactor, designed to produce 600 MW of electricity, and is considered to be a Generation III design. A two-loop layout is used which reduces the physical footprint of the NPP. The AP600 was designed as part of the Advanced Light Water Reactor (ALWR) Program in the USA in the 1990's.

The AP600 was designed to incorporate a number of passive systems, thereby simplifying the design and reducing the numbers of active components (i.e. pumps, motorised valves, chillers) present in traditional PWR technologies. These have the effect of reducing operational and construction costs. The passive safety features rely on the natural forces of gravity, circulation, convection, evaporation, and condensation, instead of AC power supplies and motor-driven (or active) components. The AP600 led the introduction of "passive" safety technology to water-cooled reactor systems.

Passive safety systems are used for emergency core cooling and containment cooling. Three separate water sources are employed for emergency cooling. Short-term high-pressure coolant is injected from core make-up tanks and accumulators. Two tanks filled with borated water are designed to function at any reactor coolant system pressure using only gravity, and the temperature and height difference from the reactor coolant system leg as the motivating force. Long-term cooling is supplied by an in-containment refuelling water storage tank. Water from this tank flows under gravity into the reactor cavity; heat is removed by convection and boiling. Water vapour rises and condenses on the surface of the steel containment vessel, the condensate then drains back into the refuelling water storage tank under its own gravity. Containment cooling is provided by the continuous, convective air-cooling of the steel containment vessel, which can be supplemented by the evaporation of water draining under gravity from the tank situated on top of the containment building.

Other key features of the design include employment of highly reliable "canned motor" pumps, mounted directly in the channel head of each steam generator. This pump design does not require shaft seals, which simplifies the auxiliary fluid systems, reduces maintenance, and eliminates possible accidents involving seal failures. The integration of the pump suction into the bottom of the steam generator channel head simplifies the steam generator and piping support systems.

The overall design of the power plant is shown in Figure 5.2-6.

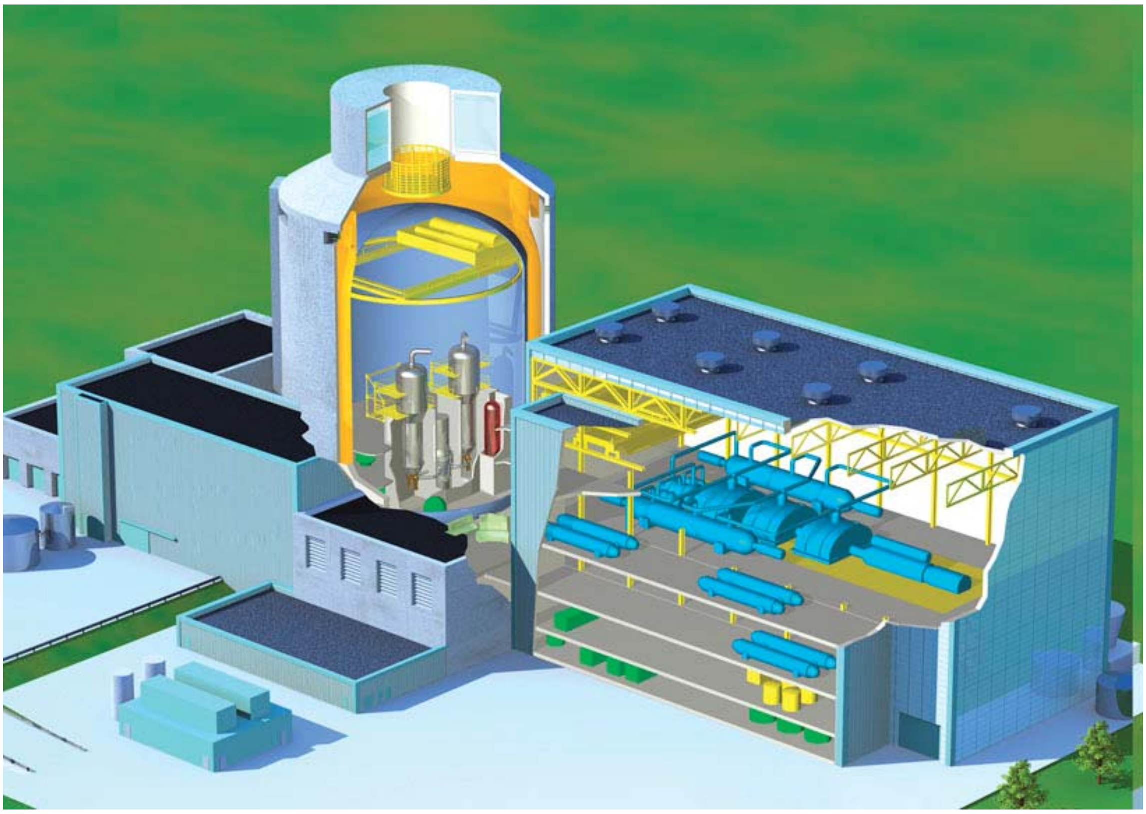


Figure 5.2-6. An illustration of the AP1000/AP600 nuclear power plant design (*AP1000 fact-sheet 2007*).

The calculated core damage frequency is <1.7 x 10^{-7}/ reactor year, and the frequency of significant release of radioactivity from the plant of <1 x 10^{-8}/ reactor year.

Plant efficiency is expected to be about 33 %. Approximately 10 TeU /year of spent fuel is produced.

Final design approval from the U.S. Nuclear Regulatory Commission was received in 1998. The AP600 is also certified as EUR compliant (2000), however no orders have been placed to date.

AP1000

The AP1000 generation III+ design is derived from the AP600 plant design. The primary purpose of developing the AP1000 was to retain the AP600 design objectives, design details and licensing basis, while optimizing the power output, thereby reducing electricity generation costs. The AP1000 is designed to generate 1117 MW of electricity. The footprint of both the AP1000 and AP600 are the same, increased power output was achieved by increasing water flow through pipe size, and increasing the size of the canned motor, pressuriser, steam generator and reactor vessel.

The AP1000 has a reduced number of active components compared to a similarly sized conventional PWR plant. It is constructed in modules, which can be fabricated prior to transportation to the construction site. A construction schedule of 36 months is anticipated.

The reactor operates on 4.95 % enriched UO_2 or with a full loading of MOX fuel. The plant has efficiency of 32.7 %. Operational cycle lengths typically are 18 months, producing 18.6 TeU/ year of spent fuel.

The calculated core damage frequency is <2.4 x 10^{-7}/ reactor year, and the frequency of significant release of radioactivity from the plant of <3.7 x 10^{-8}/ reactor year.

In May 2007 Westinghouse applied for UK generic design assessment (pre-licensing approval) based on the US Nuclear Regulatory Commission (NRC) design certification, and expressing its policy of global standardisation. The application was supported by utilities including E.ON. It has been selected for building in China (4 units) and is under active consideration for building in Europe and USA.

Atomic Energy of Canada Limited

Enhanced CANDU 6

The Enhanced CANDU 6 is a Generation III plant, unique in its design; it is the only reactor to use deuterium oxide (heavy water) as a moderator. It is designed to produce up to 740 MW of electricity. A schematic of the reactor is shown in Figure 5.2-7. Using heavy water allows the reactor to achieve a high neutron economy (the efficiency with which a critical system uses neutrons), essential to the viability of a natural U fuel cycle (avoiding the need to produce and use enriched U).

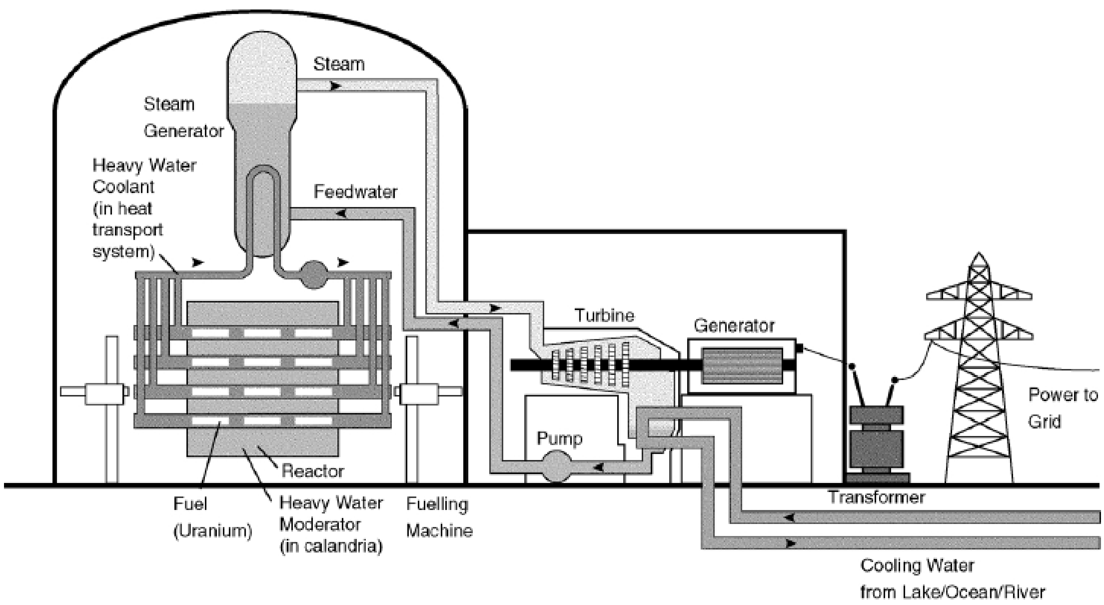


Figure 5.2-7. Schematic of the overall CANDU nuclear plant (*www.aecl.ca/reactors/*).

The high neutron economy also allows the potential for utilising different fuel types. The main fuel type for the CANDU 6 design is natural U, although a variety of different fuels such as MOX and TH/U233 can be used. CANDU reactors can also burn spent PWR fuel.

The reactor is designed to be refuelled at full power, reducing the amount of time the plant is offline. The core is divided into 380 separate pressure tubes, each having a string of natural U fuel bundles immersed in heavy water coolant. These tubes are positioned horizontally, reducing the complexity of the refuelling process. A fuelling machine visits each end of the core, one fuelling, while the other de-fuels. Fuel management provides the flux shaping, essential for increasing efficiency of the core and for long-term fuel management. Short term reactivity control is provided by controllable light-water compartments and absorber rods.

The primary coolant circuit of CANDU reactors is a two-loop design with a figure of eight configuration. This reduces the effect of a loss of coolant accidents, caused for example by a pipe failure.

The Enhanced CANDU 6 incorporates passive safety features, including two independent shutdown systems. The first is the control rods which drop in to the core under gravity. The second is a high-pressured injection of a liquid poison (gadolinium nitrate) into the low-pressure moderator. Emergency core cooling is provided by a passive emergency coolant injection system. Short-term high-pressure coolant is injected from core make-up tanks and accumulators. The long-term cooling system provides long-term recovery and recirculation of the coolant. The cool, low-pressure moderator also serves as a passive heat sink from the fuel channels in the event of severe accident.

Other safety features include a containment system, which provides a pressure-retaining envelope around the reactor core and primary circuit. This prevents the release of radioactive material to the environment. A spray system connected to the elevated reserve water tank will reduce reactor building pressures, if required, in the event of a severe accident. Finally, air coolers, located in various compartment of the reactor building provide heat removal and reduce pressures.

Fuel burn-up is comparatively low, at 7.5 GW d/ TeU, resulting in larger volumes of spent and replacement fuel, typically 100 TeU / year. The overall efficiency of the plant is approximately 35 %.

The calculated core damage frequency is <4.6 x 10^{-6}/ reactor year, and the frequency of significant release of radioactivity from the plant of <1 x 10^{-8}/ reactor year.

Following completion of Cernavoda unit 2 (October 2007), Romania is currently preparing for the completion of unit 3 and 4, commissioning is due in October 2014 and mid 2015 respectively.

Advanced CANDU Reactor (ACR-1000)

The Advanced CANDU Reactor 1000 (ACR-1000), is a development of the CANDU series of pressurised heavy water reactors (PHWR), developed by Atomic Energy of Canada Ltd (AECL). The ACR has been designed to produce 1085 MW of electricity.

The ACR is designed to retain fundamental features of the CANDU design, see while achieving higher efficiency and lower capital costs. The ACR design still retains the use of heavy water as a moderator, however incorporates light water into the design as the coolant. Light water is circulated through the pressure tubes containing the fuel bundles and around the primary circuit. The adoption of the light water coolant reduces the heavy water inventory, and therefore capital costs. Fuel burnup is improved through the use of slightly enriched Uranium fuel by 1 % - 2 %, this extends the fuel life to three times that of existing natural Uranium fuel. The volume of spent fuel is typically 72,1 TeU / year. The overall efficiency of the plant is approximately 37 %.

The ACR is a two-loop design with a figure of eight configuration; the operational principles are similar to those described in Section 5.1 for a standard PWR. The main difference is that the light water coolant passes through pressure tubes instead of a pressure vessel. Heat is removed from the core using the same techniques as the PWR.

Safety systems are similar to those of the Enhanced CANDU-6.

Construction is in modular form, with a time span of 42 months. The footprint of the two-unit plant has been minimised with the adoption of common areas. The size of the power block for a 2 unit ACR-1000 station is 48000 m^2. The reactor is designed to allow on-power fuelling, resulting in longer operating cycles between maintenance outages (3 years).

The calculated core damage frequency is <3.4 x 10^{-7}/ reactor year, the frequency of significant release of radioactivity from the plant is correspondingly lower than this.

The ACR is currently undergoing a pre-licensing review by the Canadian Nuclear Safety Commission and utility. The first ACR1000 is expected to be built in Canada, and could be producing electricity by 2014.

Mitsubishi Heavy Industries

Advanced Pressurised Water Reactor (APWR)

The APWR generation III+ design has been under development by Mitsubishi Heavy Industry (MHI) in collaboration with four Japanese utilities and Westinghouse, since the 1990's. It is a large four-loop PWR design based originally on Westinghouse technology, but incorporating several new design features which combine active and passive safety features. These include four independent safety Trains (both mechanical and electrical), an advanced accumulator system and elimination of low head safety injection system and containment isolation.

The APWR is in the process of being licensed in Japan, with the first two units (1538 MW_e generating capacity) to be constructed, at Japan Atomic Power Company's Tsuruga site (unit 3 and 4). Operation is expected by 2014.

Schematic of the US-APWR design is shown in Figure 5.2-8.

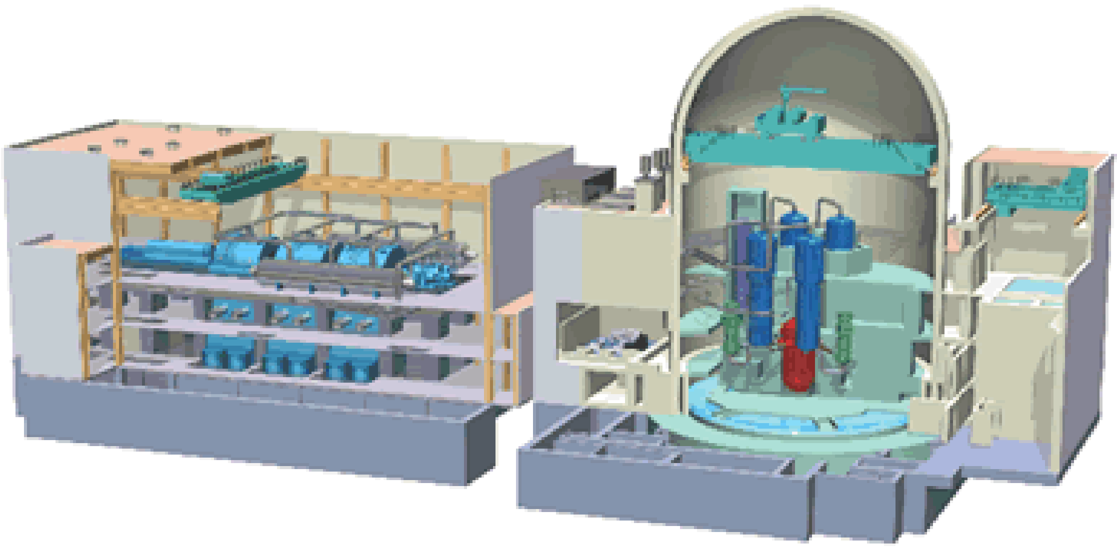


Figure 5.2-8. Schematic of the US-APWR design (*US-APWR fact sheet, 2007*).

MHI have also developed the US-PWR, an enhanced version of the APWR to be marketed in the USA and Europe, and is undergoing NRC Design Certification. This version offers several enhancements, including a thermal efficiency of 39 %, a 20 % reduction in plant building volume, a higher output of 1700 MW and a 24 month fuel cycle. The main components of the reactor system are enlarged in size corresponding to the large thermal output and improved plant efficiency.

The calculated core damage frequency is <1 x 10^{-5}/ reactor year, and the frequency of significant release of radioactivity from the plant of <6 x 10^{-8}/ reactor year.

Maximum fuel burn-up is 62 GW d/ TeU, resulting in 24 TeU / year of spent fuel.

Atomstroyexport

V-392 (or the advanced VVER-1000)

The earliest VVER's were developed by the USSR before 1970. The most common one of these designs, the VVER-440 Model V230, employs six primary coolant loops, each with a horizontal steam generator. The modified version of the VVER-440, Model V213, was a product of the first uniform safety requirements drawn up by the Soviet designers. This model included added emergency core cooling and auxiliary feedwater systems as well as upgraded accident localisation systems. The larger, VVER-1000 design, developed after 1975 is a four-loop system housed in a containment type structure with spray type steam suppression system.

One such VVER-1000 system is the Temelin power station located in the Czech Republic, housing two 1000 MW reactors. Two turbines each power a 1000 MW alternator. The entire turbine set for the Temelin Nuclear Power Station was made by Skoda Pilsen. The reactor is fuelled by 3.5 % enriched UO_2.

The Russian design organisation OKB-Gidropress offers several variants of the VVER pressurised water reactor system. The V-392 has evolved from the VVER-1000, and generates 1000 MW of electricity using fuel of 4.3 % enrichment. Several enhancements in improvements have contributed to enhanced safety and improved economy, including incorporation in to the design an advanced steam generator, a reactor coolant pump with advanced design of seals, a passive heat removal system and a passive system of rapid Boron injection.

A schematic of the VVER-1000 nuclear power plant is shown in Figure 5.2-9.

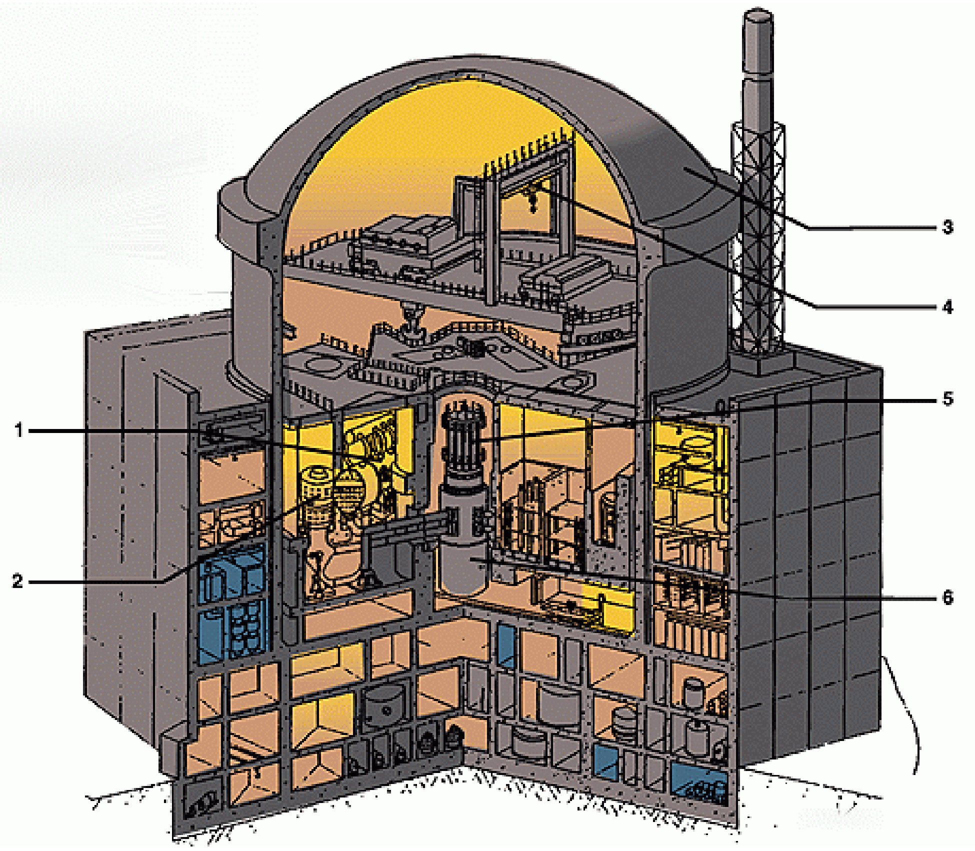


Figure 5.2-9. A schematic of the VVER-1000 nuclear power plant: (1) Horizontal steam generator, (2) reactor coolant pump, (3) containment building, (4) refuelling crane, (5) control rod assemblies and (6) reactor vessel (*International Nuclear Safety Centre Website*).

The V-392 units are planned for Novovoronezh and are being built in India. Construction time is 54 months.

The calculated core damage frequency is <5 x 10^{-6}/ reactor year, and the frequency of significant release of radioactivity from the plant of <1 x 10^{-8}/ reactor year.

Average fuel burn-up is 47 GW d/ TeU, resulting in some 21 TeU / year of spent fuel.

V-448 (or the VVER-1500)

The V-448 is also a 4 loop pressurised water reactor with the capacity to generate 1500 MW of electricity. Enhanced features include a larger reactor vessel, decreased core power density compared with the VVER-1000, a longer fuelled zone and enhanced performance horizontal steam generators.

The design includes two protective shell containments with a ventilation gap between. The inner containment ensures leak tightness of the volume within the reactor unit and its major auxiliary components. The outer containment is capable of withstanding all natural or manmade impacts on the NPP, e.g. aircraft crash, explosion, tornado etc. The volume between the shells contains two independent ventilation systems providing an additional degree of containment, one active and one passive.

A passive emergency shutdown system is employed by gravity insertion of control rods or fast injection of boron into the coolant. A passive heat removal system is also incorporated into the design in the event of an accident without a large loss of primary coolant. Heat is removed through the steam generators, transferring heat to surrounding air through specific heat exchangers located outside of the protective casing. In the event of core melt, it is technically possible to contain the molten core within the reactor vessel, if for some reason the molten core isn't contained it will be collected in a special container under the reactor vessel. The core damage frequency is <5.4 x 10-8/ reactor year, and the frequency of significant release of radioactivity from the plant smaller than this.

The maximum fuel burn-up of 62 GWd/TeU produces approximately 23 TeU/ year of spent fuel. Plant efficiency of the plant is approximately 31 %.

This model is being developed, and two units are planned as replacement plants for Leningrad and Kursk. The first units are expected to be commissioned in 2012-2013.

5.3 FUNDAMENTALS OF NUCLEAR SAFETY

5.3.1 Introduction

Nuclear energy has been produced in Lithuania for the last 25 years at the Ignalina NPP: Unit 1 started commercial operation in 1983 and was finally shutdown 31st December 2004; Unit 2 is expected to cease operation in 2009. During these years, valuable experience has been gained in the operation and regulation of a nuclear power plant; this complements the high-quality knowledge that has been acquired through systematic domestic research and international cooperation in the field of nuclear safety.

The use of nuclear energy is associated with a concern for the possibility of different incidents and accidents and the environmental impacts of potential radioactive releases in such situations. Of particular concern is a repetition of the consequences of an environmental release such as occurred during the Chernobyl accident. Lessons have been learnt from such events, and legislation and procedures are in place to ensure such an event does not occur again. There are no plans to build any more RMBK-1000 reactors, or reactors similar in design (such as the RMBK-1500 currently employed at

Ignalina) with international pressure to close those that remain. For preventing accidents and limiting their consequences, high safety culture and special safety principles and regulations are required in the design and operation of nuclear power plants. The use of nuclear power in Lithuania requires a license and it is regulated by law.

The following laws relate to the application of nuclear energy in Lithuania (*Ministry of Economy, www.ukmin.lt/en/energy/nuclear/relevant/ index.htm*):

- Law on the Nuclear Power Plant, 28 June 2007, No X-1231 (As amended 1 February 2008 No X-1446), Vilnius;
- Law on Nuclear Energy, 14 November 1996, No I-1613 (As amended 2 July 2002, No IX-1021), Vilnius;
- Law on Radiation Protection, 12 January 1999, VIII-1019, Vilnius;
- Law on the Management of Radioactive waste, May 20 1999, No VIII-2506 (As amended 26 October 2004), Vilnius.

These acts implement Lithuania's obligations as a signatory of the following IAEA Conventions:

- Convention on Nuclear Safety;
- Joint Convention on the Safety of Spent Fuel Management and the safety of Radioactive Waste Management;
- Vienna Convention on Civil Liability for Nuclear Damage;
- Convention on Early Notification of a Nuclear Accident;
- Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency;
- Convention on the Physical Protection of Nuclear Material.

Lithuania is also a signatory of the EURATOM Treaty governing the safeguards and use of nuclear material.

Lithuania became a member of the International Atomic Energy Agency (IAEA) in 1993. The IAEA exists to pursue "safe, secure and peaceful uses of nuclear sciences and technology".

Any new nuclear power plant in Lithuania would have to meet IAEA requirements. Licenses are issued by VATESI (for nuclear safety) after coordination with Ministry of Economy, Radiation protection centre and the local municipality.

5.3.2 IAEA Safety Principles

The IAEA's Fundamental Safety Principles for nuclear safety are given in the publication "Fundamental Safety Principles: Safety Fundamentals. IAEA Safety Standards Series, No. SF-1, Vienna: International Atomic Energy Agency, 2006". These principles and other IAEA publications will be used to guide the selection, justification and approval of the nuclear power plant project. The following text is based upon the IAEA publication:

The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation.

This fundamental safety objective of protecting people – individually and collectively – and the environment has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities conducted so as to achieve the highest standards of safety that can reasonably be achieved, measures have to be taken:

- To control the radiation exposure of people and the release of radioactive material to the environment;
- To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
- To mitigate the consequences of such events if they were to occur.

The fundamental safety objective applies for all facilities and activities and for all stages over the lifetime of a facility or radiation source, including planning, siting, design, manufacturing, construction, commissioning and operation, as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste.

Ten safety principles have been formulated, on the basis of which safety requirements are developed and safety measures are to be implemented in order to achieve the fundamental safety objective. The safety principles form a set that is applicable in its entirety.

Principle 1: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

Thus the licensee (power plant operating organisation) is responsible for:

- Establishing and maintaining the necessary competences;
- Providing adequate training and information;
- Establishing procedures and arrangements to maintain safety under all conditions;
- Verifying appropriate design and the adequate quality of facilities and activities and of their associated equipment;
- Ensuring the safe control of all radioactive material that is used, produced, stored or transported;
- Ensuring the safe control of all radioactive waste that is generated.

Principle 2: An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

Section 5.3.3 describes the governmental framework and organisations involved in the regulation and support of nuclear power plant safety in Lithuania. The relevant Laws are identified together with descriptions of the relevant regulatory bodies and other State departments involved in administration of the safety of nuclear power plants in Lithuania.

Principle 3: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

As part of the evolution of the new nuclear power project, the regulatory authorities will examine the organisation, staffing, training and experience of the developer and operating organisation, in particular to ensure that a suitable safety culture is embedded in all levels of the organisation having a direct or indirect responsibility for nuclear safety.

Principle 4: Facilities and activities that give rise to radiation risks must yield an overall benefit.

This is in part addressed by this Environmental Impact Assessment Report, and will also be required to be shown in subsequent licensing and permit applications for the project.

The Law on Nuclear Power Plant (*X-1231, X-1446*) already establishes that the development of the plant is in the national interest of Lithuania.

Principle 5: Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 6: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 7: People and the environment, present and future, must be protected against radiation risks.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 8: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

The most harmful consequences arising from facilities and activities have come from the loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or other source of radiation. Consequently, to ensure that the likelihood of an accident having harmful consequences is extremely low, measures have to be taken:

- To prevent the occurrence of failures or abnormal conditions (including breaches of security) that could lead to such a loss of control;
- To prevent the escalation of any such failures or abnormal conditions that do occur;
- To prevent the loss of, or the loss of control over, a radioactive source or other source of radiation.

The primary means of preventing and mitigating the consequences of accidents is "defence in depth". Defence in depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment. If one level of protection or barrier were to fail, the subsequent level or barrier would be available. When properly implemented, defence in depth ensures that no single technical, human or organizational failure could lead to harmful effects, and that the combinations of failures that could give rise to significant harmful effects are of very low probability. The independent effectiveness of the different levels of defence is a necessary element of defence in depth.

At the highest level Defence in depth is provided by an appropriate combination of:

- An effective management system with a strong management commitment to safety and a strong safety culture.
- Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy, mainly by the use of:
    - Design, technology and materials of high quality and reliability;
    - Control, limiting and protection systems and surveillance features;
    - An appropriate combination of inherent and engineered safety features.
- Comprehensive operational procedures and practices as well as accident management procedures.

Accident management procedures must be developed in advance to provide the means for regaining control over a nuclear reactor core, nuclear chain reaction or other source of radiation in the event of a loss of control and for mitigating any harmful consequences.

Principle 9: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.

The primary goals of preparedness and response for a nuclear or radiation emergency are:

- To ensure that arrangements are in place for an effective response at the scene and, as appropriate, at the local, regional, national and international levels, to a nuclear or radiation emergency;
- To ensure that, for reasonably foreseeable incidents, radiation risks would be minor;
- For any incidents that do occur, to take practical measures to mitigate any consequences for human life and health and the environment.

Principle 10: Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

Defence in Depth

It is clear above that nuclear safety is ensured through the application of the “defence in depth” approach. This concept concerns the protection of both the public and workers and is fundamental to the safety of nuclear installations. Its premise is that all safety activities, whether organizational, behavioural or equipment related, are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected without causing harm to individuals or the public at large. This idea of multiple levels of protection is the central feature of defence in depth (*International Nuclear Safety Advisory group, 1996*).

Defense in depth is implemented through the design and operation to provide a graded protection against a wide variety of transients, incidents and accidents, including equipment failures and human errors within the plant and events initiated outside the plant.

The historical development has led to a general structure of five successive levels of defence, shown in Table 5.3-1.

Table 5.3-1. Levels of defence in depth (*International Nuclear Safety Advisory group, 1996*).

Levels of defence in depth	Objective	Essential meaning
Level 1	Prevention of abnormal operation and failures.	Inherent safety principles, conservative design and high quality in construction and operation.
Level 2	Control of abnormal operations and detection of failures.	Control, limiting and protection systems and other surveillance.
Level 3	Control of accidents within the design basis.	Engineered safety features and accident procedures.
Level 4	Control of severe plant conditions, including prevention and mitigation of the consequence of severe accidents.	Complementary measures and accident management.
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials.	Off-site emergency response.

High quality, competent staff and responsible operation

In the design, construction and operation of a nuclear power plant, safety is ensured by high-quality operation and safety culture. Safety culture refers to the personal dedication and accountability of all individuals engaged in any activities which have a bearing on the safety of a nuclear power plant. High-quality construction and operation guarantee an undisturbed operation of a power plant. In addition to consistent electricity production, high safety-levels are also reached. The high-level of safety is ensured by the continuous quality control of the work, internal inspections, requirements guiding the operation, and inspections by the authorities.

Approval by the regulatory authorities is required for positions of responsibility within the nuclear power plant; such positions include the manager of the nuclear power plant, and any deputies, the person in charge of nuclear materials and emergency preparedness arrangements, and the operators of the nuclear power units. Training of new staff will also begin as early as in the construction stage as possible. During operation, all the staff, especially operators, will be trained on a regular basis. This training will involve the use of simulators where different scenarios can be practised and exercised. The operators must demonstrate their competence in regular exams.

Structures, systems and equipment of the nuclear power plant are classified according to their safety significance, and via derived technical specifications provide operational restrictions and functional requirements to satisfy the design intent of the plant. The classification is also used for focusing inspection, quality assurance and independent control by authorities on areas important in terms of continued safety.

Provision for incidents and accidents

A nuclear power plant must be designed in accordance with nuclear energy legislation and regulatory guides on nuclear safety in order to ensure the safety of its operation. According to the VATESI normative documents (*VD-B-001-0-97 and VD-T-001-0-97)*, fundamental safety functions are as follows:

- Management of reactivity;
- Fuel cooling;
- Localization of radioactive waste, control of operational releases and limitation of accident releases.

Fulfilment of these requirements ensures that the risk of a large-scale nuclear accident is very, very small. Safety functions are implemented both with parallel safety systems (redundancy) and with different operational principles (diversity). Parallel safety systems are segregated from each other so that, e.g. fire or other events cannot harm all parallel systems (common cause failure). Redundancy also provides protection against single failures of components in one of the parallel systems (trains). Diversity of systems providing a safety function provides protection against common mode failures, e.g. the use of both electrical and steam driven emergency feedwater pumps.

In the event of the failure of a safety system, defence in depth reduces the risk that a single failure of a critical system can lead to an accident. It denotes the practice of having multiple, redundant, independent safety systems. An example of this is two independent safety systems (the insertion of control rods and the addition of Boron (or another neutron poison) into the core) to inhibit fission in the core during the event of loss of control of the nuclear chain reaction. Diversity in the reactivity shutdown systems ensures that a specific safety requirement can still reliably be fulfilled i.e. if one system fails another system is in place to provide the same safety function (in this example shutdown of the reactor). Each safety system is adequate to control the reaction independently are each designed for high reliability of operation employing the principles of redundancy and segregation.

In normal operation fuel cooling is maintained by the continued flow of coolant through the core. This may be by either natural circulation (as in the case of the ESBWR) or a series of pumps. In the event of pump failure, there exists enough redundancy in the system to maintain the flow of coolant. In the event of a loss of coolant accident (for example a sudden large failure of a primary coolant pipe), the Emergency Core Cooling (ECC) system is activated. This comprises multiple systems, which flood the core with coolant. Taking a PWR as an example the first system provides short-term coolant make-up to the reactor core through a high-pressure injection of water from accumulator and makeup tanks. The second system provides a long-term cooling system once the first system is finished; this second system may also have a normal operational purpose, to cool the reactor during maintenance. A second example considers events where there is a loss of main feedwater from the condenser to the steam generator. In this case an Emergency Feed Water (EFW) system is provided to remove the excess decay heat, drawing feedwater either from the condenser or reserve water feed tanks in case the condenser train is not available. This enables the reactor to be cooled down via the primary circuit and steam generator, with heat (steam) rejected to atmosphere or water source as available.

Prevention of radioactive releases

The safety of a nuclear power plant shall be guaranteed by applying the principle of "defence in depth", i.e. by the sequential implementation of protective measures based on a system of barriers to prevent the spread of ionising radiation and radioactive materials to the environment and a system of technical and organizational measures to protect these barriers and retain their effectiveness, and to provide direct protection for the population.

The uncontrolled release of radioactive material into the environment is physically prevented using a succession of isolating barriers. Each physical barrier has been designed to withstand the threats posed to them in potential accidents or incidents, and if the previous/inner barrier has broke down. The system of barriers includes:

- the ceramic fuel pellets;
- the fuel element cladding;

- the tight steel reactor system;
- the tight inner containment;
- the strong outer containment.

In a severe accident the most important barrier preventing the spread of radioactive waste into the environment is the double containment. This consists of the actual pressure proof, gastight inner containment made from either special steel, concrete or a combination of both. The outer containment is usually made of reinforced concrete. The outer containment surrounds the inner containment so that any gas leaking from the inner containment can be collected and filtered to minimise gaseous releases. The outer containment also acts as a radiation shield, ensuring radiation levels remain low outside, even if containment has been breached inside of the outer containment. The most important function of the outer containment is to protect the reactor from external hazards. It is expected that all new nuclear power plants will demonstrate a full capability to withstand the effect of airplane crash and other terrorist threats to the integrity of the reactor plant structures. New nuclear power plants are also designed for a high degree of tolerance to natural external hazards, including meteorological and seismic hazards. These are not expected to represent a significant threat to the new power plant, by virtue of design and careful siting.

Containment within new power plants is designed to withstand worst case scenarios; these severe accidents include core melt events, where the molten reactor core and majority of gaseous radioactive material remains contained inside the containment, so that health risks to the workforce and surrounding population are small.

Development of Reactor Safety Systems

Nuclear power plants have been developed over some 50+ years and are continuously being developed in many ways to improve their safety and operational reliability. These safety features have been developed during the evolution of reactor design.

This first and second generation of reactors (Generation I and II) utilised many “active” safety systems in their design to protect against plant malfunctions and failures of systems. These systems required electricity or hydraulic power for their operation and introduced significant complexity into the later power plant designs of the 1970’s (i.e. those operating commercially today).

Generation III rectors developed during the later 1980s and 1990s offer increased improvements in safety through the reduction of complexity by simplification of systems and incorporation of passive safety systems. Passive safety systems rely on the laws of nature, i.e. gravity, convection and evaporation, and do not require the input of either an operator or electronic system to be put in place like active systems. Passive systems are employed in many of the Generation III and above designs, and originate from the Westinghouse AP600 design developed in 1985. Westinghouse sought to dramatically simplify the safety systems operating in traditional PWR by the replacement of active components (valves, motors etc) with passive systems. The next generation of reactor, the Generation III+, are those which have recently been designed to incorporate advanced passive safety systems. These include the ACR, AP1000, ESBWR

Generation IV reactors are currently being developed and are expected to come into commercial use in the next 20-30 years. The operational principles of these reactors are significantly different to the reactors in operation today and if materials performance issues can be resolved offer the potential for even safer reactors in the future. Such reactors still require significant development before a demonstration prototype can be considered.

Assessment of safety

While developing the design of a nuclear power plant the behaviour of the plant is studied experimentally and theoretically. Computer models are used extensively to simulate effects of plant deviations and accidents; this approach has been proven reliable. Different calculation methods are used for analysing the normal operation and a variety of various potential accidents within the power plant. Methods include: incident and accident analyses, strength analyses (to confirm plant integrity and margins usually via an approved design code, failure mode and impact analysis and probabilistic risk assessment. Assumptions and assessments made in the calculation models are verified such that when calculating uncertain factors, the worst choice in respect of the plant is always chosen, as even the worst cases must be managed safely. The results are used to determine the safety functions needed in accidents, and their safety margins are designed such that they function with high reliability.

After the completion of the nuclear power plant, the analyses are maintained, taking into account operational experience, experimental research results and the development of calculation methods. The documents are kept up to date and submitted to the Nuclear Safety Authority.

Safety of the operating nuclear power station is monitored regularly. Safety assessment is carried out either as a part of the renewal of the fixed-term operating licence of the power plant or at the latest ten years after the last assessment. As part of the periodic safety assessment, the licensee will assess the safety status of the power plant units, potential objects of development and the preservation of safety. This will include a summary of the revised safety analysis and conclusions from their results. Attention will be paid to requirements set in guidelines, control of ageing of the power plant units, obsolescence, implemented and potential plant improvements and safety culture and management.

5.3.3 Nuclear safety administration in Lithuania

Nuclear energy in Lithuania is regulated and administered by several ministries including: State Nuclear Power Safety Inspectorate (VATESI), the Ministry of Health (via the Radiation Protection Centre), the Ministry of the Economy, the Ministry of Environmental and the Ministry of Internal Affairs.

VATESI (established 1991) is responsible for State regulation of the nuclear safety and supervision of radiation safety in nuclear power facilities, State regulation of the physical protection of the use of nuclear material and of nuclear power facilities, nuclear and radioactive materials being utilized in nuclear energy in the Republic of Lithuania.

In cases when ensuring nuclear safety involves other safety aspects significant for nuclear safety, e.g. fire protection, environmental protection, physical protection, emergency preparedness planning etc., responsibilities of regulation institutions are established by laws and other legal acts. VATESI and the other Lithuanian state regulation authorities cooperate to ensure that their respective responsibilities are clearly defined and coverage is complete to ensure that no relevant aspects are overlooked.

VATESI is vested with executive authority by the Republic of Lithuania, and the Head of VATESI is appointed by the Prime Minister. VATESI reports to the Lithuanian Government and has direct recourse to the highest levels of Government, if required, to address safety issues.

In performing its functions VATESI is a wholly autonomous body, independent of the power plant developer, designer or operating organisation. VATESI serves to protect both the workforce and general public from harm caused by the operation of the nuclear power plant in accordance with laws, its own regulations and other legal acts.

VATESI has offices in Vilnius and at the Ignalina NPP to ensure continuous monitoring of nuclear activities. A technical support organisation, the Independent Safety Analysis Group (ISAG) was also set up by the government at the Lithuanian Energy Institute (LEI) in Kaunas to give technical assistance to both VATESI and the existing plant.

The main functions of VATESI are:

- Drafting and, with the authority of the government, approving safety standards and rules for the design, construction and operation of nuclear facilities, for storage of nuclear radioactive materials and for waste disposal;
- Ensuring adherence to the requirements set forth in licenses and safety rules and standards;
- Establishing the system of accounting for and regulation of nuclear materials;
- Issuing licenses for the design, construction, operation and decommissioning of nuclear facilities and of their systems as well as evaluating the safety of nuclear facilities;
- Annual report to the Lithuanian Government on the safety of nuclear installations;
- In the event of a nuclear or radiological accident, provide specialist interpretive advice to Lithuanian and other authorities;
- Public and media information on nuclear safety and radiation protection.

Regarding the safe operation of nuclear plant, the role of VATESI includes inspection, surveillance, review, oversight, and in the case of some activities, the issuance of permits. VATESI has the right of access to all required documents and information.

On the basis that current (Ignalina NPP) regulatory practices are continued VATESI will maintain a group of inspectors at the plant site. Inspectors of the supervisory group visit the plant every day to perform their assigned functions and have access to operational documentation in both the main control room and other locations where work is carried out. VATESI can order the shutdown of a nuclear facility if it determines that regulations or standards of safety are being neglected.

The power plant operator is expected to submit the following reports to VATESI:

- annual report on nuclear power plant safety;
- reports on abnormal events in plant operation;
- reports on faults and defects in equipment of safety related systems (twice a year);
- monthly and annual reports on environmental impact (releases and discharges);
- annual and quarterly reports on radiation exposure of plant personnel, reports on cases of exceeding maximum permissible radiation levels and occupational diseases, etc.

VATESI requirements for Nuclear Power Plant safety are defined in the following documents:

- General Regulations for Nuclear Power Plant Safety, VD-B-001-0-97;
- Nuclear Safety Regulations for Reactor Facility of NPP, VD-T-001-0-97.

As part of work to examine the continued safety of operation of Ignalina NPP, these documents were confirmed against accepted Western practice as exemplified in the Basic Principles for NPPs:

- IAEA Safety Series No. 75 INSAG 3;

- Code on the Safety of Nuclear Power Plants: Design, IAEA Safety Series No. 50-C-D;
- Code on the Safety of Nuclear Power Plants: Operation, IAEA Safety Series No. 50-C-O;
- several of the relevant Safety Guides when more details were required.

IAEA documents are subject to periodic review and update. The relevant documents for the new nuclear power plant will be defined under a later stage of the project. Details of IAEA standards and guides can be accessed at www.iaea.org.

Any application to operate a new nuclear power plant will have to demonstrate compliance with Lithuanian and IAEA requirements.

Current legislation in the nuclear field is based on the *Law on Nuclear Energy*. The law defines the principal objectives of state regulation of nuclear energy safety. The functions of control of safety of nuclear facilities are performed by the State Nuclear Safety Inspectorate of the Republic of Lithuania (VATESI).

The *Law on Environmental Protection* in conjunction with the *Law on Environmental Impact Assessmen*t stipulates that installation of any nuclear facility must be accompanied by an environmental impact assessment.

The Ministry of Environment in accordance with the Lithuanian *Law on Environmental Protection*, approves requirements on radiation protection of environment and issues permits for radioactive discharges into the environment. The implementation of these requirements is controlled by Environmental Protection Agency under the Ministry of Environment. The Environmental Protection Agency provides environmental radiological control and monitoring within the vicinity of the nuclear facility.

The power plant operator is expected to submit the following reports to the Ministry of Environment:

- monthly and annual reports on environmental impact (releases and discharges);
- monthly and annual reports on radioactive waste and harmful chemical materials present on site;
- reports on cases of exceeding maximum permissible environmental releases, etc.

The *Law on Radiation Protection* establishes the legal basis for protection of people and the environment from the harmful effects of ionising radiation. The law also establishes a licensing system for the use of radioactive materials and radiation-emitting devices, and prescribes general rules for their use.

According to the *Law on Radiation Protection*, the Radiation Protection Centre (RPC) under the Ministry for Health Care, is the regulatory body which coordinates activities of other public institutions and local government in the field of radiation protection, monitoring and expert examination of public exposure. Among other responsibilities the RPC is responsible for the radiation protection of workers and the general public from negative impacts arising from nuclear facilities in operation and decommissioning.

The main documents regulating radiation protection requirements at nuclear facilities are:

- Lithuanian Hygiene Standard HN 73:2001 "Basic Standards of Radiation Protection";
- Lithuanian Hygiene Standard HN 87:2002 "Radiation Protection in Nuclear Facilities";

- Lithuanian Hygiene Standard HN 99:2000 “Protective Actions of Public in Case of Radiological or Nuclear Accident”.

The power plant operator is required to submit to the Ministry of Health Care annual and quarterly reports on personnel exposure, reports on cases for which the maximum permissible levels of radiation exposure were exceeded and occupational diseases.

The Ministry of Social Security and Labour is responsible for the supervision of potentially dangerous equipment (cranes, pipelines, vessels) through the Services of Technical Verification, except for that subject to inspection by VATESI, according to the *Law on the supervision of potentially dangerous technical installations*.

The Ministry of Social Security also checks adherence to labour protection requirements set in laws regulating labour relations and other regulations. The power plant operator is expected to report to the State Labour Inspection all cases of industrial accidents and send annual reports on industrial safety.

The Ministry of Interior manages fire protection of the nuclear power plant and other nuclear facilities. This includes promptly extinguishing fires, examination of construction/reconstruction designs, coordination of fire protection systems, enforcing fire protection requirements, and participating in the management of a nuclear accident and its consequences.

The Ministry of Interior through the Fire-Prevention and Rescue Department, draws up a population radiation protection plan in the event of a nuclear accident and implements the measures for the elimination of the accident and its consequences. The Fire-Prevention and Rescue Department consists of three fire brigades located outside the plant. A similar arrangement is expected to be established for the new nuclear power plant. In the event of a fire at the plant, the plant shift supervisor is in charge of operation until the officer of the First Brigade arrives at the plant.

In addition, other responsibilities include the secure transportation of nuclear and radioactive material cargoes across the territory of the country in conjunction with the Ministry of Transport and Communication.

The Ministry of National Defence, in co-operation with the power plant operator and other local and national authorities, would develop plans for anti-terrorist and anti-penetration protection plans of the nuclear power plant and other nuclear facilities.

According to the National *Law on Civil Defence*, the Department of Civil Defence performs the following activities:

- organises accident mitigation activities for nuclear power plants;
- co-ordinates activities of all institutions involved in accident mitigation at nuclear power plants;
- periodically reports to the President, Parliament and Government on the progress in accident mitigation;
- implements Governmental decisions and instructions related to the accident;
- organises public evacuation from the affected area;
- informs interested organisations, mass media, general public on accident mitigation measures and the risk of ionising radiation, etc.

5.3.4 Implementation of the safety requirements for a new NPP

As discussed above the designs of all Generation III+ design and some Generation II and III designs incorporate high safety goals. It is a requirement of the new nuclear power plant that the possibility of an accident leading to reactor core damage is less than once in 100 000 years and large environmental radioactive releases occur less often than once every 1 000 000 years. All candidate reactor plants being considered meet these requirements by a significant margin. As well as the being designed to withstand severe accidents caused by core melting, the plant must also be designed to withstand external threats and terrorism. Such effects include withstand of a collision with a large passenger airplane, and external threats caused by natural phenomena such as earthquakes or high winds.

The decision regarding the new reactor plant type will be made after this Environmental Impact Assessment Report on the basis of a number of factors including plant safety, plant efficiency and fuel efficiency/economics. The present physical security and protection measures and existing emergency preparedness at the Ignalina can be used to support a new nuclear power plant build.

Reports to be made in further developing the project

The Environmental Impact Assessment (EIA) procedure of the proposed new power plant will be followed by a Government Resolution application in accordance with Lithuanian Law and due process. When applying for Resolution neither the plant supplier nor the project safety standards and criteria *in detail* will have been chosen, hence the decision will focus on the safety goals described in the guidelines of VATESI and IAEA. If the Resolution is favourable and Parliament ratifies it, negotiations will commence with the plant suppliers.

Once the selection of a plant has been achieved, work can then start on the preliminary safety analysis report which on completion will be submitted to VATESI in order to obtain a construction licence. This safety report will include detailed plant type-specific safety assessments to demonstrate the integral safety of the design, relevant limits and conditions for safe operation and maintenance, and suitable management arrangements of the operating company and site staff. In addition to the computational analysis describing accidents, probabilistic risk assessments will also be included covering the likelihood of different events e.g. the frequency of core damage and off-site radioactive releases.

Once the construction license has been obtained a final safety analysis report will be required in order to obtain an operating license. A condition for granting the operational license is that during construction, the safety analyses are updated to reflect any changes arising due to design changes. Such change proposals will be subject to power plant developer approval and where appropriate submitted to the appropriate authority before the change can be accepted. Commissioning tests will prove the performance of plant and systems in a progressive manner, prior to permission to begin commercial operations. Plans for the physical protection and emergency response arrangements, and a quality management program for operation must be compiled and in place before nuclear operation.

5.4 PROCUREMENT OF FUEL

5.4.1 Availability of nuclear fuel

Typically a new power plant consumes annually as fuel circa 30 tons of enriched uranium, which requires 200 tons of natural uranium. The exact amount of fuel assemblies and uranium inside the nuclear reactor is dependent on the reactor type and its size. Nuclear power plants usually have their own fuel storages which normally contain fuel for one year consumption.

Nuclear fuel manufacturing can be divided into four different phases which are: mining, milling and concentrating the uranium reaching the form of U_3O_8 (or yellowcake), typically sold in international markets; its conversion to gaseous form in uranium hexafluoride (UF_6), the enrichment increasing the percentage of isotope U-235 and at the end the production of the fuel assemblies utilising uranium dioxide UO_2 derived from the enrichment process. The production chain of nuclear fuel is described more in detail in the next sections of this chapter.

It is possible to either buy fuel assemblies which are ready to use in the reactor or buy mined natural uranium. In addition, it is possible to procure separate phases of the fuel production or combinations of them from different suppliers. The continuous availability of uranium is secured with long-term supply contracts. The fuel assemblies which are ready for operation can be delivered to the nuclear power plants either by train or by truck. The deliveries for the Ignalina Nuclear Power Plant were made by train, supplying the reactor with fuel assemblies coming from Russia.

There is a uranium international market where it is possible to buy this commodity. The global total demand for natural uranium in 2006 was around 62 000 tons supplying a total nuclear production capacity of more than 370 GW_e. According to the 2007 World Nuclear Association's (WNA) basic scenario, nuclear production capacity will increase in the next years to around 520 GW_e in 2030 *(Kwasny, 2007; WNA, 2007)*.

At the moment, natural uranium (uranium produced from mining) covers two thirds of the total nuclear fuel demand. The rest of the uranium for the nuclear fuel comes from military sources, uranium storages and from the re-enrichment of the depleted uranium. Moreover, in some countries part of the spent nuclear fuel is reprocessed and utilised again. This process is not allowed in different countries including Lithuania.

In 2007, the production volume of natural uranium was just above 40 000 tons (Figure 5.4-1). In the same year, the biggest manufacturing countries for natural uranium were Canada (25 %), Australia (19 %) and Kazakhstan (13 %). Other important countries in the uranium business are Russia, some African countries, Uzbekistan and USA. In 2007, the 12 biggest manufacturing countries produced 98 % of the natural uranium produced worldwide*)*.

The biggest companies specialised in natural uranium production are Cameco (Canada) Rio Tinto (Australia) and AREVA (France), which together produced more than 50 % of the world's natural uranium in 2007. The world's biggest site for uranium extraction, named Key Lake/Mc Arthur River and controlled by Cameco, is located in Canada, ,and in 2007 produced 7200 tons of natural uranium (17 %) of the total production worldwide.

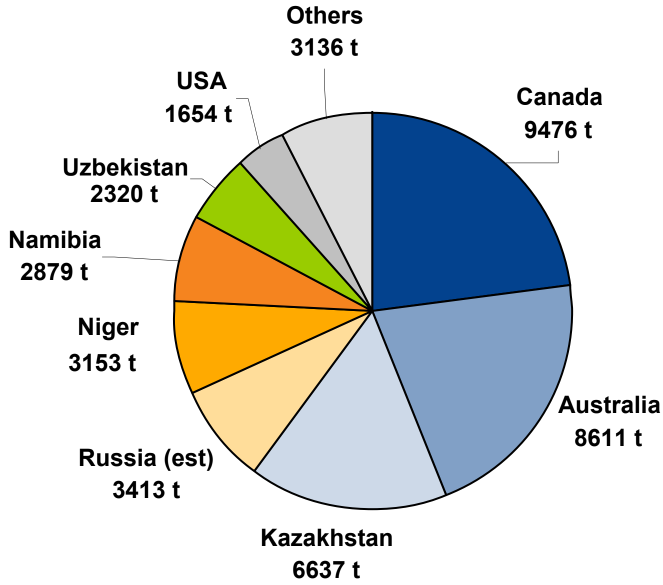


Figure 5.4-1. Uranium production from mines per country in 2007; in total 41 279 tU (*WNA, 2008*).

At the moment, the technically and economically feasible uranium resources available amount to 4.7 million tons. In addition, it is estimated that some 10 million tons of uranium resources can be utilised with existing technologies. It has been forecasted that these resources are consistent enough to cover the international demand also in the next decades, despite the increase in generation capacity from nuclear installations *(OECD and IAEA, 2006).*

During the last years, the price of uranium has increased remarkably. This has led to several new uranium explorations around the world, new mines have already been started while continuing operations in some old mines now dismissed are under consideration.

Nowadays, there are 8 uranium conversion installations around the world, with conversion plants located in France, Great Britain, Russia, USA, Canada, China and Argentina *(IAEA databases, 2008)*, with different sizes and technical characteristics, tailor made for the reactor types used in the country and the international market need.

There are more countries involved worldwide in uranium enrichment, including also Germany, Japan, the Netherlands and Pakistan *(IAEA databases, 2008)*. The different enrichment levels of the different installations also depend on the reactor characteristics and on the market needs.

The manufacturing of the fuel assemblies is finalised in several countries in addition to those previously mentioned, including also Belgium, Brazil, Germany, India, Japan, Kazakhstan, Pakistan, Romania, South Korea, Spain and Sweden (*IAEA databases, 2008*). It is a process strongly dependent on the plant type. At the moment, there is over capacity in fuel assembly manufacturing which means that in the near future there will not be any shortage in the production processes.

5.4.2 Mining and purification of uranium

In 2006, 41 % of total production of natural uranium was obtained from underground mines, 24 % from opencast mines and 26 % using underground leaching; 9 % of the total production of uranium was obtained as by-products of other mining products such as copper and gold *(WNA, 2007).*

In traditional mines, the ore is extracted from the bedrock, crushed and ground. The rock material is then usually treated with sulphuric acid at a separate mill in order to separate uranium from it (milling process). In general 75 – 90 % of the total volume of uranium content in the ore can be utilized. After this the uranium is enriched with several solvents and precipitated with ammonia. The result is U_3O_8 (triuranium oxide) which is called uranium concentrate (yellowcake).

In the in-situ leaching method (ISL) holes, through which acid or alkaline solution is circulated, are drilled in the ground. Uranium mineral dissolves into circulated solution from which the uranium is extracted at the ground level mill. The solution is processed, depending on the acidity of the groundwater, either with the method of solution extraction or ion exchangers. The uranium concentrate (U_3O_8) produced in the precipitation phase is dried in at high temperature. There are ISL mines in for instance Kazakhstan, the USA and Australia. *(WNA, 2008b)*

Environmental impacts of the uranium mine activity are related to radiation impacts of the uranium ore, radiation impacts of radon gas released from the ore, waste from mining and waste water.

Nowadays in countries where uranium mining is practised (such as Canada and Australia) the processes related to upgrading of mines and uranium are governed by regulations and guidelines of National Administration and both Environmental and Nuclear Safety Authorities, which are strictly supervising the mining operations. The state of the environment is monitored for several years after shutting down the activity and even after the restoring activities in the mining area. Environmental, health and safety issues related to mining activities are increasingly controlled by international standards and external audits.

5.4.3 Conversion and enrichment

Before enrichment, the uranium is converted in gaseous form through chemical processes to uranium hexafluoride (UF_6). In this process called conversion different chemicals and heat energy are used.

In natural uranium the share of the isotope U-235, needed in fission reactors for its ability to cause a rapidly expanding fission chain reaction, is only 0.7 %. The remaining 99.3 % is mostly U-238. In common Light Water Reactors the share of U-235 of the uranium is approximately 3.5 %. The enrichment of uranium hexafluoride is executed either by gas diffusion or nowadays increasingly by centrifuge methods by utilizing chemical and physical characteristic of the uranium. Energy consumption of the centrifuge methods is substantially lower than of gas diffusion.

Only 15 % of the original amount of uranium is transformed into enriched uranium at the end of the enrichment process, while 85 % is so called residual uranium. The residual uranium can be used to some extent in certain types of reactors and the uranium originating from the military use can be used diluted in civil reactors.

The conversion and enrichment processes are classified under chemical industry where hazardous chemicals are used, treated and stored. These operations are governed by several international and national regulations regarding the management of hazardous chemicals and waste.

5.4.4 Production of nuclear fuel

The production stages of nuclear fuel consist of the conversion of enriched uranium hexafluoride to uranium oxide, the production of pellets and the production of fuel rods.

The uranium oxide is converted to ceramic and pressed into pellets 1.5 and 2 centimetres in diameter. The fuel pellets are placed into tubes made of a zirconium compound or stainless steel around 4 meters long. Several fuel rods are afterwards composed in fuel assemblies approximately 30 centimetres in diameter.

The radiation impacts of the production stages in a fuel plant are not significant. However several hazardous chemicals are handled in the fuel plant. The handling processes are executed according to laws and regulations for the handling and storage of hazardous chemicals.

5.4.5 Reprocessing of spent nuclear fuel

The so called PUREX process (Plutonium URanium EXtraction) is at present the most developed and widely used process in re-processing plants. The fuel is dissolved into nitric acid and uranium and plutonium are separated chemically using solvents during the chemical process. The gained plutonium can be used as such in the production of MOX fuel (Mixed Oxide), whereas the recycling of uranium into fuel requires a re-enrichment process. The recovery of uranium's energy through reprocessing of spent nuclear fuel amounts to 30 %. Correspondingly, relevant amounts of untreated natural uranium are saved and, in addition, the overall amounts of strongly radioactive waste decrease.

The reprocessing option is still under discussion in the international community because of doubts of its economic feasibility and its strict interconnection with the production and disposal of nuclear weapons. In any case, at the moment it is not an available option in Lithuania, since, with the Law on Environmental Protection dated 1992 (last amended 2003), the reprocessing of spent nuclear fuel is prohibited.

5.4.6 Transports and storage of nuclear fuel

The annual amount of fuel and spent nuclear fuel in nuclear power plants is low comparing with other fuel based power production plants. For this reason, the volume of transports is relatively low. However transports are needed in several stages of the production chain, distances can be long and the material to deliver can be hazardous or radioactive. Some companies working for nuclear power plants are specialised in the transportation of nuclear fuel and other hazardous and radioactive materials.

Intermediate products and fuel compositions transported from mines to the power plant are only slightly radioactive. However, some of these materials (like uranium hexafluoride transported from the conversion plant to the enrichment plant) are chemically strongly toxic substances and measures of precaution are applied accordingly during transportation.

National and international regulations for transportation and storage of radioactive materials are based on widely adopted standards and guidelines of the IAEA (the International Atomic Energy Agency). The purpose of the regulations is to protect people and the environment from radiation during transportation of radioactive materials.

6 WASTE

6.1 CONSTRUCTION OF THE NUCLEAR POWER PLANT

The estimated construction time of a new NPP is 4–7 years, and no radioactive waste will be generated during this stage. In spite of this, a relevant amount of conventional waste will be produced and will have to be disposed of appropriately.

There are different construction stages: earthworks, construction of unit(s), installation works, commissioning etc. The waste produced typically will be civil industry waste resulting from erection of reinforced concrete structures, installing of equipment and organizing of construction activities (i.e. construction debris, packaging material waste, personnel sanitary waste, waste water polluted with petroleum products and so on).

The first step in the construction of the NNPP will be the earthworks. The depth of the NNPP construction site will vary from 8 to 16 meters. The removed soil will be moved to the projected soil dump located next to the site. The soil dump area is about 240 000 m^2 large and is capable of accommodating 700 000 m^3 of soil (see Section 7.4).

Excavated soil amounts will be in the order of 850 000 m^3 for one NPP unit, and 1 400 000 m^3 for two units. Some of the removed soil will be moved back to the NNPP construction site and the rest will be left for final storage at the soil dump.

During the construction phase, a significant amount of solid ordinary waste will be generated, generally comprising construction and domestic waste. Types of waste that will be commonly encountered together with an indicative estimation of the total amount can be found in Table 6.1-1.

Table 6.1-1 Amounts of ordinary waste generated during the construction of the new NPP.

Type of waste	1 × 1600/1700 MW reactor	2 × 1600/1700 MW reactors
Paper Glass Packaging waste Metal scraps Electronic scraps Tyre scraps End-of-life vehicles Sewage sludge Concrete sludge Lead batteries Contaminated soils Used oils Residual paints, solvents	Total amount: 14 500 t 1 000–2 000 t not suitable for further utilization (lower limit) 385 t/month as peak quantity	Total amount: 27 000 t 2 000–4 000 t not suitable for further utilization (lower limit) 740 t/month as peak quantity
Drinking and raw water – waste water treatment	730 000 m^3 20 000 m^3/month as peak quantity	1 400 000 m^3 40 000 m^3/month as peak quantity

The exact amounts, nature and volumes are linked to variables that can only be clarified as the project proceeds, such as reactor type and number, final layout of the site etc.

Considering a construction period of 50–55 months, the peak in solid waste production will rapidly be reached around the very end of the first year and during the second year of construction, slowly and steady decreasing afterwards. The rough estimations of the peak amounts can be found as well in Table 6.1-1.

The waste types can be divided into different categories:

- Recyclable materials: to be segregated and stockpiled separately;
- Bio-waste: collected in separate drums, cans or bins;
- Electrical goods and electronic scraps;
- Energy waste (waste potentially available for waste to energy plant, like paper and paperboard);
- Timber waste;
- Waste placed on landfill;
- Hazardous waste.

The proportions of these different categories, as well as the amounts that will be recycled or incinerated will depend on the organization of the licensed waste management company, and on the site specific operations. With a responsible waste management, including waste recycling enhancement and the availability of waste to energy technologies, the amount of waste ending on landfills could be limited to the amounts estimated in Table 6.1-1.

The quality of both the terrestrial environment and the lake's water can potentially be contaminated by inappropriate handling and disposal of waste during construction and operation of the new NPP.

A licensed waste management company, the winner of the public tender for the waste management of the new NPP, will be given the responsibility of the waste treatment and disposal, following the Lithuanian Law on Waste Management (*State Journal, 1998, No. 61-1726; 2002, No. 72-3016*), Regulations for Waste Management (*State Journal, 2004, No. 68-2381*) and Permission on integrated prevention and control of pollution. Solid waste will be properly handled and stored until the final disposal from site to appropriate off-site licensed landfill areas. When possible all staff shall minimize the amount of waste and water generated from their daily activities, opportunities for recycling or reuse shall be investigated and implemented if practical and cost effective. The contractor is obliged to manage all waste material generated during construction and to provide any remediation work required to leave the construction and soil dump areas in a neat and clean condition.

Concerning the amounts of potable and raw water resulting in waste water that will have to be treated, some rough estimation of the total consumption is also provided in Table 6.1-1. These figures are strictly connected to the amount of workers needed for the construction of the power plant. Considering the construction of one reactor, or different reactors built in the same timeframe of 50–55 months, the monthly waste water treatment rate will reach its peak at the end of the second year of construction and at the beginning of the third, when the amount of workers is the largest. Beforehand and afterwards, the amount will grow/diminish constantly.

Flammable/combustible waste, oxidizing waste, corrosive waste, toxic waste, and other waste classified as hazardous will also be generated and will be handled specifically. All these amounts will be sorted, packaged and confined by the contracting company and then transported by a licensed contractor to a licensed disposal site outside the construction site. Other hazardous waste like chemicals and hydrocarbons (coolants, waste oils, solvents, and other chemicals) will also be generated during the construction phase. All these amounts are difficult to estimate and largely depend on the construction activities and on site specific operation.

Liquid waste (including sewage, residual oils etc.) will be routed to suitable intermediate storage and / or drainage systems. In particular, direct discharge to the lake of polluted sewage waste water will be prohibited. Sewage water will be treated at a waste water treatments plant in an appropriate manner. Sewage water will be managed in accordance with the requirements of the "Regulation on Sewage Management" (*State Journal, 2007, No. 110-4522*).

A storm sewer system will also be implemented. Surface water will be managed in accordance with the requirements of the "Regulation on Surface Water Management" (*State Journal, 2007, No. 42-1594*).

Appropriate waste and waste water handling will be included in the environmental management system of the new NPP construction site.

6.2 OPERATION OF THE NUCLEAR POWER PLANT

6.2.1 Non-radioactive waste

Solid non-radioactive waste generated during operation of the NPP will be for example utility type and non-hazardous waste (paper, plastic, etc.) and hazardous waste generated during the maintenance (burnt-out fluorescent lamps, batteries, used oil, etc.). In this case the waste will be managed according to the Lithuanian Law on Waste Management (*State Journal, 1998, No. 61-1726; 2002, No. 72-3016*), the requirements of the Regulations for Waste Management (*State Journal, 2004, No. 68-2381*) and Permission on integrated prevention and control of pollution. The possible amounts of waste generated during the proposed economic activity, the ways of management, disposal and utilisation of waste are presented in Table 6.2-1.

Table 6.2-1. Waste and waste management during operation phase of the NNPP.

Techno-logical process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness [1]	Storage condi-tions	Maximum amount, tonnes	
Power plant operation	Municipal waste	110	205	solid	20 03 01	Non-hazardous	Temporary storage in containers	10	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Maintenance waste	15	25	solid	15 02 03	Non-hazardous	Temporary storage in containers	4	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Paper	30	60	solid	20 01 01	Non-hazardous	Temporary storage in containers	5	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Waste suitable for energy production	55	105	solid	15 01 03	Non-hazardous	Temporary storage in containers	6	Transfer to waste consumption enterprises
Power plant operation	Organic waste	30	55	solid/liquid	20 02 01	Non-hazardous	Temporary storage in containers	5	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Metal	80	150	solid	20 01 40	Non-hazardous	Temporary storage in containers	8	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Wood	120	230	solid	20 01 38	Non-hazardous	Temporary storage in containers	20	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Glass	1	1.5	solid	20 01 02	Non-hazardous	Temporary storage in containers	2	Transfer to waste consumption or disposal enterprises or disposal in specially equipped dump
Power plant operation	Electrical and electronic components	7	14	solid	20 01 35	Hazardous	Temporary storage in containers	5	Transfer to hazardous waste disposal licensed enterprises

Techno-logical process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness [1]	Storage condi-tions	Maximum amount, tonnes	
Power plant operation	Solid oily waste	15	30	Solid/liquid	15 02 02	Hazardous	Temporary storage in containers	9	Transfer to hazardous waste disposal licensed enterprises
Power plant operation	Coolants	3	6	Liquid	16 01 14	Hazardous	Temporary storage in containers	2	Transfer to hazardous waste disposal licensed enterprises
Power plant operation	Solvents	3	6	Solid/liquid	20 01 13	Hazardous	Temporary storage in containers	2	Transfer to hazardous waste disposal licensed enterprises
Power plant operation	Batteries	0.5	1	Solid	20 01 33	Hazardous	Temporary storage in containers	0.2	Transfer to hazardous waste disposal licensed enterprises
Power plant operation	Fluorescent tubes	0.3	0.6	Solid	20 01 21	Hazardous	Temporary storage in containers	0.2	Transfer to hazardous waste disposal licensed enterprises
Power plant operation	Boric Acid (H_3BO_3)	2	4	Liquid	CAS No.11113-50-1 EINECS 234-343-4	Irritant	No storage on site	-	Boric acid will be included in the effluent from the primary system. Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 2 tonnes, maximum – 7 tonnes.
Power plant operation	Lithium hydroxide (LiOH)	Less than 0.001	Less than 0.001	Liquid	CAS No 1310-65-2 EINECS 215-183-4	Toxic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – < 1 kg/unit, maximum – 4 kg/unit.

Techno-logical process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness [1]	Storage condi-tions	Maximum amount, tonnes	
Power plant operation	Hydrazine (N_2H_4)	0.007	0.014	Liquid	CAS No. 302-01-2 EINECS 206-114-9	Flammable; Carcinogenic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 7 kg, maximum – 14 kg.
Power plant operation	Ammonia	0.02	0.04	Liquid	CAS No. 1336-21-6 EINECS 215-647-6	Carcinogenic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 20 kg
Power plant operation	Sodium hydroxide 50% concentration	50	100	Liquid	CAS No. 2815 12 00 02	Carcinogenic	No storage on site		Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel.
Power plant operation	Sulphuric acid 93% concentration	28	56	Liquid	CAS No. 7664-93-9 EINECS 231-639-5	Carcinogenic	No storage on site		Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel.

1 – According to the Law on Chemical Substances and Preparations (State Journal, 2000, No. 36-987) and Order of Classification and Labelling of Dangerous Chemical Substances and Preparations (*State Journal, 2001, No. 16-509; 2002, No. 81-3501*).

The total amount of conventional waste generated every year is around 450–500 tonnes for one reactor unit, 850–900 tonnes if 2 units will be placed in operation. The exact amounts of these different materials, as well as the shares that will be recycled, placed in landfill or incinerated, will depend on the organization of the licensed waste management company, and on the site specific operations. With a responsible waste management, including recycling waste enhancement and the availability of waste to energy technologies, the amount of waste ending on landfill could be limited down to 10 % of the total amount. It is however more realistic to estimate this share as around 40–50 %, with an annual amount of waste of 250 and 500 tonnes corresponding to one and two units respectively.

The total amount of non-radioactive hazardous waste generated will be around 20 tonnes/year for one reactor unit and will include scrapped electrical and electronic components, batteries, coolants, solid oily waste, solvents and fluorescent tubes and light bulbs. Chemicals used in normal operation are sodium hydroxide and sulphuric acid. The hazardous waste has to be sorted, packaged and confined by the contracting company and then transported by a licensed contractor to licensed disposal place outside the NPP site. Some chemical effluents, with waste amounts strongly dependent on the technology chosen and the site-specific operations, used in process in both operating manoeuvres and maintenance operations of nuclear industry are thought to be discharged after reprocessing, always respecting the limits set by the Lithuanian and European legislations. These estimated amounts are presented in Table 6.2-1 as well.

There will be different types of waste water types that will have to be handled, filtered and processed, also including the use of suitable intermediate storage and / or drainage systems, before they are safely discharged to the lake in the outlet system or removed from the power plant site. The overall amount of waste water produced every day by the power plant in operation is roughly estimated as 350–400 m^3/day for 1 unit and 750–800 m^3/day for 2 units. This waste water will include sanitary water (estimated amount 50–100 m^3/day), process waste water (estimated amount 240–480 m^3/day), waste water used for the production of process water (estimated amount 60–120 m^3/day) and waste water resulting from the raw water treatment (estimated amount 25–50 m^3/day). None of these waste water types and amounts will be discharged to the lake without being treated and properly disposed of following the national and European regulations. A waste water system plant has to be studied and implemented for this purpose, as well as a storm sewer system. Sewage water will be managed in accordance with the requirements of the ”Regulation on Sewage Management” (*State Journal, 2007, No. 110-4522*). Surface water will be managed in accordance with the requirements of the “Regulation on Surface Water Management” (*State Journal, 2007, No. 42-1594*).

6.2.2 Radioactive waste

Radioactive waste originating from nuclear power plants usually includes spent nuclear fuel, operating waste and the so-called decommissioning waste originating from the decommissioning of the plant.

The basis of the waste management of the new plant is to utilise existing solutions at the INPP (designed or already in use) to the greatest possible extent. The suitability of the existing radioactive waste management and storage facilities for the management and storage of the radioactive waste from the new NPP is evaluated in Section 1.8. The capacity of planned disposal facilities can be extended when it is necessary.

The main principles of radioactive waste management are established by Clause 3 of the Law on Radioactive Waste Management (*State Journal, 1999, No. 50-1600; 2005, No 122-4361*). Management of radioactive waste must ensure that:

- At all stages of the radioactive waste management, by applying appropriate methods, individuals, society and the environment in Lithuania and beyond its borders are adequately protected against radiological, biological, chemical and other hazards that may be associated with radioactive waste;
- The generation of radioactive waste is kept to the minimum practicable;
- Interdependencies among the different steps in the radioactive waste management are taken into account;
- Safety of radioactive waste management facilities is guaranteed during their operating lifetime and after it.

VATESI document "Regulation on the Pre-Disposal Management of Radioactive Waste at the Nuclear Power Plant, VD-RA-01-2001" (*State Journal, 2001, No. 67-2467*) is applied to the safety of the pre-disposal management of radioactive waste generated from the operation and decommissioning of NPP and other radioactive waste that is transferred to NPP for storage and/or processing. This regulation sets the procedure of management both the waste from past activities and newly generated waste, except spent nuclear fuel.

Radioactive waste management program will be implemented at the new NPP. This program will include the following:

- keeping the generation of radioactive waste to the practicable minimum, in terms of both activity and volume, by using suitable technology;
- reusing and recycling materials to the extent possible;
- classifying and segregating waste appropriately, and maintaining an accurate inventory for each radioactive waste stream, with account taken on the available options for clearance and disposal;
- collecting, characterizing and storing radioactive waste so that it is acceptably safe;
- providing adequate storage capacity for anticipated radioactive waste;
- ensuring that radioactive waste can be retrieved in the end of the storage period;
- treating and conditioning radioactive waste in a way that is consistent with safe storage and disposal;
- handling and transporting radioactive waste safely;
- controlling effluent discharges to the environment;
- carrying out monitoring for compliance at source and in the environment;
- maintaining facilities and equipment for waste collection, processing and storage in order to ensure safe and reliable operation;
- monitoring the status of the containment for the radioactive waste in the storage location;
- monitoring changes in the characteristics of the radioactive waste, in particular if storage is continued for extended periods, by means of inspection and regular analysis;
- initiating, as necessary, research and development to improve existing methods for processing radioactive waste or to develop new methods, and to ensure that suitable methods are available for the retrieval of stored radioactive waste.

Most of the waste produced during normal operation of a NPP is low in radioactivity. This waste mostly includes typical maintenance waste, such as isolation materials, paper, old working clothes, machine parts, plastics and oil. The intermediate-level waste mainly consists of the ion exchange resin from the purification system of the circulating water and the evaporator bottom from sewage water treatment.

Radioactive waste is classified and segregated in accordance with the physical state (solid, liquid or gaseous), chemical properties (aqueous waste or organic liquids) and radiological properties (very low, low or intermediate level waste, short-lived or long-lived waste). The segregation of the radioactive waste is carried out taking into consideration their flammable, pyrophoric, explosive and corrosive nature.

The amounts of solid, liquid, gaseous and spent nuclear fuel are evaluated in this section based on the reactor types which are selected as technological alternatives (see Chapters 4 and 5). Also possible radioactive waste management, treatment and storage methods are described. Radioactive waste impact on certain environmental components is assessed in Chapter 7.

6.2.2.1 Solid radioactive waste

Solid radioactive waste consists of spent ion exchange resins; cartridge filters; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; contaminated rags, clothing, paper, plastic, etc. Annual solid waste generation rates for different reactor types, which are considered as technological alternatives, are summarized in Table 6.2-2. For comparison, the annual amount of solid radioactive waste generated by one unit of the existing Ignalina NPP is ~550 m^3/year (~420 m^3/year/GW).

Table 6.2-2. Annual generation of solid radioactive waste.

		For one Unit, m^3/year	Planned number of Units	Total amount from all Units, m^3/year	Amount per GW, m^3/year/GW
BWR	ABWR (*DCD ABWR, 2007*)	~430	2	~860	~330
	ESBWR (*DCD ESBWR, 2007*)	~470	2	~940	~300
PWR	EPR (*EPR FSAR, 2007*)	~225	2	~450	~135
	APWR (*DCD APWR, 2007*)	~310	2	~620	~180
	AP-1000 (*DCD AP-1000, 2005*)	~160	3	~480	~145
	AP-600 (*DCD AP-600, 1999*)	~140	5	~600	~200
	WWER (*IAEA-TECDOC-1492*)	120-250	2	240-500	85-175
HWR	CANDU-6 (*TQ AECL, 2008*)	~40	4	~160	~50
	ACR-1000 (*EIA ACR-1000, 2006*)	~55	3	~165	~50

Solid waste shall be classified and segregated in accordance with the radiological classification parameters given in Table 6.2-3.

Table 6.2-3. Solid radioactive waste classification system (extracted from VD-RA-01-2001 (*State Journal, 2001, No. 67-2467*).

Waste class	Definition (abbreviation)	Surface dose rate, mSv/h	Conditioning option	Disposal method
0	Exempt waste (EW)		Not required	Management and disposal as per requirements set in Law on Waste Management (*State Journal, 1998. No. 61-1726; 2002, No. 72-3016*)
Short-Lived low and intermediate level waste*)				
A	Very low level waste (VLLW)	≤0.5	Not required	Very low level waste repository (Landfill repository)
B	Low level waste (LLW-SL)	0.5–2	Required	Near surface repository
C	Intermediate level waste (ILW-SL)	>2	Required	Near surface repository
Long-Lived low and intermediate level waste**)				
D	Low level waste (LLW-LL)	≤10	Required	Near surface repository (cavities at intermediate depth)
E	Intermediate level waste (ILW-LL)	>10	Required	Deep geological repository
Spent sealed sources				
F	Spent sealed sources (SSS)		Required	Near surface or deep geological repository***)

*) Containing beta and/or gamma emitting radionuclides with half-lives less than 30 years, including Cs-137, and/or long-lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration less than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long-lived alpha emitting radionuclides is less than 400 Bq/g per waste package.
**) Containing beta and/or gamma emitting radionuclides with half-lives more than 30 years, not including Cs-137, and/or long-lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration more than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long-lived alpha emitting radionuclides exceeds 400 Bq/g per waste package.
***) Depending on acceptance criteria applied to sealed sources.

There are a lot of well established and worldwide used technologies for treatment of solid radioactive waste. Treatments for solid radioactive waste are used to reduce the volume of the waste and/or convert the waste into a form suitable for handling, storage and disposal. The main treatment methods are following:

- Decontamination – appropriate removal of the contamination from the surface could consequently convert equipment or material that had to be considered as radioactive waste into conventional waste or material that can be reused;
- Compaction – is a widely used method to reduce the volume of dry compactable radioactive solid waste through the application of a mechanical force;
- Incineration – produces a high volume reduction and converts the combustible radioactive waste into a form suitable for subsequent immobilization and disposal.

Non-combustible and non-compactable radioactive waste often requires special treatment, depending on its particular characteristics. Those wastes contaminated with long lived radioisotopes, such as sealed sources, should be immobilized prior to their storage and disposal. Traditionally, cement grouts have been used or recommended as the most suitable material for conditioning radioactive non-compactable waste.

6.2.2.2 Liquid radioactive waste

The primary coolant in water cooled reactors and water from the spent nuclear fuel storage pools are major potential sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Another source of liquid radioactive waste is liquids generated in controlled access area:

- sewage water from showers and toilets;
- waste water from cleaning and decontamination of equipment and building structures,
- condensation water from building structures and constructions surfaces;
- condensation water from heating, ventilation and air conditioning system.

Annual liquid radioactive waste generation rates for different reactor types which are considered as technological alternatives are summarized in the Table 6.2-4.

Table 6.2-4. Annual generation of liquid radioactive waste.

		For one Unit, m^3/year	Planned number of Units	Total amount from all Units, m^3/year	Amount per GW, m^3/year/GW
BWR	**ABWR (*DCD ABWR, 2007*)**	~29500	2	~59000	~22700
	ESBWR (*DCD ESBWR, 2007*)	~28600	2	~57200	~18500
PWR	**EPR (*EPR FSAR, 2007*)**	~8000	2	~16000	~4800
	APWR (*DCD APWR, 2007*)	~7000	2	~14000	~4100
	AP-1000 (*DCD AP-1000, 2005*)	~2500	3	~7500	~2300
	AP-600 (*DCD AP-600, 1999*)	~2300	5	~11500	~3800
	WWER (*IAEA-TECDOC-1492*)	~15000	2	~30000	~11000
HWR	**CANDU-6 (*TQ AECL, 2008*)**	~14000	4	~56000	~19000
	ACR-1000 (*EIA ACR-1000, 2006*)	n/a	3	n/a	n/a

Liquid radioactive waste shall be classified and segregated according to:

- The specific activity: in low level ($\leq 4 \cdot 10^5$ Bq/l) and intermediate level ($>4 \cdot 10^5$ Bq/l) waste;
- The chemical nature: in aqueous and organic waste;
- The phase state: in homogeneous and heterogeneous waste.

Liquid waste shall be further classified according to its chemical composition and shall be led to appropriate liquid radioactive waste treatment facilities. The suitability of existing treatment facilities and plants and the necessity of the new treatment facilities are evaluated in Section 1.8.

Methods for the treatment of liquid radioactive waste include evaporation, membrane processing (e.g. reverse osmosis, ultrafiltration, non-precoat filters), electro deionization, ion exchange, chemical precipitation, filtration, centrifugation, electro-dialysis and incineration. In each case, treatment limitations should be included in the categorization process. For example, strong consideration shall be put on the impact of corrosion, scaling, foaming, and the risk of fire or explosion in the presence of organic material, especially with regard to the safety implications of operations and maintenance.

Like any nuclear power plant, the new NPP will discharge certain amounts of liquids which contain radionuclides into the environment. Radioactive effluents, i.e. technical water, household waste water (which had no contact with radioactive materials) and surface water (i.e. storm water) may be released into the environment if the activity of the radionuclides does not exceed the limit activity, determined in the permission issued by the Lithuanian Ministry of Environment.

Radioactive materials may be released into environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the Lithuanian Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring" (*State Journal, 2007, No. 138-5693*). Possible radioactive effluents into the environment from different reactor types during normal operation are described in Section 7.1.2**.**

6.2.2.3 Gaseous radioactive waste

The possible sources of gaseous radioactive releases include the following:

- leakage from the coolant, the moderator systems or the reactor itself;
- degasification systems for the coolant;
- condenser vacuum air ejectors or pumps;
- the exhaust from turbine seal systems;
- activated or contaminated ventilated air.

Emissions into the atmosphere can include noble gases, iodine, aerosols, tritium and carbon-14. Atmospheric emissions occur through the vent stack. Gaseous waste processing systems ensure the removal of the radioactive contaminants such as aerosols, noble gases and iodine from off-gases under both normal and abnormal conditions to levels permissible to discharge effluents within the discharge limits set by the Ministry of Environment. These systems include an exhaust active ventilation system with delay, iodine and aerosol filters.

Radioactive materials may be released into the environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the

Authorisation of Release of Radionuclides and Radiological Monitoring" (*State Journal, 2007, No. 138-5693)* Possible radioactive releases into the environment from different reactor types during normal operation are described in Section 7.2.2**.**

6.2.2.4 Spent nuclear fuel

After SNF is removed from the reactor core, it is stored in storage pools for a certain decay period before SNF could be transferred to off-site facilities for further processing or storage. All NPPs have such spent fuel pools associated with the reactor operations. Recent designs of reactors have incorporated pools that can accommodate SNF generated over periods of up to 30 years. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report.

Annual SNF generation rate of different reactor types which are considered as technological alternatives are summarized in the Table 6.2-5. Annual generation for one reactor was calculated taking into account thermal power of the reactor, average fuel burnup and reactor availability per year. As can be seen, about ten times higher amount of SNF is generated in HWR reactors. Such higher amount is due to the fact that HWRs use natural or low enriched nuclear fuel. For comparison, the annual SNF generation at one unit of the existing Ignalina NPP is 50–70 $tonnes_{HM}$/year (38–54 $tonnes_{HM}$/year/GW). Such range of amount is due to the fact that nuclear fuel with different initial enrichments (from 2.0 % to 2.8 %) is used in the existing Ignalina NPP.

Table 6.2-5. Annual generation of SNF.

		For one Unit, $tonnes_{HM}$/year	Planned number of Units	Total from all Units, $tonnes_{HM}$/year	Amount per GW, $tonnes_{HM}$/year/GW
BWR	ABWR	26.4	2	52.8	~20
	ESBWR	30.2	2	60.4	~20
PWR	EPR	23.4	2	46.8	~15
	APWR	27.4	2	54.8	~16
	AP-1000	17.6	3	52.8	~16
	AP-600	10.0	5	50.0	~17
	V-392	21.4	3	64.2	~21
	V-448	27.3	2	54.6	~20
HWR	EC-6	92.4	4	369.6	~132
	ACR-1000	53.5	3	160.5	~49

There are different SNF management options. The selection of a strategy for SNF management is a complex decision with many factors to be taken into account including politics, economics, resource conservation, environmental protection, and public perception. Main strategies for SNF management are as follows:

- Storage of SNF in pool type facilities away from the reactor. Such facilities where SNF is submerged under the water are usually referred to as SNF wet storage facilities.

- The dry storage technology is used for SNF storage away from the reactor. Such SNF management is presently chosen for Ignalina NPP spent fuel storage.
- SNF reprocessing. During this process useful elements such as uranium and plutonium are separated from fission products and other materials in SNF. Reprocessing facilities exist in UK, France and Russia. Presently reprocessing of SNF is prohibited by Lithuanian legislation.

The existing national Strategy on Radioactive Waste Management (*State Journal, 2002, No. 15-567*) foresees several options to be investigated prior the final decision will be taken:

- Possibility to dispose of the SNF in a national deep geological repository;
- Possibility to dispose of the SNF in a regional deep geological repository;
- Possibility to transfer and dispose of the SNF in other countries;
- Possibility to safe store the SNF for 100 years and more.

SNF management options and technical solutions for storage or disposal directly depend on SNF characteristics. The main SNF characteristics that shall be taken are as follows:

- Criticality of the system where SNF is stored to prevent self-sustaining nuclear chain reaction ;
- Content and activity of fission products, actinides and light elements;
- Neutron and gamma source terms;
- Decay heat.

Measures such as fuel bundle design, correct geometrical positioning of fuel assemblies, operating controls of the environment of SNF, etc. are taken into consideration in order to prevent criticality occurences during SNF handling, wet/dry storage or disposal.

After the SNF is discharged from the reactor core, it contains intensive sources of gamma and neutron radiation, therefore the continuous shielding to protect personnel and restrict direct radiation doses outside the NPP buildings is necessary. Initially such shielding is provided by the thick layer and the large volume of the water in the storage pools. As the radioactive decay of fission products, which are the main contributors of ionising irradiation, occurs with time, the intensity of radiation reduces to the values when SNF could only afterwards be safely transferred to a dry storage facility.

The decay of the fission products also generates thermal energy which must be removed to prevent fuel rod heat up and risk of cladding failure, leading to release of fission product gases. Therefore, submerging the SNF under water within the storage pool also assists in controlling fuel bundle temperatures through convective cooling.

Usually after 5-10 years the SNF from storage pools could be transferred to a dry storage or reprocessing facilities. The dry storage facility provides adequate containment and shielding barriers and decay heat removal systems. As mentioned earlier, presently SNF from Ignalina NPP is stored in interim dry storage facility.

6.3 DECOMMISSIONING

It is expected that the new NPP will operate about 60 years. After this time period the decommissioning process of the NPP will start. This process will generate radioactive and non-radioactive wastes of various physical states (solid, liquid, chemical and radiological properties). Since design lifetime of the existing INPP waste management facilities will be expired, the decommissioning waste of the new NPP will be processed in newly constructed appropriate waste management, treatment and storage facilities.

Part of the resulting conditioned waste will be freely released; disposed of into the landfill, near-surface repositories or temporarily stored on site.

According to Swiss estimations, amounts of decommissioning waste depend on the thermal power installed. Amount (in terms of m^3) of decommissioning waste for PWR can be estimated multiplying thermal power (MW_{th}) of reactor by factor 3.03; for BWR multiplying by factor 3.5. BWRs produce slightly more waste than PWRs. Based on such rough estimation, the highest amount of decommissioning waste would be for ESBWR – about 16 000 m^3 per unit.

The International Atomic Energy Agency document (*IAEA TECDOC Series No. 1394*) provides guidance on planning and managing the decommissioning of nuclear facilities and the lessons learned.

6.3.1 Decommissioning strategies, procedures and methods

Specific decommissioning factors and constraints are analysed in IAEA document "Selection of Decommissioning Strategies" (*IAEA TECDOC Series No. 1478*) in order to provide support in the decommissioning strategy selection process. When selecting a proper decommissioning strategy in a specific facility, a range of general and site specific factors needs to be considered, typically, in a multi-attribute analysis. These factors include cost, health and safety issues and environmental impact, availability of resources, social impacts and stakeholder involvement, etc.

Three decommissioning strategies have been defined by the IAEA, namely: immediate dismantling, deferred dismantling and entombment (*Reisenweaver, D.W., 2003; Safety Standards Series No. WS-R-5*). "No action" is not regarded as an acceptable decommissioning strategy and therefore it will not be further discussed in this report.

Immediate dismantling commences shortly after shut down, if necessary following a short transition period to prepare for implementation of the decommissioning strategy. Decommissioning is expected to commence after the transition period and continues in phases or as a single project until an approved end state including the release of the facility or site from regulatory control has been reached.

As an alternative strategy, dismantling may be deferred for a period of up to several decades. Deferred dismantling is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. During the deferred dismantling period, a surveillance and maintenance programme is implemented to ensure that the required level of safety is maintained. During the shutdown and transition phases, facility specific actions are necessary to reduce and isolate the source term (removal of spent fuel, conditioning of remaining operational or legacy waste, etc.) in order to prepare the facility/site for the deferred dismantling period.

Entombment is a strategy in which the remaining radioactive material is permanently encapsulated on site. A low- and intermediate-level waste repository is effectively established and the requirements and controls for the establishment, operation and closure of waste repositories are applicable.

Although evaluation of the prevailing factors could clearly indicate one of the above mentioned strategies, constraints and overruling factors may occur in practice, and these necessitate a combination of strategies or exclude one or more strategies from consideration.

The availability and use of suitable technology are important parts of decommissioning planning and can influence the selection of a strategy. Site-specific features may demand technology development and adaptation, but in many cases mature technology is commercially available.

Decommissioning activities are performed with an optimized approach to achieving a progressive and systematic reduction in radiological hazards, and are undertaken on the basis of planning and assessment to ensure the safety of workers and the public and protection of the environment, both during and after decommissioning operations (*Safety Standards Series No. WS-R-5*).

The operating organization of the new NPP shall implement the decommissioning and related waste management activities in compliance with the Lithuanian safety standards and requirements. The operating organization shall be responsible for all aspects of safety and environmental protection during the decommissioning activities.

In order to provide an adequate level of safety, the operating organization shall, inter alia, prepare and implement appropriate safety procedures; apply good engineering practice; ensure that staff are properly trained and qualified and are competent; and keep and submit records and reports as required by the regulatory body.

Decontamination and dismantling techniques shall be chosen such that the protection of workers, the public and the environment is optimized and the generation of waste is minimized. Decommissioning activities such as decontamination, cutting and handling of large equipment and the progressive dismantling or removal of safety systems have the potential for creating new hazards. The impacts on safety of these activities shall be assessed and managed so that these hazards are mitigated and are kept within acceptable limits and constraints.

6.3.2 Decommissioning plan

During the design stage of the new NPP an initial decommissioning plan should be prepared before the operating licence is issued. The initial decommissioning plan should state in general terms that the plant can be taken out of service, and provide an outline of decommissioning methods and technologies. The initial decommissioning plan must specify the likely quantity of waste and provide an estimate of decommissioning costs.

The decommissioning plan shall be periodically updated. The updates are intended to reduce the impact of decommissioning on the public and the environment, and to ease the process by allowing for changes in decommissioning technologies and in radioactive waste management. Ongoing decommissioning plans should be corrected if systems and installations have been significantly altered, or if incidents or accidents have taken place resulting in unforeseen contamination of the NNPP site and its systems.

If a decision is made to decommission the nuclear power plant or one of its units it is obligatory, five years in advance, to submit to VATESI a decommissioning program and final decommissioning plan after co-ordinating it with the Ministry of Economy, the Ministry of the Environment, the Ministry of Health, the Ministry of Social Security and Labour, the county governor and the local authority of the territory which, in its entirety or in part, is within the facility sanitary protection zone. The Program should contain information about dismantling and conservation of equipments, management of radioactive materials and radioactive waste as well as later control and supervision of the object.

6.3.3 Decommissioning cost and fund

Once the reactor has started operation, the core is irradiated, and the primary system components have become radioactive, the cost of decommissioning a nuclear reactor is basically fixed and is permanent. Other factors may change the overall costs somewhat but the general level of decommissioning cost would remain similar. Factors during the operation phase that could lead to an increase in the eventual decommissioning cost could be, for example, potential degradation in operational performance or a major contamination event. On the other hand, innovations and developments in decontamination technologies could reduce the decommissioning cost (*Devgun J. S., 2008*). One important factor that has the potential to substantially change the decommissioning cost is the availability of facilities and cost of the radioactive waste disposal as well as the facilities for management and storage of spent nuclear fuel. The new NPP will have to install a new spent fuel storage facility since the present storage facility and the facility under construction will be completely filled by the year of the decommissioning start.

The decommissioning funds will be accumulated over the operating life of the reactor (as a levy on a per kWh basis) and held in a decommissioning fund. The decommissioning cost for an individual reactor can range from approximately \$300 million to over \$600 million depending on the reactor and the site specific factors. The average decontamination & decommissioning (D&D) cost for a full size reactor is closer to \$600 million per reactor (*Devgun J. S., 2008*). This is a significant portion of the overall life cycle costs of the reactor. The cost of decommissioning is proportional to the amount of decommissioning waste.

It can be concluded that while several factors could affect the overall decommissioning strategy and decommissioning cost, one way to reduce the decommissioning cost would be to optimize the design of the systems and structures for eventual decommissioning.

6.3.4 Decommissioning considerations during design

The main factors driving the design of the new reactors are the enhanced safety features, safeguards considerations, and the economic factors. Optimization of the facility and system design for decommissioning is generally not a high priority. This means that decommissioning considerations are not being fully represented as a design item in the new reactor design process.

Eventually all reactors, including the ones under construction or planned, will need to be decommissioned at the end of their lifecycle. The fact that the decommissioning phase for the new reactors may take sixty or more years has clearly led to decommissioning considerations being seen as a low priority in the design and the regulatory process. However, the benefits of such considerations early in the design stage are many. Incorporating decommissioning considerations into the designs of the new reactors can ensure that the eventual decommissioning can be completed in shorter time frame, with minimum generation of radioactive waste, and with better radiological safety.

Some of the reactor designs have been successfully optimized in this regard. Specific interest to the design phase of the new reactors should be given to two factors: system design and facility design (*Devgun J. S., 2008*).

6.3.4.1 System design

An emphasis on the following considerations will optimize the project from the very beginning towards eventual decommissioning. These include:

- Reduction in the system components;
- Modular designs of systems;

- More reliance on passive safety systems;
- Use of contained systems (thus, minimizing the potential for cross contamination);
- Better designs of piping systems, HVAC systems, and sumps and drains.

The experience with decommissioning projects so far shows that approximately 65 to 75 percent of the costs are related to removal activities (systems and structures – decontamination, demolition and removal), disposal of components and low level waste, dry spent fuel storage facility construction, and staffing. The remaining costs account for the other items such as security services, radiological surveys, taxes and other miscellaneous items.

System design optimization with respect to decommissioning considerations can reduce the eventual decommissioning cost of both the removal activities and the disposal costs. Both of these are a major portion of the overall decommissioning cost. A reduction in the system components and a modular design that will facilitate dismantlement activities will clearly reduce the costs of decommissioning. An additional benefit of an optimized design will be the reduction in the overall radiation exposure to the decommissioning workers.

6.3.4.2 Facility design

An emphasis on the structural design and the architectural design considerations will optimize the project from the very beginning towards eventual decommissioning. These include:

- Minimizing the foot print of structures;
- Modular designs of structures;
- Designing for large component removal.

The disposal cost of the structural debris is substantial, especially if it has to be treated as low level radioactive waste. Even though it may be possible to segregate the radioactive and non-radioactive debris, the licensing issues, the release criteria and other factors may influence the disposal of such materials. Thus, minimizing the structures that will be eventually demolished reduces the overall volume of the material that will need to be disposed.

The issue of designing for major component removal is significant because from the industry experience so far, the preference has been to avoid segmenting the reactor vessel. This reduces costs and reduces the radiation dose to decommissioning workers. Thus, a design optimized during construction that will allow for major component removal will facilitate decommissioning (*Devgun J. S., 2008*).

6.3.4.3 Summary key factors

Based on the extensive decommissioning experience that is now available, it is possible to summarize key factors that are relevant to the new reactors and that would facilitate their future decommissioning:

- Incorporation of modular concepts in structural design;
- Innovations in equipment, materials, and system layout;
- Lessons from decommissioning projects, especially in terms of major component removal;
- Access to highly contaminated components for decontamination;

- Consideration of the total life cycle including decommissioning while designing equipment and structures and while implementing modifications during the operating life of the reactor;
- Minimization of underground drains and buried piping as much as possible;
- Designs that will prevent or minimize the potential for leaks and spills and that will allow for their early detection;
- Minimization of future waste volume generation during the decommissioning phase of the reactor;
- Good historical site assessment with records of any spills, radiological contamination, soil excavations, and disposals during the plant operation;
- Design assessment in terms of estimated decommissioning cost per MW_e effectiveness;
- Design concepts incorporating early selection of the decommissioning option;
- Decommissioning engineers embedded on the reactor design team with a specific mission to optimize the reactor systems and structures for eventual decontamination and decommissioning;
- Developments in release criteria for the decommissioned sites and materials.

Designing D&D into the new reactor designs is necessary to ensure that the tail end costs of the nuclear power are manageable. Such considerations during the design stage will facilitate a more cost-effective, safe and timely decommissioning of the facility when a reactor is eventually retired.

7 PRESENT STATE OF THE ENVIRONMENT, ASSESSMENT OF POTENTIAL IMPACTS OF THE PROPOSED ECONOMIC ACTIVITY AND MITIGATION MEASURES

7.1 THE STATE OF WATERS

7.1.1 Present state of the environment

7.1.1.1 Hydrogeological conditions

The new NPP area is located in the recharge area of the eastern part of the Baltic artesian basin. Hydrogeological conditions of the area are described based on the investigations carried out around the cross-section AA' presented in Figure 7.1-1. Three different hydrodynamic zones characterized by active, slower and slow water exchange are found in the area. The active water exchange zone is separated from the slower water exchange zone by the 86–98 m thick regional Middle Devonian (Narva) aquitard, located at a depth of 165–230 m. It is composed of loam, clay, domerite and clayey dolomite. The slower water exchange zone is separated from slow water exchange zone by the 170–200 m thick regional Silurian–Ordovican aquitard, located at a depth of 220–297 m (*Marcinkevicius et al., 1995*).

The thickness of the Quaternary aquifer system varies from 60 to 260 meters (mostly between 85–105 m) including layers with low water permeability. This aquifer system consists of seven aquifers: the upper shallow unconfined aquifer and six confined aquifers attributed to different glaciofluvial intertill deposits from Pleistocene age. The detailed ages of these deposits in regional schemes are attributed to Baltija–Gruda (aqIII), Gruda–Medininkai (aqIII-II), Medininkai–Zemaitija (aqII), Zemaitija–Dainava (aqII-I), Dainava–Dzukija (aqI1) interglacials and Dzukija (aqI2) glacial (Figure 7.1-2).

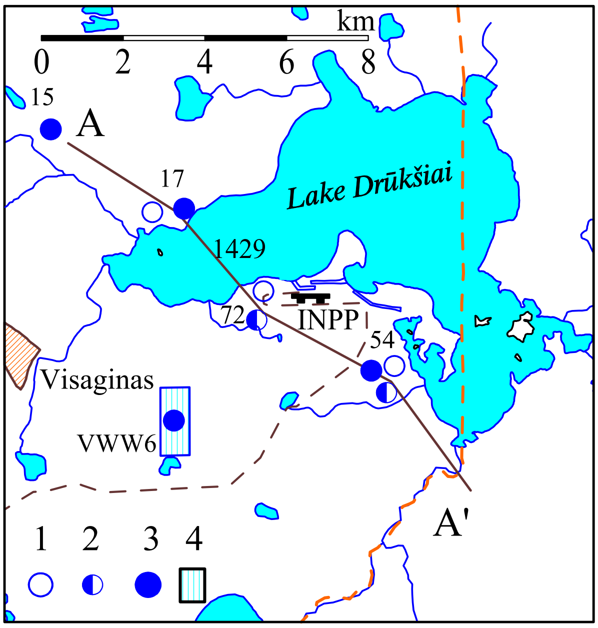


Figure 7.1-1. Location of hydrogeological cross-section AA' in the area of the new NPP: Symbols 1,2 and 3 present the observation wells (and the sample point number) of the previous monitoring system (1 – unconfined aquifer, 2 – confined Quaternary aquifer, 3 – confined Upper-Middle Devonian aquifer) and the symbol 4 presents the well-field of Visaginas Energija.

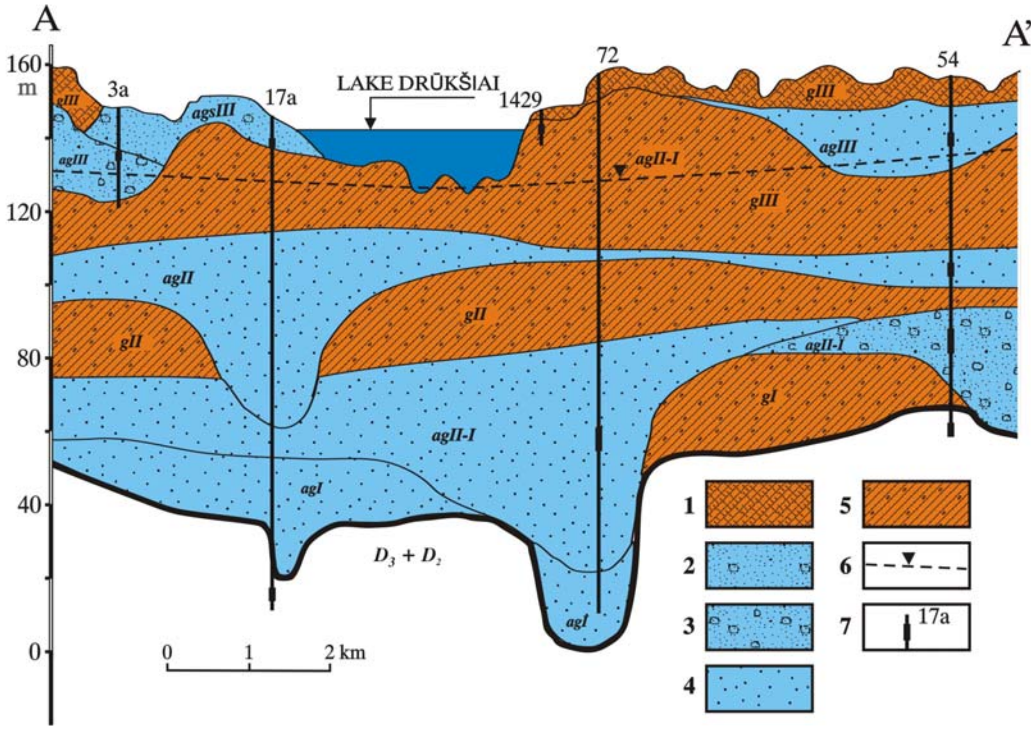


Figure 7.1-2. Hydrogeological cross-section AA' (modified after *Marcinkevicius et al. 1995*) of the new NPP area (location of the cross-section is shown in Figure 7.1-5): 1 – fissured till deposits; 2 – unconfined aquifer (fine sand with gravel); 3 – unconfined and confined aquifer (various sand with gravel); 4 – confined aquifer (various sand with gravel and interlayers of silt and clay); 5 – aquitard (till deposits); 6 – groundwater level of confined aquifer agII-I; 7 – observation well with filter interval and its number.

The confined Quaternary aquifers are separated from each other by low permeability till bodies (aquitards) of sandy loam and clayey loam with lenses of sand and gravel. The thickness of different aquitards varies from 0.5 to 50–70 m, mostly – from 10–15 to 25–30 m. The aquifers attributed to the intertill deposits are composed of sand, gravel, and, in some paleovalleys, of gravel and pebble. The thicknesses of different aquifers vary from 0.3–2 m to 20–40 m, and in paleovalleys they can be over 100 meters thick (*Marcinkevicius et al., 1995*). Unconfined groundwater occurs in bog (peat) and glaciofluvial deposits (vary-grained sand, gravel and pebbles) as well as in the fissured upper part of the eroded sandy and clayey loam.

The above mentioned aquifers constitute a common hydraulic system which is located in a water recharge area. The piezometric level of Upper-Middle Devon aquifer in the greater part of the region is lower than piezometric level of unconfined groundwater and confined intertill aquifers, which indicates that ground water is replenished by recharge. Prevailing lateral groundwater flow direction is to the north, north-east towards the Lake Druksiai and in wider region towards the Daugava River in north.

Groundwater in the main aquifers is fresh, magnesium–calcium bicarbonate type and the concentration of total dissolved solids (TDS) varies from 0.3 to 0.5 g/l. The TDS values for groundwater within the till fissures are higher, ranging between 0.58 and 0.85 g/l (*Marcinkevicius et al., 1995; Hidroprojektas Report, 2006a; Hidroprojektas Report, 2006b*). Total hardness of groundwater varies from 5.19 to 5.95 meq/l and conductivity from 610 to 705 μS/cm. According to water quality classes presented in the Lithuanian Hygiene Standard HN 48:2001 "Hygienic Requirements for Quality of Raw Water Used by People" (*State Journal, 2001, No. 104-3719*) and based on the hydrochemical data, groundwater from the Devonian aquifer system and Quaternary aquifer system fulfils the requirements of the highest class (good quality). However, groundwater of Quaternary aquifer system may in some cases be attributed to the second class due to elevated organic matter content (in terms of permanganate number) and high concentration of ammonium ions. These features are determined by natural hydrogeochemical processes.

Detailed description of the groundwater at the alternative sites and assessment of the impacts on groundwater are further discussed in the Section 7.3.

7.1.1.2 Hydrological conditions

Lake Druksiai belongs to the Dauguva catchment area. It outflows to the Baltic Sea via a 550 km long river continuum: Druksiai → Prorva → Druksa → Dysna → Daugava → Gulf of Riga.

The catchment area of Lake Druksiai (Figure 7.1-3) is only 564 km^2. Its greatest length, from south-west to north-east, is 40 km, maximum width is 30 km and average width is 15 km. Lake percentage is 16 %, which is exceptionally high in Lithuania. A greater part of the area is occupied by forests (38 %). The arable lands account for 26 % and bogs for 16 %. The area is dominated by sand, clay loam and sandy loam soils, which are the reason for varying water filtration conditions in different parts of the catchment area. (*Hydro-physical Basis State in Lake Druksiai, 1989*).

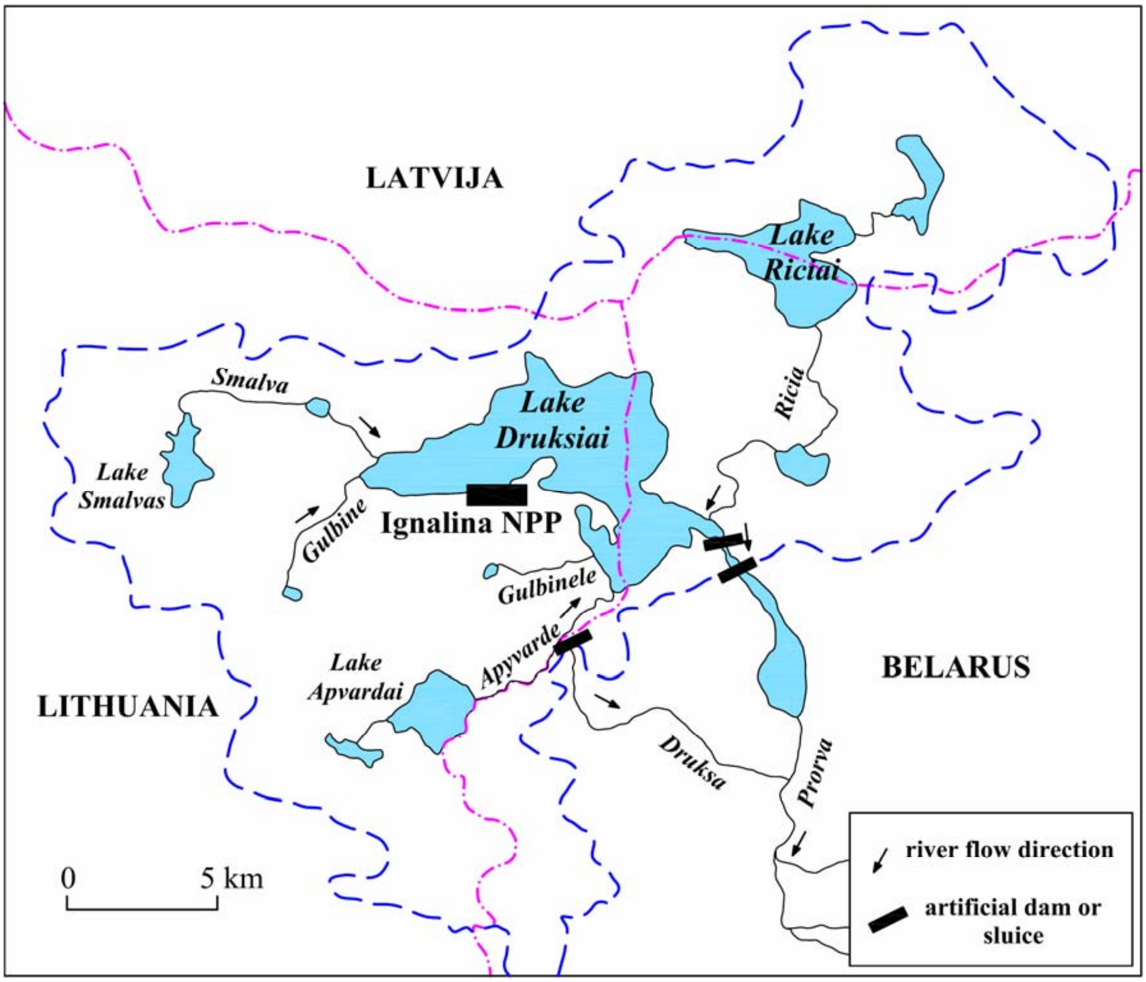


Figure 7.1-3. Scheme of Lake Druksiai catchment area.

Lake Druksiai has 11 tributaries and one river that outflows it (the Prorva). The main rivers connected to Lake Druksiai are the Ricia (Ricianka), the Apyvarde and the Smalva (Table 7.1-1).

Table 7.1-1. Lake Druksiai tributaries and their characteristics.

River	Length of river, km	Catchment area, km²	Run-off, m^3/s
Apyvarde	11.4	156.6	0.861
Gulbinele	5.9	6.3	0.035
D-1	4.0	4.3	0.024
D-2	4.9	5.6	0.031
Gulbine	8.0	33.0	0.181
Smalva	11.9	88.3	0.485
D-3	3.7	6.6	0.036
D-4	8.0	16.5	0.091
D-5	3.2	3.3	0.018
D-6	2.0	3.3	0.018
Ricia (Ricianka)	20.3	215.3	1.184

Lake Druksiai is the largest lake in Lithuania with a total volume of appr. 369×10^6 m^3. The total surface area of the lake, including nine islands, is nowadays about 49 km^2 (6.7 km^2 in Belarus, 42.3 km^2 in Lithuania). The greatest depth of the lake is 33 m and the average depth is 7 m. The southern part of the lake is the shallowest (3-7 m in depth), whereas greater depths are typical for the central, west and north parts of the lake. The length of the lake is 14.3 km, the maximum width 5.3 km and the perimeter 60.5 km. The lake is characterized by relatively slow water exchange rate. The main outflow is the River Prorva in the southern part of the lake. (*Hydro-physical Basis State in Lake Druksiai 1989; Basis State of Aquatic Animal Populations and Communities in Lake Druksiai 1986; Jakimaviciute et al. 1999, Jurgeleviciene et al., 1983*). The main hydrological parameters of the lake are given in Table 7.1-2.

Table 7.1-2. The main hydrological parameters of Lake Druksiai (at normal water level).

Parameter	Value
Catchment area, km^2	564
Surface area , km^2	49
Average run-off, m^3/s	3.33
Average annual run-off, m^3/year	105.07×10^6
Average precipitation, mm/year	592
Average evaporation from the surface, mm/year	600
Normal water level, m above sea level	141.6
Minimum allowable water level, m above sea level	140.7
Maximum allowable water level, m above sea level	142.3
Regulation height*, m	0.90
Regulating volume of the lake*, m^3	43×10^6
Total volume of the lake, m^3	369×10^6

*Regulation height and regulating volume are given as a difference between normal water level and minimum allowable water level.

7.1.1.3 Water regime of Lake Druksiai

Nearly all surface discharge (74 %) enters the southern part of Lake Druksiai via rivers Ricia (Ricianka) and Apyvarde. The rest of the surface discharge enters the western part of the lake via tributaries Smalva and Gulbine. The outlet of the river Prorva is located at the southern part of the lake. The most intensive water exchange takes place in the southern part of the lake.

The water regime of Lake Druksiai is affected by natural and anthropogenic factors. The main natural factors are surface inflow (73 %) and outflow (77 %). Due to the large surface area precipitation (24 %) and evaporation (23 %) are also significant. The inflow of unconfined and semi-confined groundwater is insignificant (less than 3 %). Outflow to the deeper laying ground water horizons is considered to be very low due to the permeability properties of bed sediments and deposits (*Hydro-physical Basis State in Lake Druksiai, 1989*).

Anthropogenic factors affecting the water regime of Lake Druksiai are regulation of the outflow by the dams (Figure 7.1-3) and cooling water discharge of the NPP. The lake is regulated to maintain stable water level and to ensure a sufficient water supply for cooling of the INPP. Lake Druksiai outflowed via River Druksa until it was dammed downstream the River Apyvarde in 1953 to direct the discharge from the Apyvarde basin to Lake Druksiai (*Mazeika et al., 2006*). In the same year a run-off regulation sluice ("Object 500") was installed on the River Prorva, to regulate the water level of Lake Druksiai. Approximately 1.5 km downstream, between the lakes Stavokas and Abaliai a hydroelectric power plant (HPP) "Tautu draugyste" was built in 1953. The HPP was taken out of operation in 1982. After construction of Ignalina NPP Lake Druksiai water level is regulated using structures of the former HPP.

Evaporation from the lake surface has increased due to the heat entering the lake with INPP cooling water. The average increase in evaporation was 49 % (from 31 % to 67 %) during the warm period of 1984-1996 (V-VIII months) compared to evaporation rates before the construction of INPP (*Kriauciuniene and Sarauskiene, 2008*).

An estimation of the annual water balance of Lake Druksiai is presented in Table 7.1-3 both for regulated and unregulated lake. Water balance of the unregulated lake has been calculated for an average hydrological year. The main inputs are surface inflow (MQ=3.27 m^3/s) and precipitation (592 mm). Groundwater inflow is quite insignificant. The main output is the river outflow (MQ= 3.33 m^3/s). The natural annual evaporation rate is in average 600 mm. Water balance for the regulated lake has been calculated for a dry year with a 1-in-20 year return period (95 % probability). Parameters are the same as for the unregulated lake except that the outflow differs. It is lower than for the unregulated lake (Q= 0.64 m^3/s^*) since the run-off is regulated by the dam at the river Prorva. Due to the regulation the volume available for additional evaporation is larger than in the unregulated lake. In a dry year approximately 33.1 mln.m^3 of water is available for the additional evaporation before the water level drops below the normal (141.6 m).

[*] By order No D1-382 signed in July 29, 2005 (State News, 2005, No 94-3508) of Minister of Environment of Lithuania, that is a minimum acceptable river discharge (for regulated river)

Table 7.1-3. The annual water balance (mln. m^3) for Lake Druksiai.

Parameter	Unregulated, average hydrological year (Outflow MQ = 3.33)	Regulated, average hydrological year (Outflow MinQ = 0.64)	Regulated, dry hydrological year (Outflow MinQ = 0.64)
Surface inflow	103	103	51
Ground water inflow	3.5	3.5	3.5
Precipitation	29	29	22.3
Total input	**135.5**	**135.5**	**76.8**
Outflow	105.1	20.2	20.2
Evaporation	29.4	29.4	23.5
Total output*	**134.5**	**49.6**	**43.7**
Available water volume**		**85.9**	**33.1**

*Approximate amount of ground run-off value or surface water inflow/outflow data, that have been calculated using river-analogue, could be the reasons of water balance inaccuracy (1.004 mln. m^3).
**The available water volume is the volume available above the normal water level (141.6 m) and does not include the regulating volume

The impact of cooling water to the evaporation has been assessed by a regression equation based on actual measurements of the lake evaporation and the INPP operation data. The evaporation measurements were carried out during a warm period. The impact of the NPP on evaporation from the lake is given by ΔE = f (N), where N = NPP operating capacity (in GW). In a range of N = 1-2500 MW the dependence between evaporation and operating capacity can be approximated by linear equation (*Janukeniene 1992*) (Figure 7.1-4):

$\Delta E_{monthly} = 21,4\ N_{\mathrm{monthly}} + 4,9.$

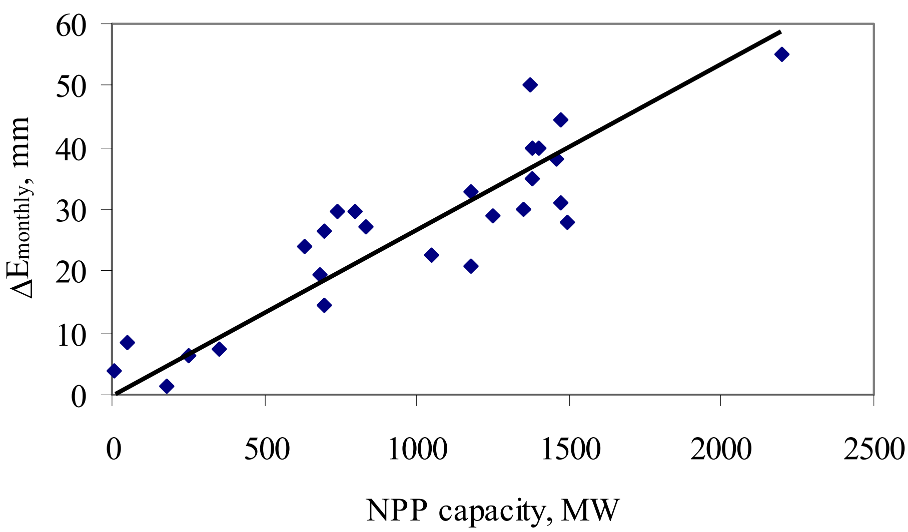


Figure 7.1-4. Correlation between the additional monthly evaporation from Lake Druksiai and the operating capacity of NPP.

The adequacy of the water resources for cooling purposes of the new NPP, with a maximum power output of 3 400 MW, can be assessed based on the regression equation and water balance calculation. According to experts (*Janukeniene 1992*) it can be estimated that 1 000 MW rise in NPP load corresponds to 14.3 million. m^3 increase in evaporation. According to water balance estimation, the amount of water available in a dry year (water height remains at normal level) for cooling is app. 33.1 million m^3. In addition the regulation volume of 43.0 million m^3 is also available for cooling (before the lake level drops below the minimum allowable level). The annual input of 33.1 million m^3 and the regulating volume of 43.0 million m^3 would give adequate water supply in all the evaluated scenarios for about three successive dry years (with a 1-in-20 year return period).

However, there are several factors affecting the reliability of this assessment. First, there can be uncertainties in the estimation of the parameters in water balance calculation due to the limited amount of the hydrological data. For instance, the evaporation measurements have been carried out only in one part of the lake and are therefore not necessarily representative for the whole lake. In water balance calculation for regulated lake the outflow has been estimated based on the difference between total annual input and evaporation, because the actual data of the present outflow from the lake does not exist. Second, the regression equation of the evaporation and NPP capacity is based on evaporation measurements carried out mainly for the effects from 0 to 1 500 MW. The evaporation rate, however, is extrapolated over double (3 400 MW) the original measurement range and hence it includes uncertainties. Therefore the represented assessment should be considered preliminary. A precise hydrological study of the water resources and evaporation rate needs to be carried out as a part of the detailed technical design in the project.

7.1.1.4 Aquatic ecosystem of Lake Druksiai

Several significantly different stages of ecological change in Lake Druksiai, due to the anthropogenic impact, can be distinguished. The first stage began immediately after the construction of the Ignalina NPP started. During that time large amounts of nutrients entered the water together with terrigenic materials (coming from the soil after works, from erosion phenomena, etc.), activating markedly the growth of autochthonous cryophilic (preferring or growing best at low temperatures) algae and cyanobacteria and increasing the activity of primary producers. This, in its turn, affected the organisms of other trophic levels. Even so, Lake Druksiai was classified as low productivity mezotrophic type of lake according to the mean annual values of primary production (25 g C/m^2).

The second stage of ecological change began after the first unit started operating in 1984. The heated water activated the processes, which continued to modify the structure and functional relations of organism communities. The destabilisation of the natural environmental conditions in the lake caused a decrease in the diversity of plankton organisms. The seasonal changes in quantity and biomass became very pronounced. Only 19 % of the phytoplankton species remained in comparison with the pre-operational period. Evidently dominating species composition had been changing. Accordingly, the primary production of organic substances was reduced 5-10-fold. A pronounced change in the diversity of plankton was recorded – their number and biomass were reduced 2.6-fold. It was noted that species of eurytermic organisms adapted themselves more easily to the new unstable conditions and their numbers increased. The abundance of cold-water species decreased.

The third stage of the change of the ecosystem started when the second unit was brought into operation in 1987, which was followed by a period of stable operation of the plant. New conditions developed and stabilised in Lake Druksiai ecosystem. The diversity of plankton organisms began to be restored. However, species more tolerant to increased temperature dominated. Their numbers and biomass and the primary production, particularly during the warm season, now resemble what is seen in eutrophic water bodies.

Water quality based on physicochemical parameters and bioindicators

The most intensive hydrochemical monitoring of Lake Druksiai was carried out between 1979 and 1997. The measurements were made at several sampling points all over the lake (Figure 7.1-5). More recent results (1999-2006) are available from reports on occasionally made investigations and from the monitoring programmes performed by INPP and EPA.

The main pollution source of Lake Druksiai is the household waste water load from the INPP and Visaginas town. The lake receives treated waste water used for household needs in the town and the INPP and untreated water from Visaginas and INPP rainwater sewers. The rainwater from the outbuildings of the INPP (8×10^6 m^3/year) and drainage water (1.5×10^6 m^3/year) extracted in order to keep the groundwater level of the INPP site low enough are led into a rainwater sewer and discharged to Lake Druksiai.

The wastewater treatment plant is designed for biological treatment and complementary cleaning with sand filters. The treated waste water is discharged into Lake Druksiai through the pond of additional purification (Lake Skripku) (tertiary treatment). However, Lake Skripku can nowadays be considered as a secondary source of organic pollution since the settled biomass or superior plants have not been removed and the accumulation of the produced biomass leads to a secondary eutrophication process. Around 5.5×10^6–8.5×10^6 m^3 of water enters Lake Druksiai annually from the wastewater treatment plant.

The INPP consumes about 365 tons of H_2SO_4 and 14 tons of NaOH per year for the regeneration of the resins loaded with strong acidic cationite and strong alkaline anionite, which are used to eliminate soluble salts from the water for the circulation circuits. The spent reagents neutralise one another in a specific tank (pH brought to between 6 and 9). After neutralisation, they are discharged into the rain sewerage system of the site, together with dissolved salts (SO_4^{2-}, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, etc.) (*Almenas et al., 1998*).

Other anthropogenic activities affecting the water quality in Lake Druksiai include the discharge of organic components from agricultural facilities and agricultural fields (fertilizers, soil particles, etc.). These are, however, considered less significant.

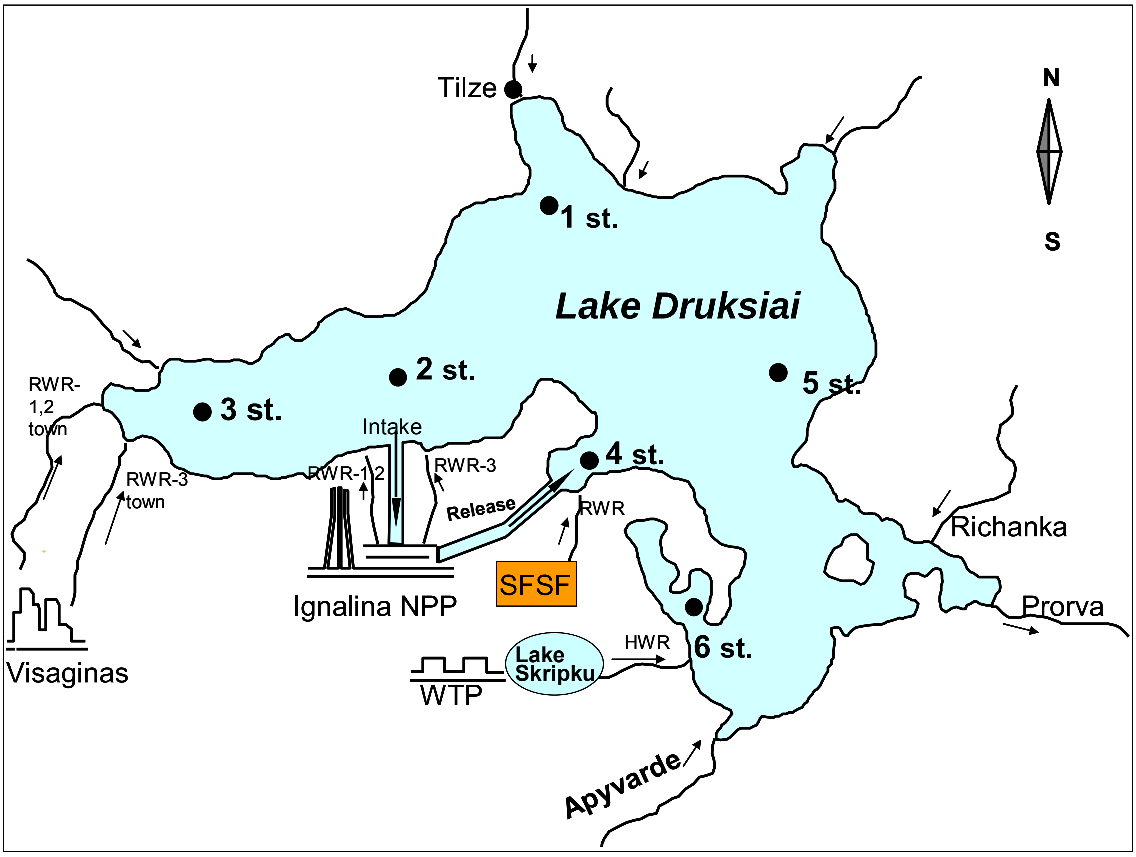


Figure 7.1-5. Permanent sampling station locations (1–6 st.; commonly used for the hydroecological investigations 1979–1997) and main inputs of cooling and waste waters in Lake Druksiai. RWR – rain water release, Intake – cooling water intake, Release – cooling water release, WTP – Wastewater treatment plant of effluents of INPP and Visaginas, HWR– household waste water release after biological treatment and pond (Lake Skripku) of additional purification, SFSF – Spent Fuel Storage Facility.

It can be concluded that the household waste water discharges from Visaginas and the INPP are major contributors of nutrients into the lake. This eutrophication has caused the major changes observed in the aquatic ecosystem of Lake Druksiai. Up to 1000 tons of organic carbon, 700 tons of nitrogen and 50 tons of phosphorus has been entering the lake annually with maximum values before the year 1991 (*Assessment of incoming…, 1991*). It was evaluated that mean annual concentrations of nitrogen and phosphorus in treated effluents even after the pond of additional purification (Lake Skripku) at that time were 37.7 mg N/l and 3.5 mg P/l accordingly. These figures considerably decreased in the last few decades due to improvement of the purification facility of household effluent (Figure 7.1-6). Still this source supplies ca. 55 % of nitrogen and 80 % of phosphorus of total annual amount to the lake (Table 7.1-4) (*Research Study…, 2008*).

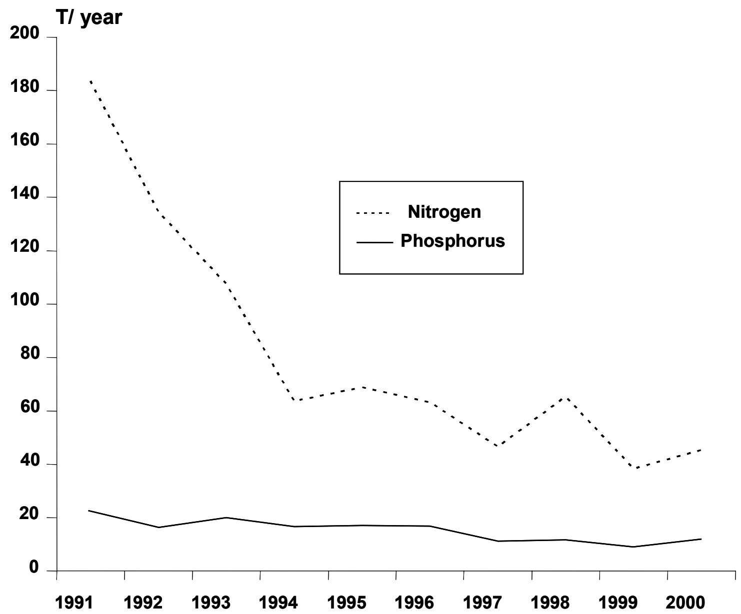


Figure 7.1-6. Nitrogen and phosphorus load into Lake Druksiai.

Table 7.1-4. Long-term balance (1991-2000) of nutrient load to Lake Druksiai.

Sources	N_t, t (N) year $^{-1}$	P_t, t (P) year $^{-1}$
Domestic and urban runoff	**85.53**	**15.291**
rainwater drainage of INPP site (RWR-1,2)	1.663	0.244
rainwater drainage of INPP site (RWR-3)	0.335	0.081
treated household effluents of INPP and Visaginas	81.625	14.720
rainwater drainage of Visaginas town (RWR-2 town)	0.617	0.046
rainwater drainage of Visaginas town (RWR-1 town)	0.416	0.04
rainwater drainage of site of spent nuclear fuel storage facility (RWR –SNSF)	0.870	0.16
Natural runoff	**62.02**	**3.88**
Total input	**147.54**	**19.17**
Prorva (output)	**98**	**14.11**

In addition, the thermal pollution which began in 1984 accelerated the processes of eutrophication. Heated water discharge led to changes in the hydrological conditions of the lake. The surface temperatures increased, the natural vertical thermal stratification was altered and the fast temperature and water usage changes due to unstable operation of the INNP led to acceleration of the hydrodynamic processes. Also, evaporation rates increased.

The increased temperature of the lake and the subsequent decrease of the cold water volume (see Figure 7.1-7 and Table 7.1-4) did not only stimulate the acceleration of eutrophication of the lake but also changed the prevailing conditions unfavourably for organisms able to live only within a narrow low temperature range (stenothermal cryophilic species). However, Lake Druksiai was still classified as low productivity mezotrophic type of lake according to the mean annual values of primary production (25 g C/m^2) (*Research Study…, 2008*) (Figure 7.1-8).

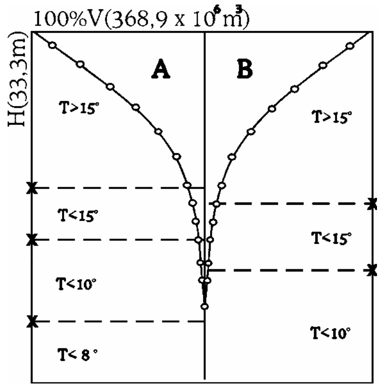


Figure 7.1-7. The distribution of thermic zones during summer stratification in Lake Druksiai, 1977–1983 – A and 1984–1997 m. – B (*Lithuanian State Scientific ..., 1998*).

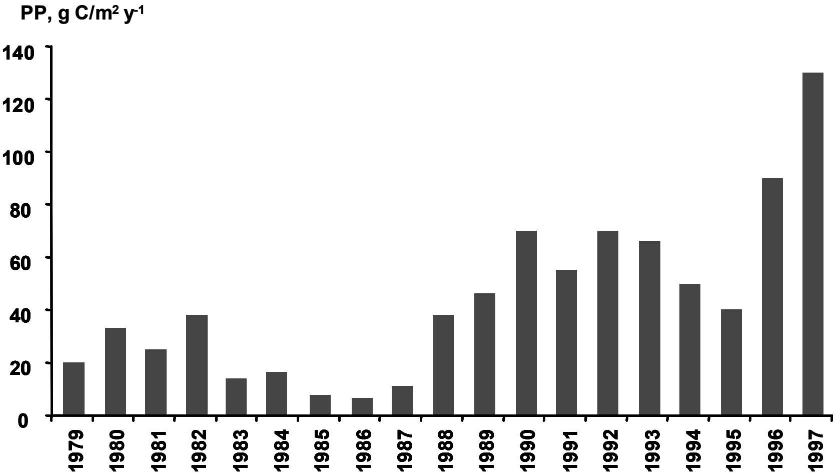


Figure 7.1-8. Mean annual values of primary production (PP, g C/m^2y^{-1}) in Lake Druksiai.

Increased sedimentation of terrigenic materials and organic substances (from 0.5 kg/m^2 in 1979 to 2.9 kg/m^2 per year in 1983) particularly in the deep water areas of the lake led to a fast accumulation of organic matter and nutrients into the bottom sediments. Concentration of dissolved organic material (DOC) has increased since 1979–1983 from 14 mg/l up to 19 mg/l in 2004. Also, increase in particulate organic matter (POC) has been observed in the bottom sediment of the lake.

Due to high activity of micro-organisms a decrease of dissolved oxygen content was also observed, particularly during summer periods and at a depth of below 12 m (Table 7.1-5).Recently the oxygen concentration has fallen below 4 mg/l already at 10 m, i.e. in the upper metalimnion. Oxygen depletion and some products of the terminal anaerobic processes produced unfavourable conditions especially to the cryophilic fish fauna inhabiting the deep layers of the lake.

Table 7.1-5. Distribution of oxygen in Lake Druksiai.

Depth, m	August 1983	August 2007
	O_2, mg/l	
0	8.5	8.64
6	-	8.32
10	6.9	3.84
12	3.3	3.52
14	0.6	1.44
16	0.4	0.64
18	0.1	-
20	0	0.34
30	0	0

Due to the complex (thermal and chemical) anthropogenic impact the following ecological zones have developed in Lake Druksiai (Figure 7.1-9)**:**

- **Zone A**: The most eutrophicated south-eastern part of the lake, where the main source of eutrophication is the household effluents of the INPP and Visaginas with an elevated amount of nutrients (N, P). Increased amount of plankton as well as enhanced activity of production-decomposition processes are observed in this area. BOD_5 reached sometimes 12.5 mg O_2/l in this most polluted area;
- **Zone B**: The cooling water outflow zone is the area of the greatest thermal impact, where water temperature in many cases exceeds 28°C. The lowest abundance and variety of most planktonic organisms (phytoplankton and zooplankton) as well as lower rates of primary production and more intensive decomposition processes of organic matter are observed in this area;
- **Zone C**: The rest of the lake, including the deep and mediate deep zones, where the various impact factors affect the ecosystem occasionally, depending on the INPP operation, wind direction, waves, etc.

Table 7.1-6. Range of fluctuations of some parameters in different zones of Lake Druksiai, July–August 1993–1997 (*Research Study…, 2008*).

Parameter	Zone A	Zone B	Zone C
Secchi depth, m	1.0–2.8	3.0–3.9	1.2–6.5
Chlorophyll a, µg/l	6.6–113.5	0.88–16.5	0.99–70.0
Zooplankton biomass, mg/m^3	2 046–7 180	431–1 863	596–1 153
Phytoplankton primary production, mg C/m^3 d^{-1}	330–2 800	44–440	2–1 500
$C_{org.}$ total in bottom sediments, %	11.7–12.4	3.5–3.7	7.6–12.6
Organic matter mineralization in bottom sediments, mg C/m^2 d^{-1}	1 127–1 590	915–939	513–720

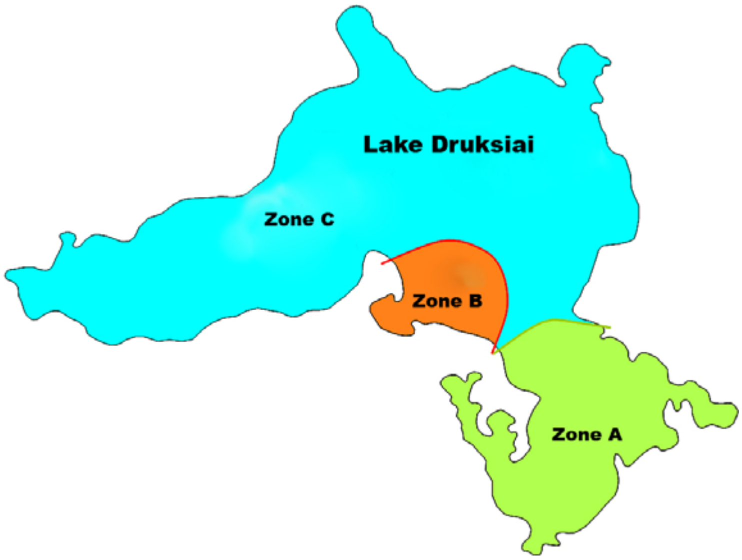


Figure 7.1-9. Distribution of different ecological zones in Lake Druksiai (1997).

During the last 20 years, from the pre-starting period of INPP operation, Lake Druksiai has changed from a mesotrophic lake (with medium concentration of nutrients and biological production) to a eutrophic lake (with elevated concentration of nutrients and biological production). The most obvious evidence of eutrophication has been the evolution of the N_{total}/P_{total} annual average weight ratio from 21:1 (1983) to 8:1 (1997) (*Salickaitė-Bunikienė, Kirkutytė, 2003*). It can be concluded that this has stimulated the changes observed in the plankton community, since reduction of the N/P ratio to values of 5-10 can lead to a community dominated by *Cyanophyta* (*Bulgakov, Levich, 1999*). Until recently the N/P ratio has fluctuated at the same low level or has had a slight tendency to increase (Figure 7.1-10).

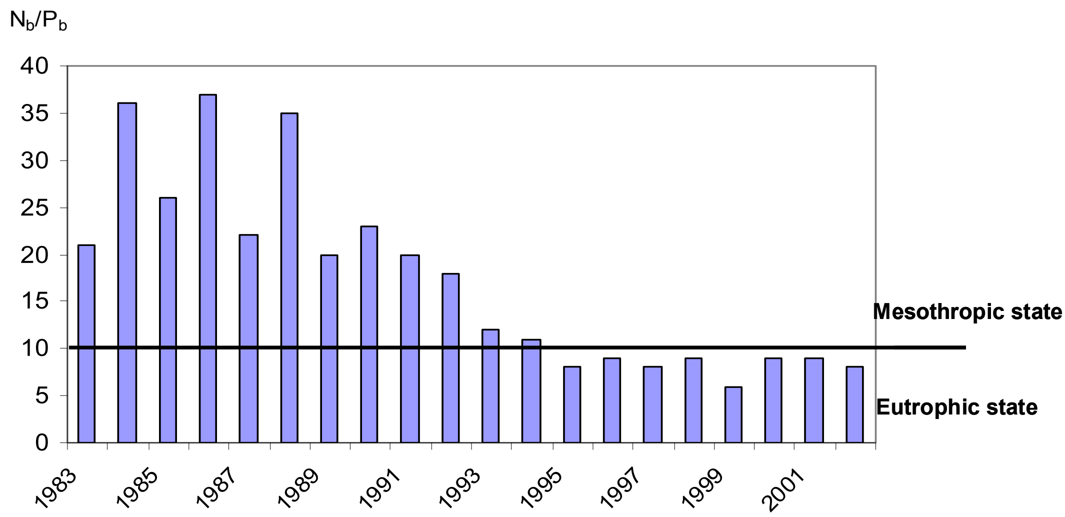


Figure 7.1-10. Mean annual values of N_{total}/P_{total} weight ratio in Lake Druksiai.

After the beginning of INPP operation (1984–1988) mean annual concentration of N_{total} in the water of Lake Druksiai has increased up to 1.53 mg N/l in comparison with that of the prestarting period (1.29 mg N/l) (Table 7.1-7). Later on immobilization and export of organic matter as well as high activity of denitrifying micro organisms in bottom sediments have reduced the amount achievable for other organisms. It has been evaluated that losses of nitrogen due to denitrification reaches 40 % of the total load (*Assessment of incoming…, 1991*).

Table 7.1-7. Long-term annual mean values of of the nutrient concentrations in Lake Druksiai (*Research Study…, 2008*).

Parameters	Periods					
	1979–1983	1984–1988	1989–1993	1994–1997	1998–2002	2001–2006
N-NH_4^+, mg/l	0.22	0.35	0.21	0.20	0.29	0.058
N-NO_x^-, mg/l	0.051	0.062	0.072	0.083	0.054	0.05
N_{total}, mg/l	1.29	1.53	1.14	1.26	1.55	0.93
$P_{min.}$, mg/l	0.007	0.012	0.023	0.025	0.028	0.031
P_{total}, mg/l	0.061	0.05	0.072	0.146	0.179	0.058

At the end of last century the annual average concentration of N_{total} had an even higher range and reached 1.55 mg N/l. According to the data of EPA, at present the annual average nitrogen concentration has a lower range and varies between 1.028 and 0.863 mg N/l (*http://aaa.am.lt/VI/index.php#r/1696*).

Contrary to nitrogen, concentration of phosphorus, both mineral and total concentrations have been increasing almost throughout all the investigation time in Lake Druksiai (Table 7.1-7). Average concentration of phosphates still has tendencies to increase, although total phosphorus (according to EPA data) decreased significantly. This in turn should indicate a tendency of improvement of the environmental conditions in Lake Druksiai.

A slightly increasing tendency of total dissolved salts in the water has been observed recently. Waters of Lake Druksiai are dominantly bicarbonate-calcium with medium total dissolved solids (TDS) content. Evaporation from the surface of a lake was expected to become the most important push to increase the concentration of salts in the remaining water (*Dryzius et al., 1984*). However, it did not have a noticeable effect during several decades of operation of the INPP mainly due to the decrease of HCO_3^- and Ca_2^+ concentration despite the fact that the content of chlorides, sodium, potassium, sulphates, magnesium increased (Table 7.1-8) (*Research Study…, 2008*).

Table 7.1-8. Average long-term main ion concentrations and TDS (Σj) values in Lake Druksiai.

Parameters	Periods				
	1979–1983	1984–1988	1989–1993	1994–1997	2001–2006
Cl^-,mg/l	8.8	9.9	10.7	9.8	12.9
SO_4^{2-}, mg/l	8.9	12.6	18.6	19.3	18.0
HCO_3^-, mg/l	160.5	150.4	157.6	159.4	169.5
Ca^{2+}, mg/l	39.3	35.8	36.8	35.8	37.9
Mg^{2+}, mg/l	10.0	10.9	12.9	13.8	15.9
Na^+, mg/l	4.6	6.3	7.0	6.9	7.5
K^+, mg/l	1.8	2.7	3.0	2.9	3.2
TDS, mg/l	233.9	228.6	246.6	247.9	264.3

It is assumed that fast mass development of alien zebra mussels and aquatic vegetation has led to the decrease of Ca^{2+} and HCO_3^- concentrations at the beginning of INPP operation (*Research Study…, 2008*). Minimal values of TDS were observed in 1985 (Figure 7.1-11).

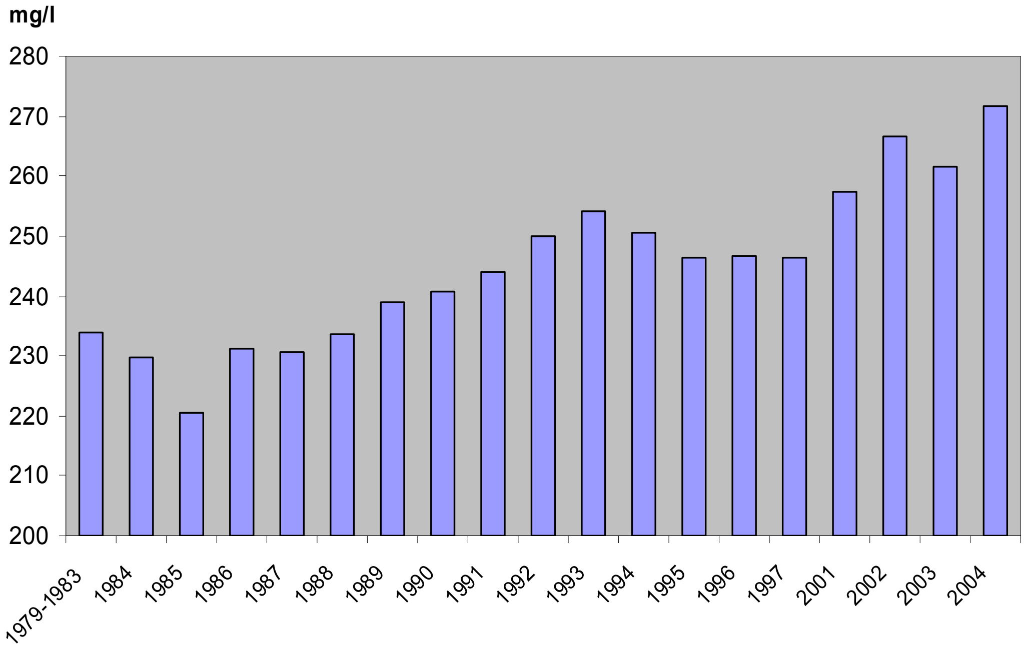


Figure 7.1-11. Long-term TDS values in Lake Druksiai (1979–1997 – average for the whole lake, 2001–2004 measurements were made only in the western part of the lake).

One of the most evident changes that has happened during the operation of the INPP is the quite fast increase of sulphates in the lake water and bottom sediments. The main sources of these sulphur compounds are the discharges of spent reagents (H_2SO_4 and NaOH) into the rain sewerage system after regeneration and neutralization processes. This has led to intensification of microbial sulphate reduction in bottom sediments very fast, eliminating the other terminal process methanogenesis. Therefore, in the pre-start-up and commissioning periods of the first unit hydrogen sulphide was already observed in the bottom sediments in the closest vicinity of the INPP. The highest rate of sulphate reduction (up to 3.8–4.3 mg $S^{2-}/dm^3\ d^{-1}$) was observed in 1992. Later on the intensity of the processes decreased but it continues to remain relatively high in some parts of the lake (Figure 7.1-12). In combination with oxygen depletion it can harmfully influence the living conditions of the fauna inhabiting these water layers.

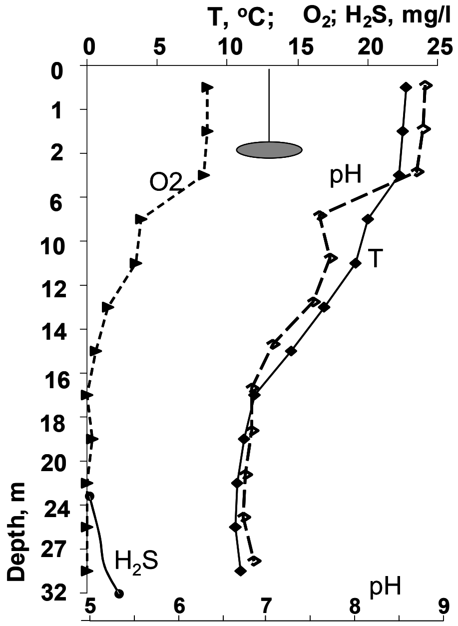


Figure 7.1-12. Vertical distribution of physical-chemical parameters in Lake Druksiai during maximal midsummer stratification, August, 2007 (standard station No. 1).

Direct contamination of Lake Druksiai emanate from the industrial areas and the town via the rain water release systems, supplying the lake ecosystem with many contaminants and inhibitors of biological processes. However, the concentration of copper, lead, chrome, cadmium and nickel has not exceeded the allowable values for water quality, except that manganese reached 47 µg/l (5 times the maximum allowable value) (*EPA Annual report, 2003, http://aaa.am.lt/VI/index.php#r/1696*). It has been estimated that heavy metal contaminated sediments (from intermediate to high level of contamination) cover 27.5 % of the lake bottom area but the major part of this has a natural origin since the natural hydrocarbons dominate. Pollution with oil products was identified in 3.9 % of the bottom area (*Lithuanian state scientific ..., 1998*).

In conclusion, eutrophication, the increase of salts content and warming of the lake water interact to influence the habitats and ecosystems of the lake. Despite these changes in the lake ecosystem, the parameters examined still meet the requirements and range within the limit (imperative or guide) values set up by Directive 78/659/EEC and national legislation (*Order No. D1-663, 2005*) concerning the quality of fresh waters needing protection or improvement to support fish life. The water quality and state of the lake are described to be good and to conform to the quality requirements. All the values are of the same order of magnitude as the ones commonly encountered in surface water bodies (*http://aaa.am.lt/VI/index.php#r/1696*).

Phytoplankton and zooplankton communities in Lake Druksiai

Most of the investigations concerning planktonic organism communities were performed from 1979 to 1997. Tendencies of the changes in different ecological zones were evaluated in 1993-1997 *(Lithuanian State Scientific ..., 1998)*. Since 2001 phytoplankton has been monitored by Lithuanian Environmental protection agency (*http://aaa.am.lt/VI/index.php#r/1696*). In accordance with the State environmental monitoring program only one sampling site was determined in Lake Druksiai in its western part. Due to reduced sampling sites and collecting frequency, data of recent years are scarce and sometimes controversial.

It can be stated that the main impacts that have modified the plankton communities are the thermal releases from the INPP and household waste water or wastes from other activities. The increase in the temperature of the lake and the subsequent decrease of cold-water volume led to changes in species composition. Since 1984 the amount of the prevailing plankton species decreased 2 to 3 fold in comparison with INPP pre-operation: phytoplankton – from 116 to 40–50, metazoo- and protozooplankton – from 118 to 38 and taxa from 129 to 45–53. Phytoplankton dominants from the pre-starting period of the INPP (cyanobacteria *Limnothrix redekei* (Van Goor) Meffert, *Planktothrix agardhii* (Gomont) *Anag*. and *Komar.* and some diatom species) and zooplankton species (e.g. *Limnocalanus macrurus Sars*, relic from glacial period) have disappeared.

The diversity of phytoplankton has decreased and the abundance of the few dominant species has increased in the lake. This can lead to a phenomenon where colonies of one single species (e.g. *Stephanodiscus binderanus* (Kütz.) in March 1992) may become almost monodominant in plankton community. These diatom species have cells surrounded with bulk mucilage during the resting stage of the development. They can hinder the plant operation by accumulating at the cooling water supplying system. In Lake Druksiai this has happened several times in the early nineties during the vernal phytoplankton blooms. Several potentially toxic cyanobacteria species (from genus *Anabaena, Aphanizomenon, Gloeotrichia, Microcystis*) have also been identified. The mass development has been occasionally observed in Lake Druksiai during the midsummer phytoplankton blooms.

The abundance and biomass of phytoplankton have varied significantly during the years 1979-2006 and no clear trend can be observed. However, the biomass of phytoplankton dropped from 2.6 mg/l in 1984 to 0.2 mg/l in 1988 (Figure 7.1-13). It has become more abundant later on performing high variability of development during different years. It could be attributed to instability of the working regime of the INPP within the year. New dominant species composition in phytoplankton community may or may not thrive in randomly changing environmental conditions.

Changes in phytoplankton community in the different parts of the lake were studied during the years 1993–1996 (Figure 7.1-14). Despite high spatial and temporal variability in biomass density the most eutrophicated south-eastern zone has always been the most productive one. Even in this part the interannual variability of phytoplankton development has been quite evident and not necessarily always fluctuating in the manner as in the rest of the lake. In addition, the interannual variability of average concentration of chlorophyll *a* (from 2 to over 14 µg/l) also indicates instability in the ecosystem which has led to high spatial variety even in a highly eutrophicated water body. Therefore, it is not possible to evaluate the state and tendencies of changes of such a water body by means of occasionally performed investigation from one site, not taking into account the large variation between different sites.

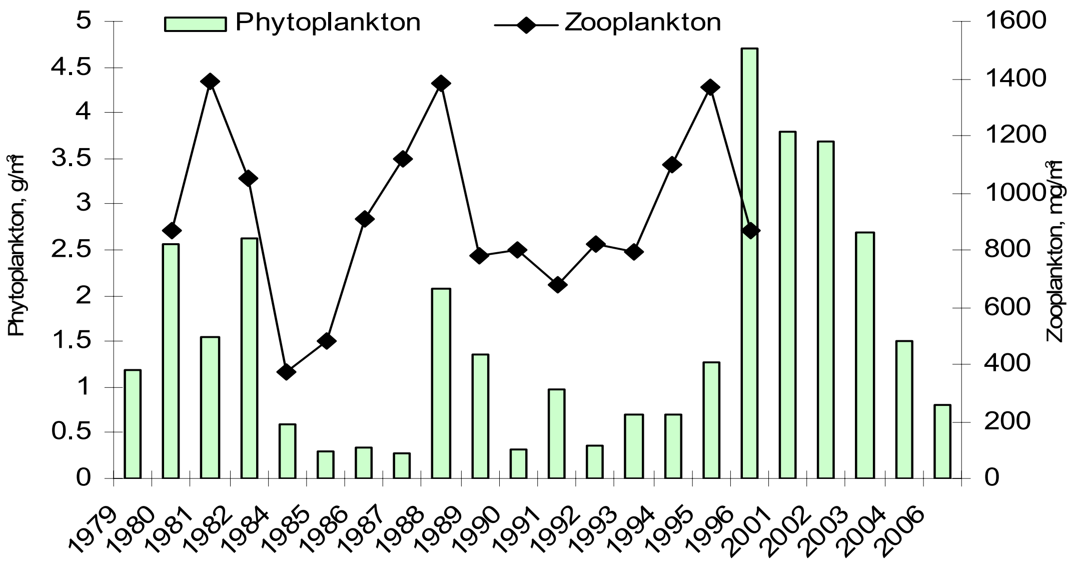


Figure 7.1-13. Interannual variability of yearly average phytoplankton (g/m^3) and zooplankton (mg/m^3) biomass in Lake Druksiai.

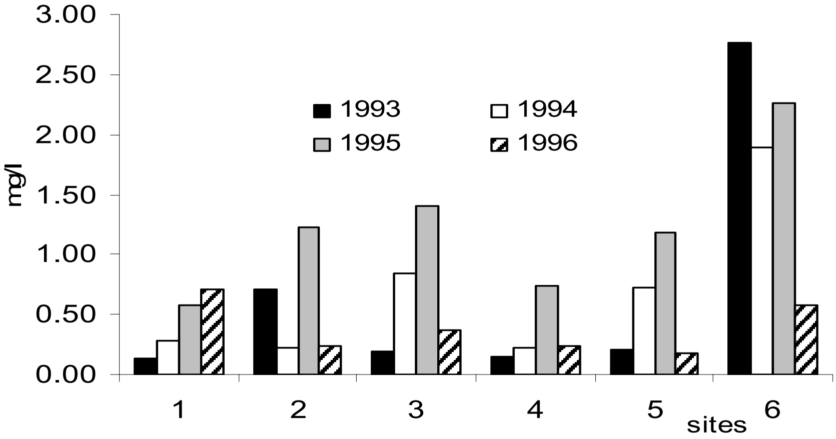


Figure 7.1-14. Interannual variability of yearly average phytoplankton biomass (mg/l) in the different sites of Lake Druksiai.

The abundance of metazooplankton decreased more than 2.7-fold (107.5 to 39.1 thousand ind./l) and protozooplankton halved (from 2.8 to 1.2 thousand ind./l) during the first two years of INPP operation (Figure 7.1-15). After a certain gap of low productivity and changes in dominant species composition in the community, a relatively short increase in zooplankton biomass was observed in Lake Druksiai from 1986 onwards when new conditions developed and stabilised in the ecosystem. At the same time, former numerous but less adaptive to fast changing conditions Rotatoria decreased more than 10-fold (Figure 7.1-15). Crustaceans and especially Cladocera increased significantly for a few years after the plant had started operation. After the year 1988 unstable conditions led to a constant fluctuation in the abundance, biomass and taxonomic variety of the zooplankton in Lake Druksiai.

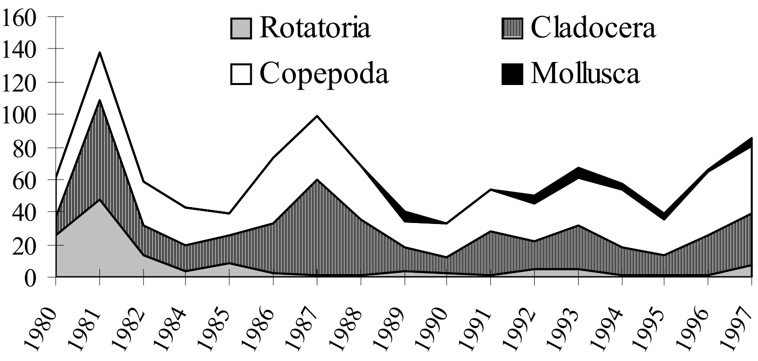


Figure 7.1-15. Interannual variability of yearly average metazooplankton groups abundance (thous.ind./m^3) in the deepest part of Lake Druksiai during 1980-1997 summer periods.

The INPP operation has obviously influenced the plankton community by stimulating temporal and spatial instability of the seasonal succession. Despite the fact that mean annual plankton biomass values have not increased permanently other phytoplankton parameters indicate unpredictable effects of the lake eutrophication. In addition to decreased species diversity, the mass occurrence of cyanophytes is always a signal of severe eutrophication of a lake. Intensity and frequency of the blooms have increased and are varying during the year. Until recently dominant species composition has not stabilized in Lake Druksiai. However, the species mostly characteristic of the eutrophic water bodies are dominating the plankton community.

Aquatic vegetation in Lake Druksiai

During the investigations of Lake Druksiai in 1996–1997 73 aquatic macrophyte species were recorded, among them eight *Charophyta*, two *Bryophyta*, one *Equisetophyta*, and 58 *Magnoliophyta* species.

Altogether 27 vegetation communities (associations) were found. Among them common reed (*Phragmitetum australis*) and common club rush (*Scirpetum lacustris*) communities were dominant in the zone of emerged plants from shore up to a depth of 1.5–2 m; communities of pondweeds (*Potamogetonetum lucentis Potamogetonetum perfoliati*, *Potamogetonetum mucronati*, *Potamogetonetum rutili)* are quite common in the zone at a depth of 1-5 m; community of starry stonewort (*Nitellopsidetum obtusae*) was dominant in the zone of completely submerged plants (limneids) at a depth of 3-5(7) m. Communities of march-grass (*Scolochloetum festucaceae*), smooth stonewort (*Nitelletum opacae*) and horned pondweed (*Zanichellietum palustris*), which are rare for Lithuanian water bodies, were found.

Before operation of the INPP (investigation period of 1979–1983) Lake Druksiai was characterized as a typical mesotrofic lake of moderate depth with well developed submerged vegetation (dominant species *Chara rudis, C. filiformis, Nitellopsis obtusa, Potamogeton lucens, P. perfoliatus*) and fragmentally developed floating leaved and emerged vegetation (*Potamogeton natans, Phragmites australis*). Maximum depth limit for vegetation varied from 7 to 9 metres.

At that time Lake Druksiai was a typical example of water bodies with dominant benthic vegetation of Charophytes. This habitat type is included in Annex I of EEC Habitats directive, as important for protection throughout Europe.

After 20 years of INPP operation significant changes were observed in all ecological zones of aquatic vegetation.

Charophyta species have totally become extinct from the submerged plant zone of shallow areas near the INPP (stations 4, 6 areas influenced by sewage and cooling waters) and only species tolerant to eutrophication (*Ceratophyllum demersum, Myriophyllum spicatum*) have survived.

The decline of Charophytes, especially the earlier dominant *Chara rudis* and *Chara filiformis* species, was observed in the limneid zone (zone of completely submerged vegetation) of the entire lake.

Depth limit for submerged vegetation decreased from 7–9 m to 5–6 m. The intensive development of filamentous green algae during a prolonged vegetation period and decrease of water transparency was an important reason for the decline of submerged vegetation (e.g. Charophytes) from the deepest locations. The areas occupied by helophyte communities (*Phragmites australis, Schoenoplectus lacustris*) increased significantly in shallow areas up to 2 m.

The observed changes in aquatic vegetation, first of all, extinction of *Charophyta* in the zones of obvious thermal and chemical impact and declining of those species in the whole lake is evident indication of increasing trophic state in the cooling reservoir of the INPP (*Blindow, 1992*). Spatial and seasonal fluctuation of turbidity and mass development of filamentous green algae were actual reasons of significant decreases in maximal depth limit of submerged vegetation. Simultaneously, mass development of helophytes in shallow coastal zones of the lake evidently indicates anthropogenic eutrophication.

Bottom fauna and other invertebrates in Lake Druksiai

In investigations on the basic state (1976–1983) of populations and communities of aquatic animals of Lake Druksiai 143 macrozoobenthos species were found, including *Spongia* – 1, *Coelenterata* – 3, *Turbellaria* – 2, *Nematomorpha* – 1, *Oligochaeta* – 37, *Hirudinea* – 7, *Mollusca* – 39, *Crustacea* – 10, *Insecta* – 43 (*Grigelis, 1986*). Dominating taxa were chironomides and oligochaetas and in the littoral and sublittoral zones also molluscs; especially *Dreissena polymorpha*, which settled in the lake during the period of the basic investigations. The dominating species in the littoral and sublittoral were *Stictochironomus psammophilus*, *Psammoryctides barbatus*, *Lumbriculus variegatus*, *Bithynia tentaculatae*, *Leptocerus cinerans*, and in the profundal – *Chironomus anthrecinus*, *P. hommoniensis*, *Chaoborus flavicans*, *Mysis oculata relicta*, *Pallasea quadrispinosa*. Also, several stenothermal (tolerate only a narrow range of temperatures) species were observed; *Ch. ahthracinus*, *S. longiventrus*, *P. amnicum* and glacial relicts *M. o. relicta* and *P. quadrispinosa*.

In the period of 1984–1986 (during the first year of INPP operation), the abundance of former bottom fauna communities (crustaceans and bivalve molluscs - unionids) has decreased. At the same time the number of worm-like organisms (oligocahetes) has increased (*Grigelis, 1993*). The crustaceous species which preferred a narrow range of low temperature and well oxygenated conditions (relicts of the glacial period) have been either completely eliminated or their quantity has significantly decreased.

Changes in the littoral communities have been due to the intensive development of the eurythermal mussel *Dreissena polymorpha* (zebra mussel), which spread to the lake during the period of INPP construction. Until the year 1981 it was observed in only low numbers. However, the juveniles dominated in 1982, and exhibited rapid growth rates during 1983–1984. Massive developments were observed in the meadows of Charophytes and reeds (*Phragmites*) communities. In 1985 the biomass of zebra mussels was 1300 tonnes (*Grigelis, 1993*). The highest biomass observed in 1989 reached 5 600 tonnes.

The biomass of zoobenthos, except that of *Dreissena polymorpha*, has remained unaltered from 1976 until today. Any signs of decrease in zoobenthos due to bottom erosion or redistribution of sediments by circulating currents have not been observed in Lake Druksiai.

Fish community in Lake Druksiai

In its basic state, Lake Druksiai was a typical mesotrophic lake, i.e. one of the early successive stages of Lithuanian lakes, according to the composition of fish community. During the construction and operation of Ignalina NPP the composition of fish community has altered (*Virbickas et al., 1993*).

According to the data from different sources, 23–26 fish species were recorded in the lake in the second half of last century. Before the beginning of the construction of the INPP (1950–1975), the fish community of Lake Druksiai was dominated by lake smelt and vendace, the biomass of which accounted for ca. 40 % of the total fish biomass of the lake. Also roach (*Rutilus rutilus L.*), perch (*Perca fluviatilis L.*), bream (*Abramis brama L.*) and pike (*Esox lucius L.*) were common. Lake Druksiai was also inhabited by alien species introduced from the neighbouring lakes through small streams, namely the Peipsi whitefish (*Coregonus lavaretus maraenoides Poljakow*), common carp (*Cyprinus carpio L.*) and later the pikeperch (*Sander lucioperca L.*) and sunbleak (*Leucaspius delineatus Heck*.), which became widespread all over Lithuania. It is also interesting to note that at that time the lake was home for rarer species – wels (*Silurus glanis L.*) and gudgeon (*Gobio gobio L.*). The littoral zone where rivers take their rise was even inhabited by typical river fishes: bullhead (*Cottus gobio L.*), dace (*Leuciscus leuciscus L.*) and ide (*Leuciscus idus L.*). High fish diversity, including the occurrence of stenothermal species, evidenced highly favourable ecological conditions for this group of fish.

The biomass of lake smelts started to decrease already in the period of construction of the power plant in 1976–1983, when considerable amounts of nutrients found their way from land to water and large zones with lack of oxygen formed in the near-bottom strata of deepwater areas. Particularly drastic decreases in the biomass of stenothermal fish were observed in the first years of operation of the INPP (1984–1986): the total biomass decreased 8-fold, of lake smelts 2.7-fold, and of vendaces even 58.8-fold. In the meanwhile, the total biomass of eurythermal fish species went up by ca. 35 %, though the total biomass of fish community increased by merely 2.5 %. After launching the second reactor unit (1987–1988), the total biomass of fish increased by 14.2 % compared to 1976–1983 (*Research Study…, 2008*).

The population of vendace decreased 28.9-fold during the NPP construction, from 2.31 million in 1979 to 0.08 million individuals in 1981. In the following years abundance of vendace was very low and partial recovery of the population was observed only starting from 1991. The abundance fluctuated insignificantly during the period of 1993–1997 (Table 7.1-9).

Table 7.1-9. Abundance of pelagic fishes in Lake Druksiai according to hydroacoustic study, verified by gillnetting (millions of individuals).

	1979	1981	1983	1985	1986	1991	1992	1993	1994	1995	1996	1997
Lake smelt	25.47	60.78	19.02	5.12	1.12	0.14	0.04	0.02	0.03	0.028	0.027	0.03
Bleak	24.31	12.62	13.2	5.85	2.38	0.79	2.62	4.5	6.2	2.8	3.37	9.85
Perch	0.58	0.96	1.62	1.75	2.99	1.66	7.44	8.9	9.3	7.8	6.94	7.46
Roach	2.59	4.18	3.73	3.19	1.38	1.76	5.41	5.5	7	6.6	5.14	4.43
Vendace	2.31	0.08	0.04	0.08	0.09	0.27	1.2	3.2	3.3	2.3	2.76	2.74
Ruffe	0.29	1.04	0.16	0.25	0.03	0.37	1.31	2.4	2.3	1.8	1.49	1.06
Silver bream	0.05	0.08	0.15	0.17	0.01	0.4	2.1	2	3.4	1.9	1.37	1.29
Bream	0.39	0.48	0.46	0.34	0.48	0.41	1.03	0.8	1.2	0.5	1.32	0.18

Abundance of smelt amounted to 60.8 million individuals in 1981. Later its population decreased to 1.1 million individuals in 1986 and during the period from 1993 to 1997 the population remained very sparse in number. Physiologically optimal temperature for smelt during the summer thermal stagnation is 12°C which is lower than the optimal temperature for vendace. Sharp decrease of smelt abundance could also be attributed to deteriorated oxygen regime in the near-bottom layers, increased rate of sedimentation, and emergence of epizootic sources.

Since the beginning of INPP construction and following its initial operation, the amount of eurythermal and thermophylous fish species constantly increased as well as their relative biomass in the fish community. Notable increase in numbers of perch was observed in the pelagic zone of the lake. Its amount increased from 0.6 million ind. in 1979 to 7.4 million in 1992. Abundance of perch during 1993–1997 remained at high levels and fluctuated insignificantly.

Species composition in the pelagic zone of Lake Druksiai did not change notably during 1992–1997. Eurythermal fish species such as roach, perch, bleak and silver bream (*Blicca bjoerkna L.*) were dominant amounting to 35.5, 20.0, 11.2 and 8.8 % respectively in the total fish biomass. Relative biomass of vendace decreased to 5.5 %, while the amount of smelt in the total biomass dropped even lower to 0.001 %.

No significant fluctuations in the biomass of most fish species were recorded in 1994–1999. The fish biomass of the lake was mainly composed of the populations of 10 species: roach, perch, silver bream, bream, bleak, rudd (*Scardinius erythrophthalmus L.*), gudgeon (*Gymnocephalus cernuua L.*), pike and tench (*Tinca tinca L.*). In total, 18 fish species have been registered in the lake during the investigation period.

Investigations into the change of reproductive indices of fish were carried out in Lake Druksiai in the first years of operation of the INPP (*Virbickas et al., 1993*). However, subsequent investigations in the lake focused merely on changes in fish numbers and biomass in the pelagial of the lake; therefore, they could not give a complete view of qualitative and quantitative changes in the fish community. Investigations into the structure and growth rates of different age groups of the vendace of Lake Druksiai after the INPP started operation showed that their growth rates changed significantly because of change of ecological conditions in the lake (*Research Study…, 2008*).

Roach was a predominant species in both littoral zones of different temperatures in Lake Druksiai. In the 'cold' zone it constituted 41.4 % of the total number of fish, amounting to 50.7 % of the total fish biomass. In the 'warm' zone these numbers were 46.6 and 34.3 % respectively. High abundance of perch and silver bream populations was observed in the littoral zone. Perch amounted to 23 % of fish number in both zones, whereas silver bream constituted 28.9 % and 11 % in the 'cold' and 'warm' zones accordingly. Relative abundance of roach amounted to 17.5 % in the 'warm' zone of the littoral. Relative biomass of the species reached 32.0 %. However, in the 'cold' littoral zone its share was low, constituting 1.7 % in number and 1.7 % of the total biomass. Other fish species in the littoral zone were characterized by low levels of abundance and biomass.

Studies on fish community in different aquatic areas of Lake Druksiai in 2005–2007 revealed significant changes in species diversity and community structure caused by changes in thermal regime and intensive anthropogenic eutrophication.

The species diversity in Lake Druksiai decreased from 23–26 fish species (before INPP operation) to the current list of 14 species. The lake is no longer home to the lake smelt, wels and some introduced species such as the whitefish and pikeperch. The littoral of the lake does not hold river fish species such as the bullhead, dace, ide nor gudgeon, a recent dweller of the littoral. The numbers and distribution of the tench and introduced warm-water species such as the gibel carp and common carp increased; catches of the grass carp and silver carp are also recorded. The list of fish community was composed of typical, most frequent dwellers of such type lakes: vendace, pike, roach, bream, silver bream, tench, bleak, rudd, crucian carp, common carp, spined loach, burbot, ruffe and perch. Among those, 2 fish species are from the list of protected species in the EU Habitat Directive: spined loach, which is a rather frequent species dwelling exclusively in the shallow part of the lake, and vendace, which, contrary to the spine loach, is habiting the deepwater zone of the lake and is a pelagic coldwater fish.

Considerable changes can be observed in the fish community structure as a result of thermal regime changes and impact of intensive anthropogenic eutrophication. The structure of the fish community from years 2005–2007 (density (N, %) and biomass (B, %) per CPUE (catch per unit effort) in Lake Druksiai is presented in Figure 7.1-16.

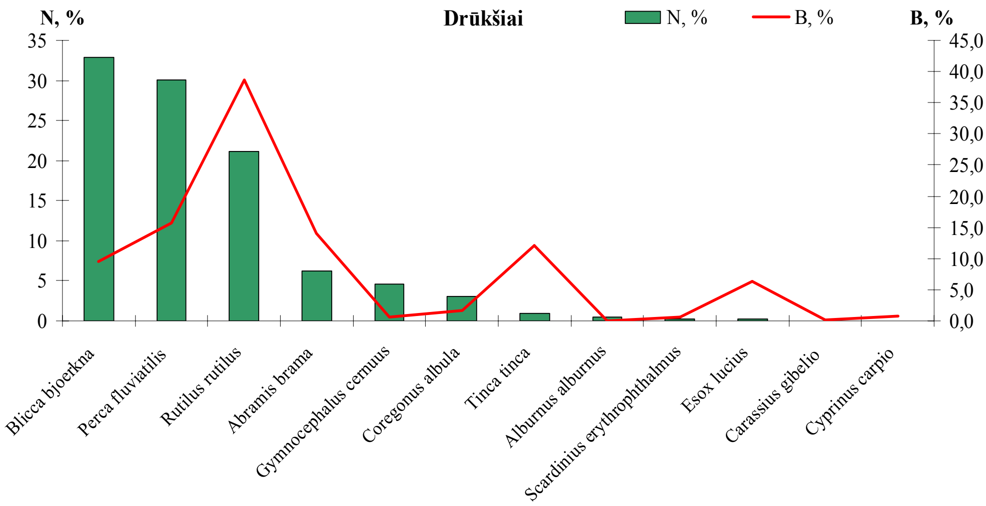


Figure 7.1-16. Fish community structure by density (N, %) and biomass (B, %) per CPUE (30 m length net) in Lake Druksiai in 2005–2007.

Lake Druksiai has undergone a change of dominant species. The fish community is composed mainly of 3 eurythermal species: silver bream (32.9 %), perch (30.1 %) and roach (21.7 %). Recently the abundance of silver breams particularly increased whereas the numbers of the roach and bream decreased accordingly. The populations of stenothermal species decreased to the critical level: the lake smelt is not caught at all and the vendace accounts for merely ca. 3 % of the total number of fish. By biomass, the lake is dominated by the roach (38.7 %) followed by several species with insignificant variations in biomass: perch (15.7 %), bream (14.0 %), tench (12.1 %) and silver bream (9.5 %).

The results of the monitoring of 2007 have revealed differences in abundance and biomass of fish between different sites in Lake Druksiai. In the "warm water" zone, fish abundance in summer and autumn was higher than in the "cold water" zone and reached 61.4 individuals per CPUE, whereas in the "cold water" zone, abundance averaged merely 25.1 individuals. As regards biomass per CPUE, the situation was the opposite, i.e. 59.96 kg in the "cold water" zone against 15.01 kg in the "warm water" zone (Table 7.1-10, Table 7.1-11 and Table 7.1-12) (*Research Study…, 2008*).

Table 7.1-10. Fish species composition, abundance (n), biomass (kg) and catches per unit effort (CPUE, 30 m long net) in the "cold water" zone of Lake Druksiai in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	22	1.4	5.6	0.912	0.059	1.7
Pike	2	0.08	0.31	3.79	0.203	5.9
Roach	141	7.0	27.9	28.767	1.686	49.0
Bream	23	1.3	5.2	8.104	0.457	13.3
Silver bream	69	3.8	15.1	1.654	0.093	2.7
Bleak	3	0.16	0.64	0.008	0.0005	0.01
Tench	10	0.51	2.1	9.835	0.526	15.3
Rudd	2	0.08	0.31	0.345	0.018	0.5
Perch	159	9.4	37.4	6.29	0.382	11.1
Ruffe	23	1.4	5.6	0.258	0.015	0.4
Total:	327	25.13	100	59.963	3.439	100

Table 7.1-11. Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "cold water" zone of Lake Druksiai (profundal zone close to INPP intake) in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	15	1.6	19.0	0.568	0.060	9.7
Pike	1	0.1	1.2	2.230	0.239	38.6
Silver bream	1	0.1	1.2	0.034	0.004	0.6
Perch	54	5.8	69.0	2.876	0.308	49.7
Ruffe	8	0.8	9.5	0.074	0.008	1.3
Total:	79	8.4	100	5.782	0.619	100

Table 7.1-12. Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "warm water" zone of Lake Druksiai in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Roach	93	12.7	20.7	3.424	0.467	22.1
Bream	28	3.8	6.2	0.924	0.126	6.0
Silver bream	221	30.1	49.0	6.066	0.827	39.2
Rudd	1	0.1	0.2	0.054	0.07	3.3
Perch	89	12.1	19.7	4.349	0.593	28.1
Ruffe	19	2.6	4.2	0.194	0.026	1.2
Total:	451	61.4	100	15.011	2.109	100

Fish growth rates in Lake Druksiai changed after the operation of the INPP begun. During the first year of operation, growth rates of almost all fish species, increased, which was due to the rise in water temperature and widespread distribution of molluscs Dreissena (*Virbickas, 1988*).

The growth rates of many species in the "warm water" zone of the lake were faster than those in the "cold water" zone, which could be demonstrated by the comparison of roach and perch growth rates in two thermally different areas of the lake in 2005, i.e. "cold water" zone where the thermal contamination of the INPP was minimal, and the "warm water" zone where water temperature was 4–6°C above the norm. The growth rates of both roaches and perches were considerably faster in the "warm water" zone as regards all middle-age groups.

It can be concluded that the fish community of Lake Druksiai has changed along with the thermal and trophic trends. During a quite short period the fish community of the lake passed over several stages of succession, the rates of succession being tenths of times higher than those in the natural lakes. The species diversity decreased from 23-26 fish species (before launching the INPP) to the current list of 14 species. Abundance of previously dominant stenothermal coldwater fish decreased to the critical level: the lake smelt got extinct, while the vendace accounts for merely ca. 3 % of the total number of fish. Latterly, the fish community is composed basically of 3 eurythermal species: silver bream (32.9 % of the total fish abundance), perch (30.1 %) and roach (21.7 %).

Fishing in Lake Druksiai

Data on commercial fisheries in Lake Druksiai have been collected from 1950 (*Bružinskienė, Virbickas, 1988*). Commercial catches of fishermen were approximately 18.62 t of fish each year during the period 1950–1973, ranging from 6.23 to 36.4 t. The main catch was smelt (38.1 %). The share of bleak in the catches reached 6 t and sometimes more. Catches of vendace were relatively high in some years, e.g. 8 t in 1973. However, considering the large area of the lake, such catches were comparatively low and amounted to 4.4 kg/ha only.

Fishery was not intensive as indicated by age composition of the catches. Common bream were 6-22 years old (predominantly 8–17 years old), pike were represented by 2-14 (5-7), roach – 4-18 (12-15), perch – 4-14 (5-10), vendace – 2-6 (2-3) and smelt by 2-3 years old individuals.

Since the beginning of INPP operation, catches of roach, common bream and bleak increased. At the same time the share of smelt, vendace and pike decreased. During 1974–1983 the average catch per year was 23.43 t (5.5 kg/ha). Catches consisted predominantly of bleak (39.3 %), vendace (14.4 %), roach (13.9 %) and smelt (11.4 %).

Total commercial catches of fish, following the beginning of INPP operation, increased from 18.6 t (4.4 kg/ha) in 1950–1973 to 23.4 t (5.5 kg/ha) in 1974–1983 (Table 7.1-13) (*Research Study…, 2008*).

Table 7.1-13. Commercial catches (t/a) in Lake Druksiai in 1950–1973 and 1974–1983.

Species	1950–1973			1974–1983		
	min	max	mean	min	max	mean
Vendace	0.03	8	1.8	0.01	8.5	3.4
Smelt	0.08	13.1	7.5	0.1	12	2.7
Pike	0.4	2.1	2.3	0.5	4	1.4
Roach	0.4	2.4	0.7	0.2	12.7	3.3
Bleak	0.2	6.8	2.3	0.3	18.4	9.2
Bream	0.04	2.8	0.5	0.3	2.6	1.6
Perch	0.6	6.6	1.7	0.2	1.6	0.7
Other species	0.06	6.2	1.8	0.01	11.6	1.2
Total	1.9	36.4	18.6	9.2	43.9	23.4
kg/ha	1.4	8.6	4.4	2.1	10.1	5.5

Concerning fishery, Lake Druksiai is a highly productive water body intensively used by anglers, but insufficiently exploited by commercial fishery. In 2007, fish stocks of the lake averaged ca. 671.78 t, and the commercial fish catch limit was ca. 67.180 t, or 18.5 kg/ha. Compared with fish stocks of 1994–1999 (ca. 737.59 t), the decrease was ca. 9 % (Table 7.1-14) (*Research Study…, 2008*).

Table 7.1-14. Fish stocks (kg) and commercial production (kg) per year in Lake Druksiai.

Species	Estimation of the size of the fish stocks (kg)	Total catch (kg)		
		Total	Maximum permissible catch of recreational fishery	Maximum permissible catch of commercial fishery
Perch	94860	9486	4743	4743
Roach	290860	29086	14543	14543
Pike	46800	4680	2340	2340
Bream	81740	8174	2452	5722
Tench	93850	9385	2815	6570
Vendace	11410	1141	0	1141
Other	52260	5226	2613	2613
Total	671780	67178	29506	37672

The stocks of some low-value and rarer species have been assessed based on the actual data of experimental fishing; therefore, precise calculations cannot be made. In fact, the general productivity of these species might be higher. This concerns productivity of populations of bleak, burbot, rudd and silver bream. The most remarkable decreases have been registered in the stocks of perch (from 180.5 t to 94.86 t) and vendace (from 30.56 t to 11.4 t). The biomass of other species decreased insignificantly. Tench stocks increased from 7.14 t to 93.85 t, and pike stocks increased from 7.81 t to 46.8 t.

Statistical data show that in 1950–1973 commercial catches used to be 18.6 t (4.4 kg/ha) on average, and in 1974–1983 they increased up to 23.4 t (5.5 kg/ha) (*Bruzinskienė, Virbickas, 1988*). Currently, commercial fishing is not actually pursued, e.g., the catches in 2005–2007 averaged merely 0.381 t (*Research Study…, 2008*).

7.1.1.5 Radionuclides in the water of Lake Druksiai and groundwater

Permission to release radionuclides from nuclear installations into environment is issued by the Ministry of Environment according to the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring" (State Journal, 2001, No. 13-415; 2007, No. 138-5693). According to the existing rules, the Ministry of Environment issues permissions for INPP for releases of radioactive substances into the environment. Waterborne radioactive substances released from Ignalina NPP to Lake Druksiai are continuously monitored. The information on radionuclides that have been actually released into the lake is presented in Table 7.1-15 (*INPP Report ПТОот-0545-14, 2007*). Existing releases to the water are far below the permissible values indicated in the valid permission of the Ministry of Environment.

Lithuanian Hygiene Standard HN 87:2002 (*State Journal, 2003, No. 15-624*) requires that the annual effective dose to the critical group members due to operation and decommissioning of nuclear facility shall not exceed a dose constrain of 0.2 mSv/year. Different release routes (e.g. into the air and water) can lead to doses for the same critical group members. Therefore the dose constraint value used for each route should be one half of the actual dose constraint (i.e. 0.1 mSv per year) (*LAND 42-2007*).

Doses of the ionizing radiation to population due to the existing releases from Ignalina NPP into water are summarized in Table 7.1-16 (*INPP Report ПТОот-0545-14, 2007*). The actual annual dose to critical group members of the population due to the existing radioactive releases of the Ignalina NPP is about 1 % of the established dose limit for the release route trough water (0.1. mSv/year).

Table 7.1-15. Activity (10^6 Bq) of radionuclides released into Lake Druksiai during 2000–2006 and annual limit values.

Nuclide	Year							Average	Annual limit value	% of annual limit value
	2000	2001	2002	2003	2004	2005	2006			
Cs-137	45.5	512	1190	386	245	21.4	24.6	291	20800	1.4
Cs-134	0	1.2	0	0.2	0	0	0	0.2	255.7	0.08
Mn-54	0.3	67.6	0.4	2.4	0.6	0.09	0	10.2	4374	0.23
Co-58	0	15.4	0	0.4	0	0	0	2.26	634.8	0.36
Co-60	39.9	424	8.1	0.9	17.9	10.7	0	71.6	37040	0.19
Fe-59	0	92.1	0	1.9	0	0	0	13.4	872.9	1.54
Cr-51	0	79.9	0	0.9	0	0	0	11.5	1323	0.87
Zr-95	0	83.8	0	0.4	0.2	0	0	12.1	670	1.8
Nb-95	0	129	0	0.7	0.3	0	47.9	25.4	975.7	2.6
I-131	0	0	0	0	0	0	0	0	8641	0
Sr-90	350	91	-	0	0	411	0	142	793.5	17.9
H-3	8.70E5	5.70E5	9.70E5	6.80E5	7.5E5	3.24E6	5.76E5	1.09E6	8.733E6	12.5
Total (gamma)	85.7	1400	1190	394	264	32.1	72.8	491	-	-

Table 7.1-16. Annual dose (Sv) to critical group members of the population (during 2000–2006) due to radionuclides released to Lake Druksiai.

Nuclide	Year						
	2000	2001	2002	2003	2004	2005	2006
Cs-137	$1.09{\cdot}10^{-7}$	$1.23{\cdot}10^{-6}$	$2.85{\cdot}10^{-6}$	$9.26{\cdot}10^{-7}$	$5.88{\cdot}10^{-7}$	$5.1{\cdot}10^{-8}$	$5.98{\cdot}10^{-8}$
Cs-134	-	$9.09{\cdot}10^{-9}$	-	$1.71{\cdot}10^{-9}$	-	-	-
Mn-54	$3.0{\cdot}10^{-11}$	$5.54{\cdot}10^{-9}$	$3.0{\cdot}10^{-11}$	$1.9{\cdot}10^{-10}$	$4.8{\cdot}10^{-11}$	$7.4{\cdot}10^{-12}$	-
Co-58	-	$4.0{\cdot}10^{-10}$	-	$1.0{\cdot}10^{-11}$	-	-	-
Co-60	$4.79{\cdot}10^{-8}$	$5.09{\cdot}10^{-7}$	$9.72{\cdot}10^{-9}$	$1.13{\cdot}10^{-9}$	$2.14{\cdot}10^{-8}$	$1.28{\cdot}10^{-8}$	-
Fe-59	-	$1.57{\cdot}10^{-9}$	-	$3.0{\cdot}10^{-11}$	-	-	-
Cr-51	-	$1.0{\cdot}10^{-10}$	-	-	-	-	-
Zr-95	-	$4.4{\cdot}10^{-10}$	-	-	$1.11{\cdot}10^{-12}$	-	-
Nb-95	-	$1.80{\cdot}10^{-7}$	-	-	$9.7{\cdot}10^{-10}$	$4.41{\cdot}10^{-10}$	$6.71{\cdot}10^{-8}$
I-131	-	-	-	-	-	-	-
Sr-90	$6.57{\cdot}10^{-7}$	$1.73{\cdot}10^{-6}$	$9.42{\cdot}10^{-7}$	-	$6.93{\cdot}10^{-7}$	$7.81{\cdot}10^{-7}$	0
H-3	$7.46{\cdot}10^{-8}$	$1.76{\cdot}10^{-7}$	$2.33{\cdot}10^{-7}$	$1.07{\cdot}10^{-7}$	$1.20{\cdot}10^{-7}$	$1.13{\cdot}10^{-7}$	$2.02{\cdot}10^{-8}$
Total	$8.93{\cdot}10^{-7}$	$3.79{\cdot}10^{-6}$	$4.08{\cdot}10^{-6}$	$1.04{\cdot}10^{-6}$	$1.42{\cdot}10^{-6}$	$9.59{\cdot}10^{-7}$	$1.47{\cdot}10^{-7}$
Total (from γ nuclides)	$1.57{\cdot}10^{-7}$	$1.93{\cdot}10^{-6}$	$2.86{\cdot}10^{-6}$	$9.30{\cdot}10^{-7}$	$6.10{\cdot}10^{-7}$	$6.41{\cdot}10^{-8}$	$1.27{\cdot}10^{-7}$

The total average annual dose of the total doses during 2000–2006 given in Table 7.1-16 is 1.23 10^{-6} Sv or 1.23 10^{-3} mSv/year. As mentioned above, the dose constraint for release route into the water is 0.1 mSv/year. Therefore, the annual total dose to critical group members of the population constitutes only 1.23 % of the dose constraint established by Lithuanian legislation and regulations.

The measurements of ^{3}H and ^{14}C activity concentration in water from the Lake Druksiai and other surface water bodies have been started already before INPP operation (*Jasiulionis et al., 1993; Mazeika et al., 1995; Mazeika et al., 1998*). After the start-up of INPP operation the new monitoring points on surface water bodies related to INPP industrial site were established: cooling water inlet channel (IC), heated water outlet channel (OC), industrial rain drainage (IRD) channels 1, 2, and 3 (Figure 7.1-17).

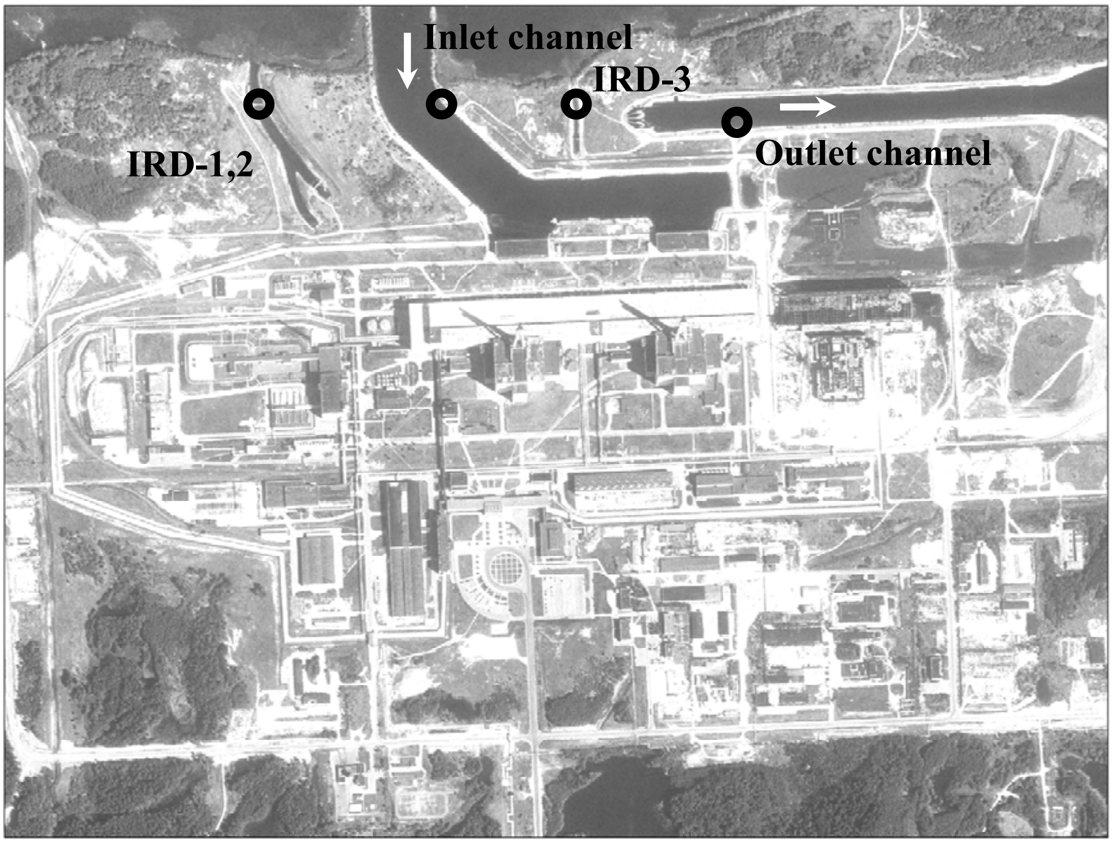


Figure 7.1-17. Observation points on main channels related to INPP industrial site.

The water samples for ^{3}H and ^{14}C measurements were usually taken 1–2 times a year. In the period of 2003–2004 ^{3}H activity in water was measured almost every month. Because of complicated methods for ^{14}C determination, the samples for the ^{14}C measurement in this period were taken only 1–2 times a year. Activity concentration of other radionuclides (^{90}Sr, ^{60}Co, ^{137}Cs) in surface water bodies were measured rarely.

The measurements of ^{3}H and ^{14}C activity concentration in groundwater started in the period of INPP construction. In that time groundwater samples were taken from shallow dug wells in Kimbartiske, Antalge, Zibakiai rural localities. Systematic monitoring network for unconfined groundwater observation was established in 1987. There were about 30 observation wells with depth up to 10 m in the INPP region, including Lake Druksiai catchment territory in Belarus and Latvia. From that period about 15 observation wells remain in Lithuanian territory. The majority of observation wells are suitable for water sampling for ^{3}H measurements but none of them is suitable for ^{14}C activity measurement. The water inflow to the filters of observation wells is too low to collect necessary quantity of water for ^{14}C activity measurements. The general view of groundwater monitoring network is shown in Figure 7.1-18.

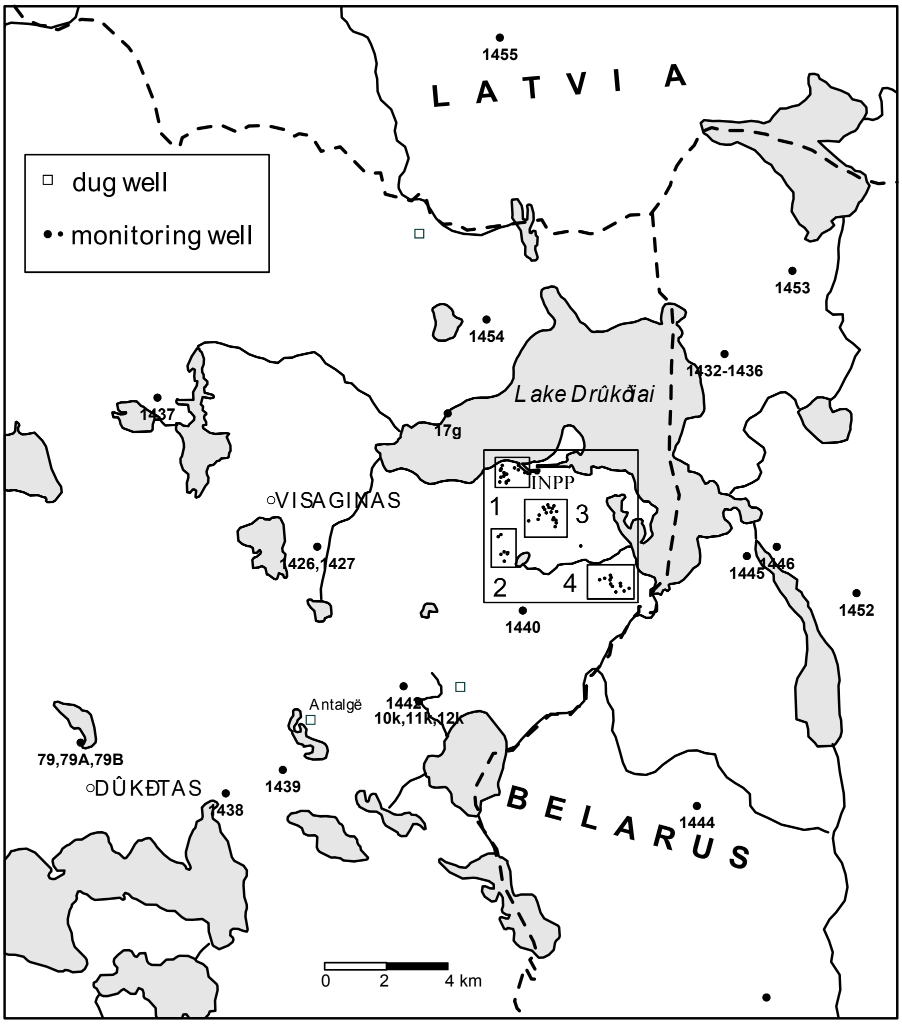


Figure 7.1-18. Groundwater monitoring network in the INPP region existed in different periods.

On this scheme the first group of observation wells is located close to the radioactive waste storage area of the INPP in the western part of the INPP industrial site between NPP and the Lake Druksiai. The second group of observation wells is located in the surroundings of Visaginas wastewater treatment plant. The third group of observation wells is located in Stabatiske site and the fourth in Galilauke site.

The activity concentration of ^{14}C in environmental samples was measured by liquid scintillation counting on benzene prepared from sample material as described in Gupta and Polach 1985. The ^{3}H activity concentration in surface water, groundwater and water extracted from biota was also measured by liquid scintillation counting of water sample mixed with scintillation cocktail (*LST ISO 9698:2006*).

An intensive monitoring study of radionuclides in the environment was carried out in 2007. ^{3}H activity concentration was measured from 6 surface water samples and ^{14}C activity concentration was measured from 3 surface water samples. From groundwater monitoring wells 17 water samples were taken for ^{3}H activity concentration analysis. ^{14}C activity concentration was measured from 4 groundwater samples. Gamma ray emitting radionuclides and ^{90}Sr were measured from 5 groundwater samples. ^{3}H and ^{14}C activity concentrations were also measured from other objects such as birch sap, aquatic and terrestrial plants and bottom sediments. The main results of the study are presented in Table 7.1-17, Table 7.1-18 and Table 7.1-19.

Table 7.1-17. ^{3}H and ^{14}C activity concentration in surface water in 2007.

No	Sampling point location	Sampling date	^{3}H, Bq/l ±1σ	^{14}C, Bq/m^{3} ±1σ
1	Zarasai district, Smalvele river	29-06-2007	1.3±0.4	6.8±0.3
2	INPP, inlet channel (IC)	28-06-2007	4.9±0.5	9.3±0.5
3	Lake Druksiai, 1 station, top water	27-06-2007	4.2±0.5	8.9±0.2
4	Lake Druksiai, 1 station, bottom water	2007-06-27	5.4±0.5	-
5	IRD-1,2	28-06-2007	36.9±2.0	-
6	IRD-3	28-06-2007	16.9±1.0	-

Table 7.1-18. ^{3}H and ^{14}C activity concentration in groundwater in 2007.

No	Sampling point location	Sampling date	^{3}H, Bq/l ±1σ	^{14}C, Bq/m^{3} ±1σ
1	Zarasai district., Budiniai, well 17g	02-04-2007	1.6±0.4	-
2	Zarasai district., Budiniai, well 17g	28-06-2007	1.2±0.4	-
3	INPP region, Stabatiske, well 6k	02-04-2007	1.3±0.4	-
4	INPP region, Stabatiske, well 6k	29-06-2007	0.5±0.4	11.0±0.1
5	INPP region, Grikiniske, piezometer	28-06-2007	1.1±0.4	-
6	INPP region, piezometer 40036p	28-06-2007	2.5±0.5	-
7	INPP region, well 40036	28-06-2007	2.5±0.5	20±0.2
8	INPP region, well 40035	28-06-2007	1.0±0.4	16.4±0.2
9	INPP region, Stabatiske, well 4	28-06-2007	1.4±0.4	-
10	INPP region, well 71z	28-06-2007	4.6±0.5	-
11	INPP region, well 1431	29-06-2007	2.7±0.5	-
12	INPP region, well 35955	29-06-2007	0.3±0.4	-
13	INPP region, well 1430	28-06-2007	2.7±0.5	-
14	INPP region, well 1429	28-06-2007	3.7±0.5	-
15	INPP region, well 35221	29-06-2007	1.5±0.5	40.4±0.4
16	INPP region, well 35219	29-06-2007	1.1±0,5	-
17	INPP region, well 35220	29-06-2007	7.1±0.7	-

Table 7.1-19. ^{90}Sr, ^{137}Cs and ^{60}Co activity concentration in groundwater in 2007.

No	Sampling point location	Sampling date	Activity concentration, Bq/m^{3} ±1σ		
			^{90}Sr	^{137}Cs	^{60}Co
1	INPP region, well 1429	28-06-2007	33±4	<1.5	<1.5
2	INPP region, Grikiniske	29-06-2007	1.0±0.3	<1.4	<1.5
3	INPP region, well. 35955	29-06-2007	30±4	<1.1	<1.1
4	INPP region, well 40035	28-06-2007	<1	<1.0	<1.0
5	INPP region, well 35221	29-06-2007	<1	<2.1	11.5±1.7

The measurements of ^{3}H activity concentration in water from Lake Druksiai occurred with different frequency. ^{3}H activity concentration trend line of the background water bodies (Lake Druksiai till 1984, Lake Dysnos and Smalvele River for later years) is decreasing. This is due to the decrease of ^{3}H, originating from the thermonuclear weapon tests, almost to the level of ^{3}H activity which corresponds to the cosmogenic production of ^{3}H. The difference between the background water bodies and Lake Druksiai display the increase of ^{3}H activity concentration originating from the radioactive effluents released by the INPP during normal operation. For the period of 1980–2007 the highest ^{3}H activity concentration in Lake Druksiai was observed in year 2003 and reached 24 Bq/l. ^{3}H activity concentration in Lake Skripkos located next to the Visaginas wastewater treatment plant was highest in 2000 and reached 30 Bq/l. During this period ^{3}H activity concentration in the background water bodies was 2–3 Bq/l, therefore approximately 20–25 Bq/l originated from INPP releases (Figure 7.1-19).

The ^{3}H concentration in the additional monitoring points on surface water bodies such as cooling water inlet channel (IC), heated water outlet channel (OC), industrial rain drainage (IRD) channels 1, 2 and 3 has been systematically measured since 1992. The same ^{3}H background line has been applied to this data. ^{3}H activity concentrations in the channels exceeded the background level during the whole period of observation.

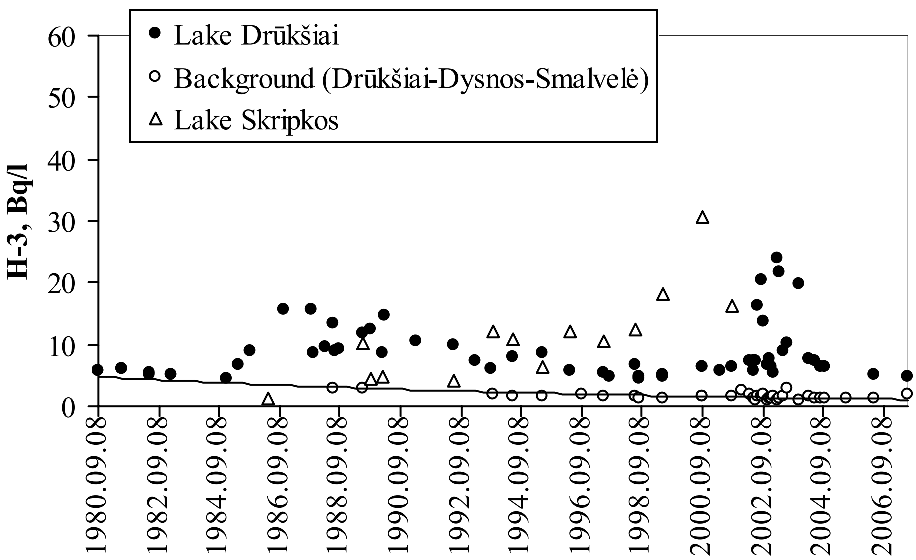


Figure 7.1-19. ^{3}H activity concentration in Lake Druksiai, Lake Skripkos and background water bodies in 1980–2007.

The flow rate of industrial rain drainage (IRD) channels 1 and 2, and especially that of channel 3 is low compared to the flow rate of the heated water outlet channel. Therefore radioactive effluents in IRD channels are less diluted and more variable in terms of ^{3}H activity concentration compared to the whole Lake Druksiai water body. The ^{3}H variations were investigated with higher temporal resolution in 2001–2004 when samples were taken more frequently – about once a month. At that time ^{3}H activity concentration in the water from channels 1 and 2 varied from 10 to 50 Bq/l (Figure 7.1-20).

Traces of ^3H originating from the INPP are found in the surface water. However, the impact on human and ecosystems is considered insignificant since the individual effective dose to critical group member is less than 0.02 µSv/year.

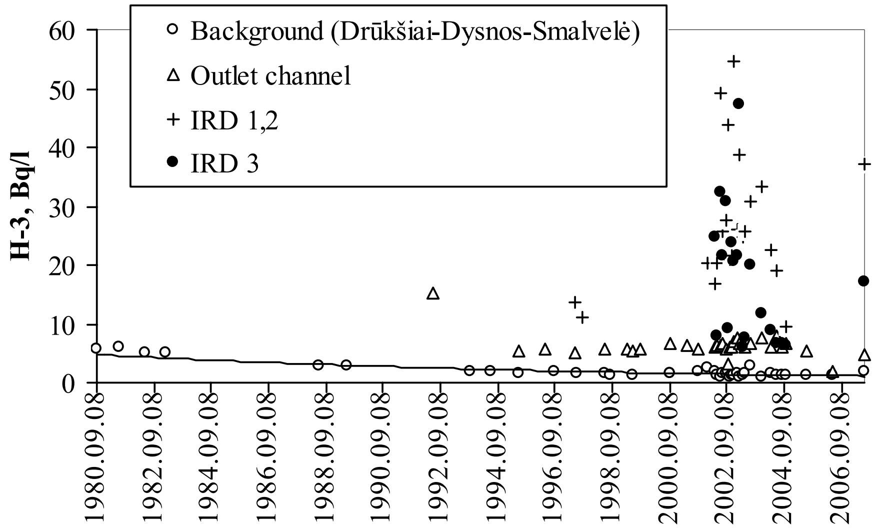


Figure 7.1-20. ^3H activity concentration in channels related to industrial site of INPP in 1980–2007.

^{14}C activity measurements in DIC of surface water bodies started in 1975. Water samples were taken with varying frequencies (Figure 7.1-21).

^{14}C activity concentration in background water bodies is parallel to the international data for Northern Hemisphere. The excess of ^{14}C originated from thermonuclear weapon tests declined almost to the ^{14}C level of cosmogenic origin for all studied surface water bodies. From period of 1992–1993 in the atmosphere and in the surface water all over the world predominates ^{14}C of cosmogenic origin. Almost for the whole period of the ^{14}C monitoring in surface water the influence of INPP has been hardly detected. ^{14}C activity concentration in water from Lake Druksiai and from the cooling water inlet channel has increased in 2001–2006, while it decreased again in 2007. The highest activity of ^{14}C, 13.6±0.2 Bq/m^3, was observed in 2005, while the background level was about 10.0±0.2 Bq/m^3. The increase of ^{14}C activity was about 3.6 Bq/m^3. The ^{14}C activity reduced in 2007 to 8.9 Bq/m^3.

Traces of ^{14}C originating from the INPP are found in the surface water. However, the impact on human and ecosystems is considered insignificant since the individual effective dose to critical group member is less than 0.5 µSv/year.

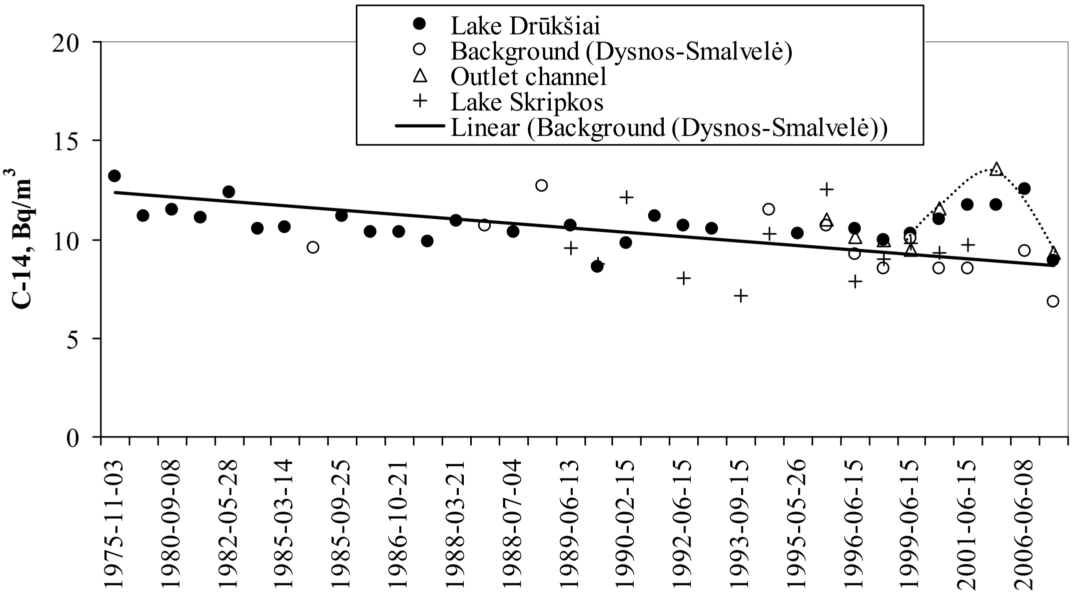


Figure 7.1-21. ^{14}C activity concentration in Lake Druksiai, Lake Skripkos, heated water outlet channel and background water bodies in 1975–2007.

^3H activity concentrations were measured systematically in the groundwater from monitoring wells 71z, 1429, 1430, 1431, which are located close to the INPP. These monitoring wells are located in line downflow from the INPP to Lake Druksiai. The ^3H concentrations in groundwater were monitored between 1987 and 2007 (Figure 7.1-22).

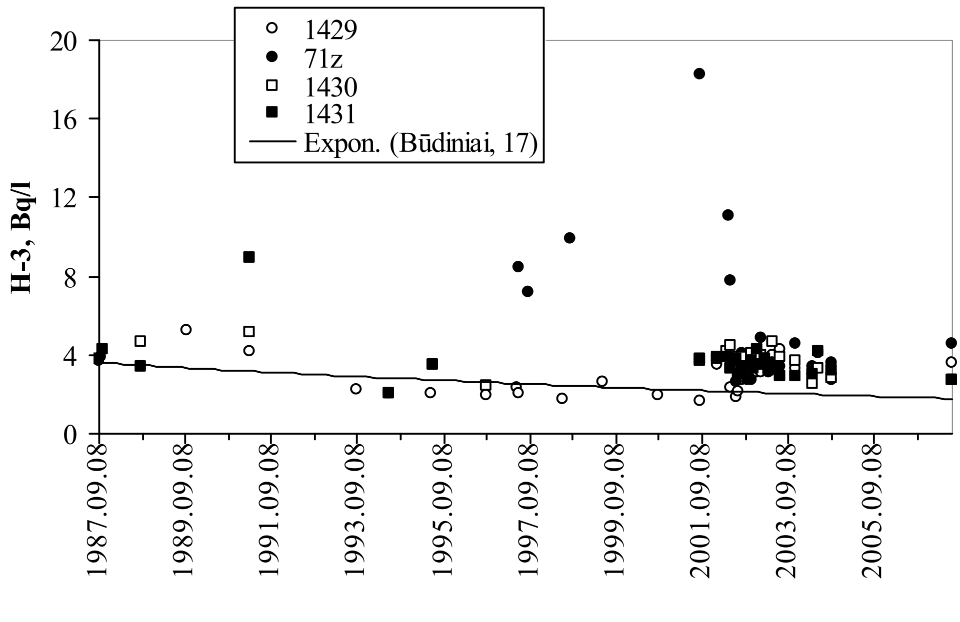


Figure 7.1-22. ^3H activity concentration in groundwater in 1987–2007.

Background samples were taken from the observation well Budiniai, 17. This well is located on the northern shore of Lake Druksiai and is not related to the INPP industrial site. ^3H activity concentration was higher than the background level only in observation piezometer 71z, which is closest to the INPP. The highest ^3H activity (18.3 Bq/l) was measured in 2001. ^3H background level at that time was about 2 Bq/l. In down-flow direction from INPP the level of ^3H activity in groundwater is decreasing and for the most part remains very close to the background level. The ^3H concentration in observation well 1431 installed very close to the lake was somewhat higher than the background level when there was inflow to the well from Lake Druksiai.

There are more ^{3}H data available than ^{14}C data of groundwater. The ^{14}C activity concentrations in groundwater from the years 1987–2007 are presented in Figure 7.1-23.

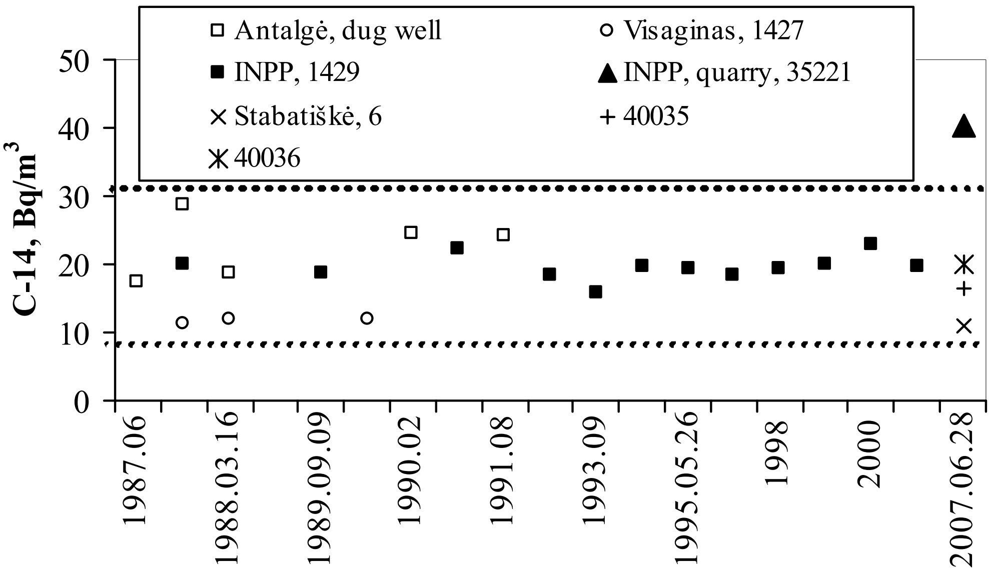


Figure 7.1-23. ^{14}C activity concentration in groundwater in 1987–2007 (dashed lines show ^{14}C background level range).

The ^{14}C activity in groundwater has never exceeded the global level. The influence of INPP has not been observed.

Large water volume (150–300 l) for ^{14}C activity measurements is required. Therefore it is possible to take samples only from a few observation wells located in the area of INPP. In 2007 it was observed that the ^{14}C activity level in the quarry observation well 355221 was somewhat higher than the activity caused by global sources. ^{14}C activity was 40.4±0.4 Bq/m^{3}. In the previous period the sludge from the Visaginas wastewater treatment plant was disposed of to the same quarry.

The activity of ^{90}Sr and gamma ray emitting radionuclides in groundwater was also measured together with ^{3}H and ^{14}C. Their activities were often very low and mostly less than minimal detectable activity (<MDA). Very insignificant activity concentration of ^{60}Co was determined in the water from quarry observation well.

7.1.1.6 Radioecological state of flora and fauna of Lake Druksiai

Research scope and methods

Samples of plants and bottom sediments were collected at the monitoring stations of Lake Druksiai and in the INPP industrial storm water discharge and cooling water channels in 1988–2004 and 2007 (Figure 7.1-24). In addition samples of fish and mollusc were collected. Indicator organisms of flora in Lake Druksiai are presented in Table 7.1-20. Activity of ^{137}Cs, ^{90}Sr, ^{60}Co, ^{54}Mn and ^{90}Sr was measured according to the methods described by Gudelis et al,(*2000*), Luksiene et al (*2006*)*,* Sokolova (*1971*)*,* Pimpl (*1996*) and Suomela (*1993*).

Terrestrial plants for determination of the radioecological state of the Ignalina NPP region were collected in the reference sites of the region and in background monitoring stations of the regions of Lithuania (Figure 7.1-24). The indicator organisms of terrestrial flora and research results are presented in section 7.6.1.1.2.

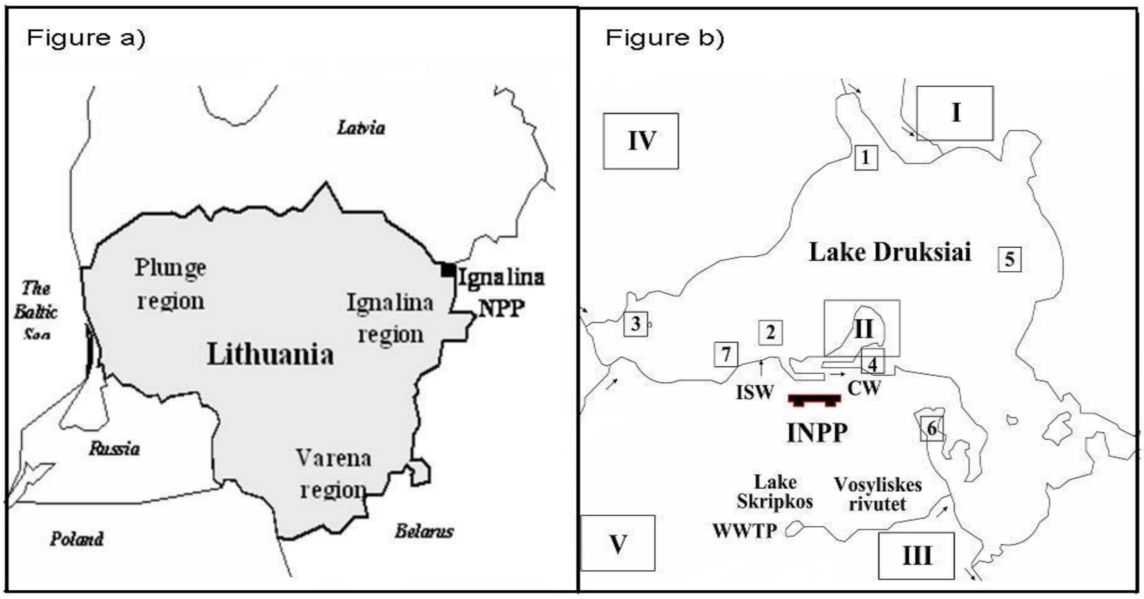


Figure 7.1-24. Regions of sample collection of water plants, bottom sediments and terrestrial plants: Figure a) Stations of background monitoring of the regions of Lithuania (Plunge, Varena, Ignalina); Figure b) Reference sites of the Ignalina NPP region (I – Tilze, II – Grikiniskiai, III – Vosyliskes, IV – Sakiai – Zavisiskes, V – Visaginas). Monitoring stations of the Lake Druksiai.[1]

Research results

The radioecological state of plants, bottom sediments, mollusc and fish of Lake Druksiai (1988–2007) is presented in this section.

The values of ^{137}Cs, ^{90}Sr, ^{60}Co and ^{54}Mn activities detected in plants and bottom sediments of Lake Druksiai in 1988–1999 were high depending on year and monitoring station. Highest values of ^{60}Co and ^{54}Mn activity in lake plants (respectively 200 and 90 Bq/kg) and bottom sediments (respectively 180 and 204 Bq/kg) were detected in the impact areas of the waste water of ISW and CW channels (7-th and 4-th monitoring station). In most cases highest values of activities of all analyzed radionuclides in bottom sediments and plants of Lake Druksiai were detected in the period 1988–1990. However, from 1994–1996 a tendency of reduction of radionuclides activity, especially ^{60}Co and ^{54}Mn, in plants and bottom sediments has been observed.

In 1996 ^{134}Cs activity varied between 2–52 and 2–20 Bq/kg in bottom sediments and plants in Lake Druksiai. In the period 1991–1997, values of ^{137}Cs activity levels of molluscs *Dreissena polymorpha* in Lake Druksiai, depending on the year of analysis

[1] St. 1 – the furthest from the INPP; St. 2 – at the zone of the power plant water collection; St. 3 – to the west from the power plant by the Visaginas city (at the zone of industrial-storm water sewage discharge of the city); St. 4 – about 200 m from the cooling water discharge channel; St. 5 – at the end of the cooling water zone; St. 6 – to the east from the power plant, in the impact zone of waste water of the Visaginas municipal WWTP; St. 7 – close to the INPP, in waste water zone of industrial-storm water sewage discharge; CW – cooling water channel; ISW – channel of industrial-storm water and process water discharge; WWTP –Visaginas municipal waste water treatment plant.

and place of collection (monitoring station), ranged between 4–50 Bq/kg, ^{60}Co – 3–129 Bq/kg, ^{54}Mn – 1–56 Bq/kg, and ^{90}Sr – 24–94 Bq/kg dry weight (d.w.).

Highest values of activity of radionuclides in fish in Lake Druksiai were detected in 1988. Activity of ^{137}Cs in predatory fish (perch and Northern pike) was significantly higher than in cyprinid fish (roach and carp bream). However, activity of ^{137}Cs in both predatory fish and cyprinid fish has dropped in 1994. Activities of ^{137}Cs in muscles of fish have been higher than in whole fish (Figure 7.1-25). Values of ^{90}Sr activity in fish did not depend on the nutrition. Values of ^{60}Co and ^{54}Mn activities in fish of Lake Druksiai have been low. (*Luksiene, 1995; Marciulioniene, Petkeviciute, 1997*).

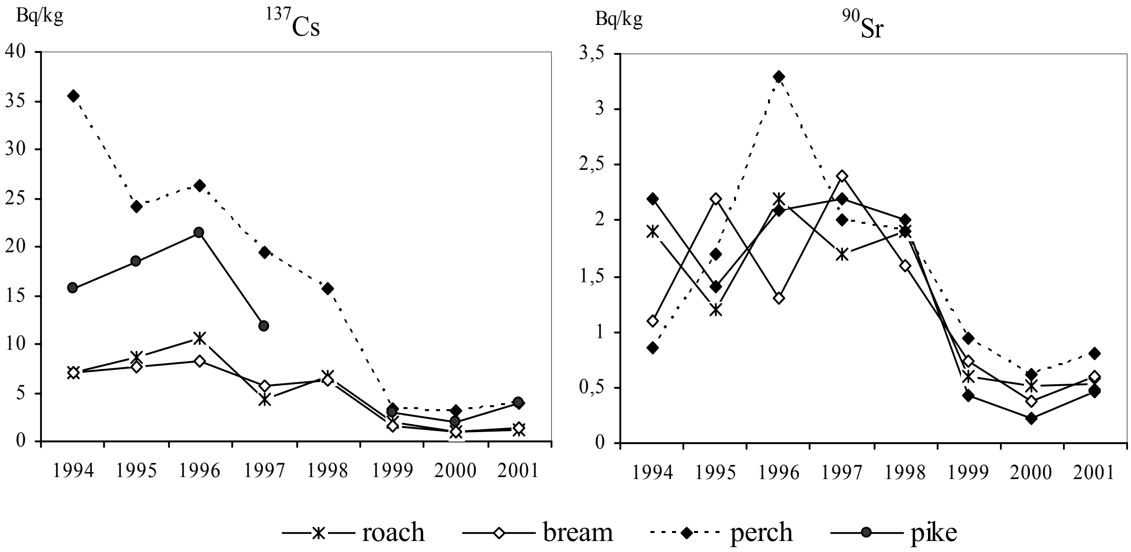


Figure 7.1-25. Annual changes of values of ^{137}Cs and ^{90}Sr activities (Bq/kg w. w.) in muscles of fish in Lake Druksiai.

According to the data of long-term analyses of radionuclide activity in bottom sediments, flora and fauna of Lake Druksiai, the radioecological state of the lake has constantly improved due to reduced penetration of radionuclides to the lake from Ignalina NPP. However, decreasing of the activity of ^{137}Cs has been rather low and in some areas of the bottom sediment values of ^{137}Cs activities have increased (Figure 7.1-26). In 2007, in bottom sediments of the Lake Druksiai values of ^{134}Cs activity were lower than minimum detectable level, and values of ^{60}Co and ^{54}Mn activity reached respectively 7.4 and 0.9 Bq/kg and were significantly lower than in period 1989–1996 (Figure 7.1-26).

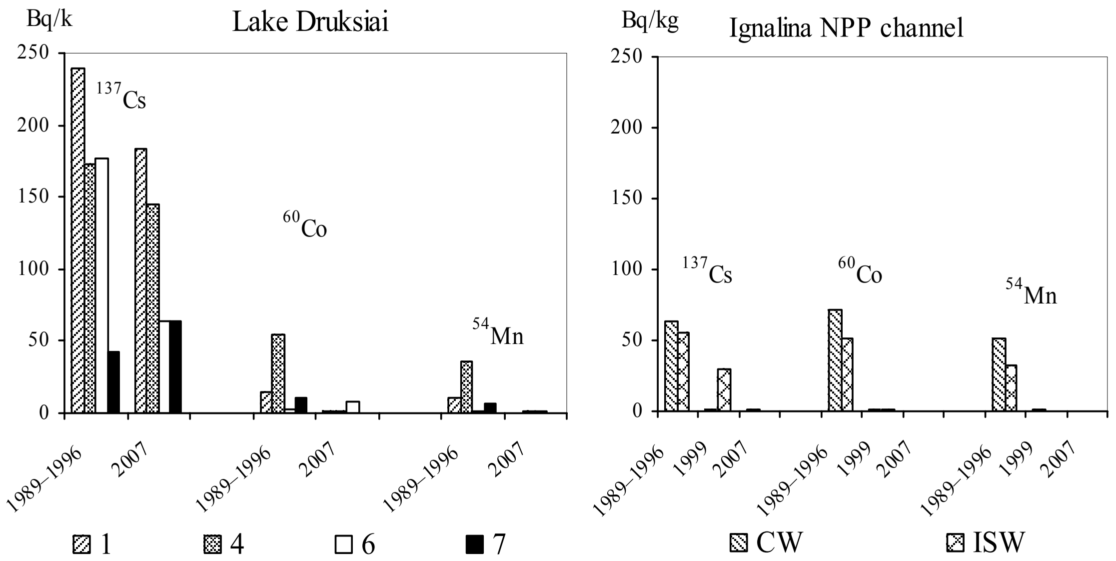


Figure 7.1-26. ^{137}Cs, ^{60}Co and ^{54}Mn activity (Bq/kg, d.w.) in bottom sediments of monitoring stations of Lake Druksiai (1-st, 4-th, 6-th, 7-th) and in ISW and CW channels of INPP in 1989–1996, 1999 and 2007.

In 2007, values of activity ^{90}Sr in bottom sediments of Lake Druksiai were very low (ranged between 0.5–2.5 Bq/kg).

According to the data of D. Adliene and R. Adlyte (*2005*) the measured activity values in aquatic plants of Lake Druksiai during the period of 2001–2004 varied from 2.5 to 14 Bq/kg d.w. for ^{137}Cs, from 0.5 to 7.5 Bq/kg d.w. for ^{60}Co, and from 0.9 to 3.7 Bq/kg d.w. for ^{54}Mn.

In 2007, only two species of plants (macrophytes) were found in Lake Druksiai (Table 7.1-20). Values of ^{137}Cs activity in these plant species, depending on the place they were collected, ranged between 3–22 Bq/kg. ^{60}Co activity was detected only in plants at the 7-th and 4-th monitoring stations (respectively 42 and 1.3 Bq/kg) (Table 7.1-20). ^{54}Mn activity in the analyzed plants of Lake Druksiai was lower than minimum detectable level, except at the 7-th monitoring station, at which activity of radionuclide to plants was 2 Bq/kg (Table 7.1-20). Values of ^{90}Sr activity in the analyzed plants were very low and depending on place of their collection (monitoring station), ranged between 1.2–6.2 Bq/kg (Table 7.1-20).

Table 7.1-20. Activity of radionuclides (Bq/kg d. w.) in water plants of Ignalina NPP waste water channels and in Lake Druksiai in 2007.

Monitoring stations	Species	^{137}Cs	^{60}Co	^{54}Mn	^{90}Sr
Lake					
1-st station	*Ceratophyllum demersum*	22 ± 2	< mdl	< mdl	1.2 ± 0.3
	Myriophyllum spicatum	3 ± 0.4	< mdl	< mdl	2.5 ± 0.5
4-th station	*Ceratophyllum demersum*	7 ± 0.7	1.3 ± 0.2	< mdl	21.9 ± 0.4
6-th station	*Ceratophyllum demersum*	7 ± 0.7	< mdl	< mdl	6.2 ± 0.8
	Myriophyllum spicatum	4 ± 0.4	< mdl	< mdl	3.3 ± 0.6
7-th station	*Ceratophyllum demersum*	17 ± 2	42 ± 2	2 ± 1	2.9 ± 0.5
	Myriophyllum spicatum	4 ± 0.8	< mdl	< mdl	5.2 ± 1.0
Waste water channels					
CW channel	*Myriophyllum spicatum*	4 ± 0.8	< mdl	< mdl	6.6 ± 0.9
ISW channel	*Ceratophyllum demersum*	20 ± 2	34 ± 2	2 ± 0.6	2.3 ± 0.5

< mdl – under minimum detectable level

Values of ^{137}Cs and ^{60}Co activity in the plants from ISW channel were respectively 20 and 34 Bq/kg, and in plants from CW channel ^{137}Cs activity was 4 Bq/kg, ^{60}Co and ^{54}Mn activity was lower that minimum detectable level (Table 7.1-20). ^{90}Sr activity in plants in INPP channels reached 6.6 Bq/kg (Table 7.1-20).

Long-term research data show that from 1988 to 2007 in plants of Lake Druksiai a strong tendency of diminishing of ^{137}Cs activity has been observed (Figure 7.1-27). A similar tendency of diminishing of ^{60}Co and ^{54}Mn activities has been observed in plants of Lake Druksiai.

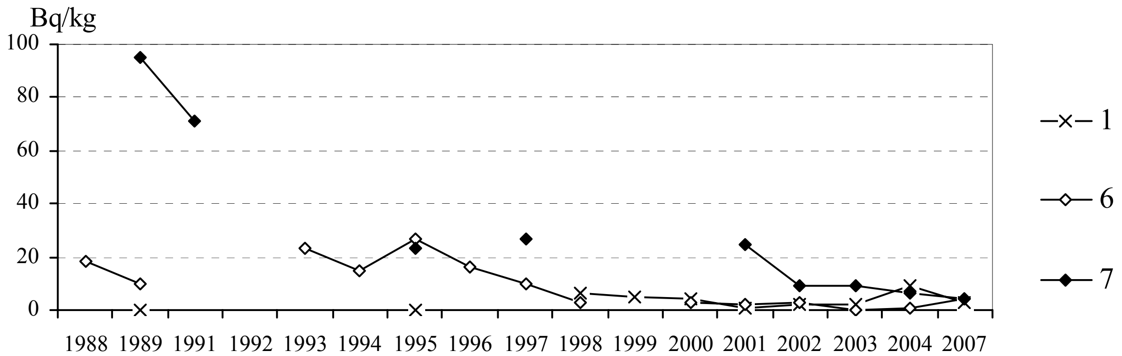


Figure 7.1-27. Annual changes of values of 137Cs activity (Bq/kg d. w.) in water plant *Myriophyllum spicatum* in 1-st, 6-th and 7-th monitoring stations of the Lake Druksiai.

In 2007 in molluscs of Lake Druksiai 1-st, 6-th and 7-th monitoring stations ^{137}Cs activity was respectively 5, 7 and 4 Bq/kg, and ^{60}Co and ^{54}Mn activities were lower than the minimum detectable level.

Long-term radioecological investigations of Lake Druksiai show that in 1988–2004, during operation of both units of INPP, the greatest values of activities of radionuclides (^{137}Cs, ^{134}Cs, ^{90}Sr, ^{60}Co ir ^{54}Mn) in the bottom sediments, flora and fauna of this lake were detected in the period 1988–1993. Since 1994, and in some cases since 1996, tendency of activity decrease (particularly of ^{137}Cs, ^{60}Co and ^{54}Mn) in the bottom sediments, flora and fauna of Lake Druksiai has been observed. Values of activities of ^{137}Cs and ^{90}Sr in plants, and especially in bottom sediments of Lake Druksiai were higher than at INPP channel of industrial-storm water and process water discharge (ISW) and cooling water channel (CW). Values of activities of ^{60}Co and ^{54}Mn, on the contrary, were lower in Lake Druksiai than in these INPP channels.

Summarizing data of long-term investigations, it may be stated that the radioecological state of Lake Druksiai has constantly improved during the operation of both units as well as after closure of the first unit of INPP.

7.1.1.7 Ecotoxicological state of Lake Druksiai

Research scope and methods

Samples of water and bottom sediments were collected at the monitoring stations of Lake Druksiai and in INPP industrial storm water discharge and cooling water channels and Visaginas municipal WWTP channel and route of the waste water of the WWTP into Lake Druksiai in 1988–2004 and 2007 (Figure 7.1-24). According to the bioassays applied in the ecotoxicological investigations distillate or artesian water was used as background water.

Toxicity and genotoxicity tests of INPP discharge channels and bottom sediments were carried out based on the biological tests widely used in the world (*EPA, 1996a,b; OECD, 2003; Minouflet et al., 2005*): common duckmeat (*Spirodela polyrrhiza* (L) Schleid.), garden-cress (*Lepidium sativum* L.) (*Magone, 1989; Montvydiene, Marciulioniene, 2004*); piderwort (*Tradescantia*) (*Marciulioniene et al., 2004*) and rainbow trout (*Oncorhynchus mykiss* Walbaum.) (*ISO, 1994; ISO, 1999; Vosyliene et al., 2005*). The level of toxic impact of water and bottom sediments on common duckmeat and garden-cress was assessed following methods suggested by Wang (*1992*), and genotoxic level to spiderwort, following methods suggested by Marciulioniene et al. (*1996*).

Research results

The impact of waste water of INPP on plant test-organisms in 1988–2000 and 2007 according to toxicity and genotoxicity scale differed slightly. In most cases, these waste waters caused a weak toxic impact or were non-toxic for common duckmeat and garden-cress, for spiderwort they were medium or strongly genotoxic. In 1988–2000 and 2007 from the INPP waste water flowing directly into Lake Druksiai the most toxic waste water for the tested plants was waste water from ISW channel. Waste water (after treatment) of Visaginas municipal WWTP and water of Lake Skripkos and Vosyliskes rivulet were more toxic to the tested plants than waste water of ISW and CW channels. Water of Lake Druksiai was mostly non-toxic for common duckmeat, slightly toxic or non-toxic for garden-cress, and for spiderwort water of the 6-th and the 7-th monitoring stations was medium, and for the 1-st station slightly or medium genotoxic. All tested waste water caused various (non-specific) morphological changes of common duckmeat.

In 1989–1996, the research performed by Dr. N. Kazlauskiene shows that waste water most toxic to embryos and larvae of rainbow trout within the waste water of INPP was waste water from the ISW channel. The water in the outlet areas of ISW and WWTP in Lake Druksiai has been marked by low toxicity, and water of the 1-st station was non-toxic. Comparison of the results of the toxicity of waste waters of INPP and water of Lake Druksiai obtained in 2007 with earlier investigations showed, that mortality of juveniles of rainbow trout in water of the 6-th and 7-th monitoring stations of Lake

Druksiai has increased. However, impact of the waste water of INPP and water from the 1-st monitoring station of Lake Druksiai on mortality of rainbow trout juveniles and average body mass and on the increase of relative body mass has not changed. In 1989–1996, in all tested waste water of INPP channels a deterioration of the physiological state of embryos and larvae has been detected.

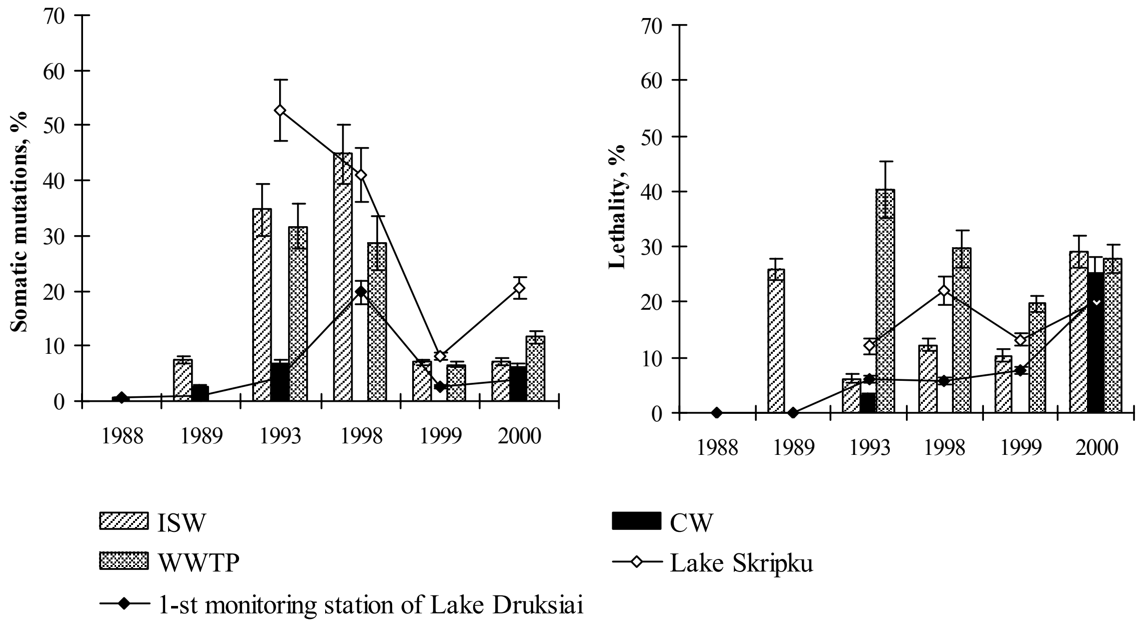


Figure 7.1-28. Genotoxic effect of bottom sediments of ISW and CW waste water channels, channel of the waste water (after treatment) of Visaginas municipal waste water treatment plant (WWTP) and Lake Druksiai and Skripku on *Tradescantia* (spiderwort) during 1988–2000.

It has been estimated that in 1996–2000 and 2007 the toxic impact of bottom sediments of waste water channels of INPP and of Visaginas municipal WWTP to garden-cress ranged from strong to weak toxic or non-toxic. For spiderwort the genotoxicity of tested bottom sediments ranged from medium to strong (Figure 7.1-28). Bottom sediments of all analyzed monitoring stations of Lake Druksiai caused a higher than 1 % amount of somatic mutations in the stamen hair (SH) system of spiderwort, and it is considered (*Shevchenko, Pomerenceva, 1985*) that 1 % of somatic mutations that occurred in the SH system of spiderwort revealed genetic changes, which may cause extinction of sensitive plant species.

Water of INPP discharge channels and Lake Druksiai and bottom sediments usually caused colourless and morphological, and only rarely (and only till 1993), pink mutations, which as it is thought (*Sparrow et al., 1972; Ichikawa, 1992; Marciulioniene et al., 1996*) generally occurs due to impact of radiation. Therefore, the scientist have concluded that genotoxicity of water and bottom sediments of INPP discharge channels and Lake Druksiai was caused not by ionizing radiation, but more by the impact of the mixture of non-radioactive and radioactive substances present in the waste water of INPP.

Long-term investigations show that water and bottom sediments of Lake Druksiai were most toxic in 1993–1998. Most usual radioactive and chemical pollution of the Lake Druksiai was detected in the period from 1988–1993, and the most evident genetic changes in biological tests were recorded in 1993.

7.1.1.8 Water temperature monitoring

The regulation in force "Standard Limits of Permissible Warming of Lake Druksiai Water and Methodology for Temperature Control" (*LAND 7-95/M-02*) has been prepared for protection of the Lake Druksiai ecosystem, i.e. trophic regimen, water quality and fauna. According to this regulation the following standard limits have been established for Lake Druksiai:

- Water surface temperature shall not exceed 28 °C in a water area not less than 80 % of the total area of the lake (*Clause 1.1 of LAND 7-95/M-02*);
- In the cooling water inlet channel at a depth of 10 centimetres the temperature shall be less than 24.5 °C (*Clause 1.2 of LAND 7-95/M-02*);
- Operation of two INPP units shall not be limited in the cool period of the year (from October 1 till April 30) (*Clause 2 of LAND 7-95/M-02*).

In the methodological part of this regulation there are the following requirements:

- Temperature of Lake Druksiai water is controlled by always measuring the temperature of water surface in the flow of the INPP cooling water inlet channel in the same point;
- Water surface temperature shall be measured at a depth of 10 centimetres each day from 10 till 12 o'clock;
- Temperature is measured by mercurial thermometer, standard error of which is ±0.2 °C. If measuring is performed using other devices, the standard error of them shall not exceed ±0.2 °C;
- The measured lake water temperature shall be recorded in a special register.

According to existing practice and Ignalina NPP Environmental Monitoring Program the INPP is measuring the temperature of:

- Inlet channel – every day, one measurement a day from 10:00 till 12:00 (designation: Intake near the Building 120/1, according to attachment 1 of the Environmental Monitoring Program);
- All outlet channels (namely RSR-1,2, Intake, RSR-3, Release, RSR SFSF, , according to attachment 1 of the Environmental Monitoring Program) every fortnight; Lake Druksiai – 3 times per year (e.g. see Table 7.1-21 1-3, measurement locations are shown in Figure 7.1-29);
- Lake Druksiai, a lot of measurements over the area at the day when inlet channel water is more than 24.5 °C, usually 1–3 times per year, according to LAND 7-95/M-02.

If the standard limits of temperature of water in the inlet channel are exceeded, i.e. temperature exceeds 28 °C in 20 % of the lake surface, there must be a reduction of power production and discharge of cooling waters.

Table 7.1-21. Water temperatures of Lake Druksiai.

Measurement date	Water temperature (°C) at the measuring positions 1, 2, 3, 4 and 6 shown on Figure 7.1-29				
	1	2	3	4	6
May 30, 2005	18.1	19.2	15.8	25.4	19.1
August 1, 2005	23.1	25.4	21.9	30.3	22.6
September 19, 2005	16.8	17.3	16.0	16.1	16.0
May 10, 2006	12.3	14.5	15.2	22.9	15.9
July 10, 2006	27.6	26.8	27.8	33.2	26.3
September 25, 2006	17.9	20.0	17.1	21.0	16.6

During the operation of one Ignalina NPP unit the heat load to Lake Druksiai is more than 0.06 kW/m^2 (i.e. the amount of heat transmitted to the lake per month is 8700 TJ) and during the operation of two INPP units it is 0.11 kW/m^2. Cooling water impact on lake temperature can be seen from Table 7.1-21 and Figure 7.1-29. Water temperature at the location 4 of Lake Druksiai, where the cooling water is discharged, is approximately 4–7 °C higher than at location 2, where the cooling water is taken from.

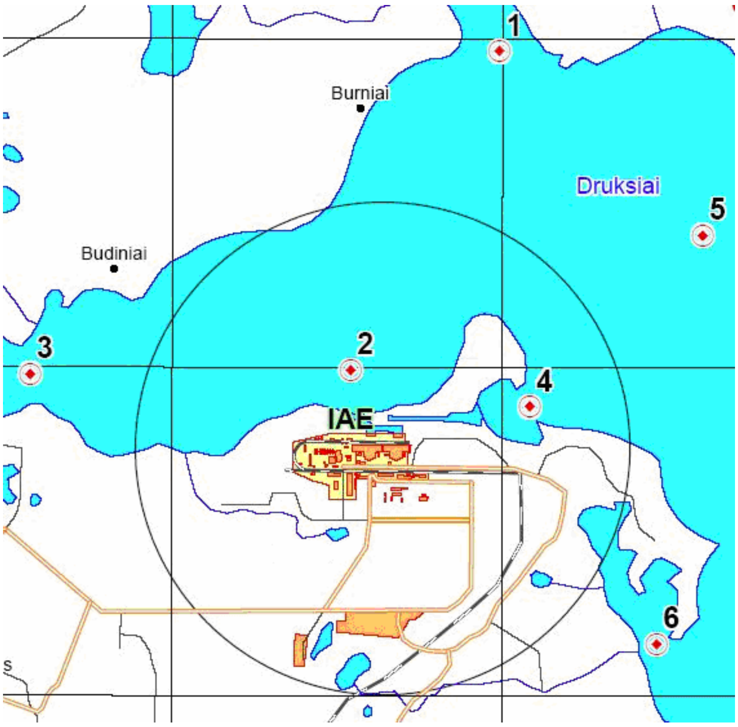


Figure 7.1-29. Locations for investigation of the "zero" background in Lake Druksiai (location 5 has not been investigated in recent years because of close proximity to the state border with Republic of Belarus).

The water temperature data covers 18 years (1981–1998), under wide range of different weather and INPP capacity conditions. The survey on surface temperature has been made over 150 times, at 12-90 sites (depending on the season) (Figure 7.1-30). Digital maps have been developed interpolating the point data of the lake surface temperature.

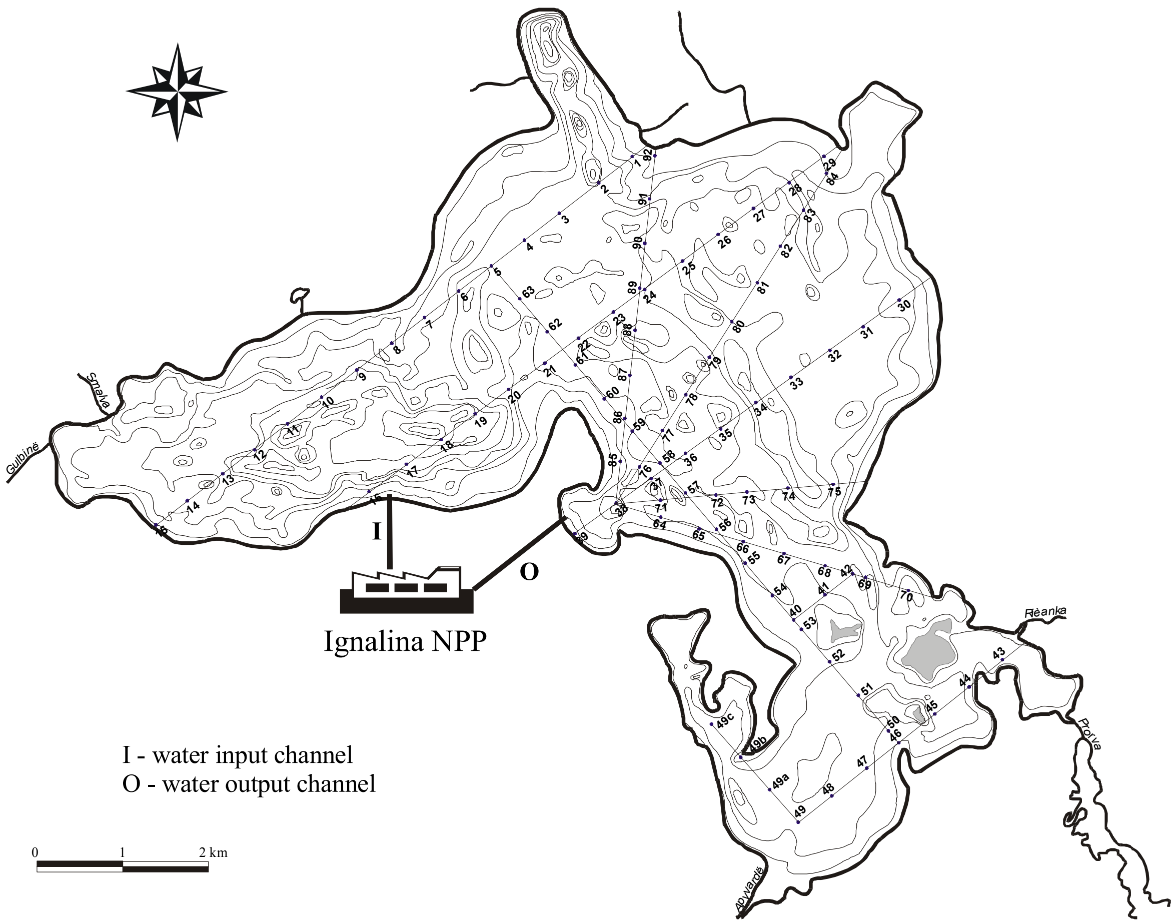


Figure 7.1-30. The scheme of the lake water temperature measurement sites and INPP location.

The surface temperature natural distribution in summer before the INNP was taken into operation (August 3, 1983) is presented in Figure 7.1-31. Since the wind was weak (0.75 m/s), its impact can be ignored and the lake temperature can be considered evenly distributed according to the lake bathymetry, shape and tributaries' inflows. The main determinant for water surface layer temperature was the air temperature.

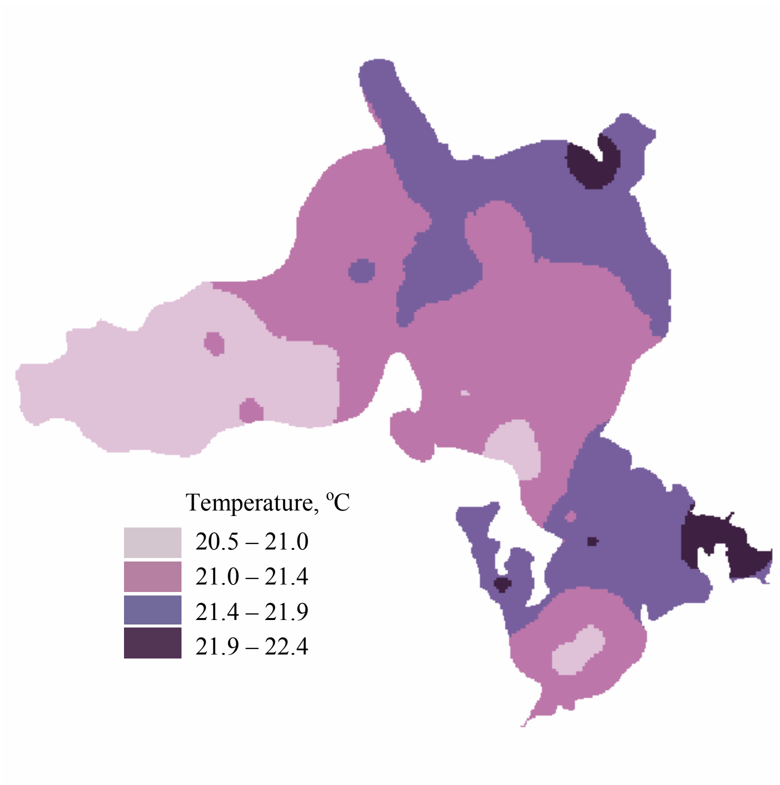


Figure 7.1-31. The surface temperature natural distribution in the lake (August 3, 1983; before the INNP was taken into operation).

A large area of lake surface allows a wind to run up. Strong winds change the temperature distribution forcing the warm surface water to move downwind (Figure 7.1-32).

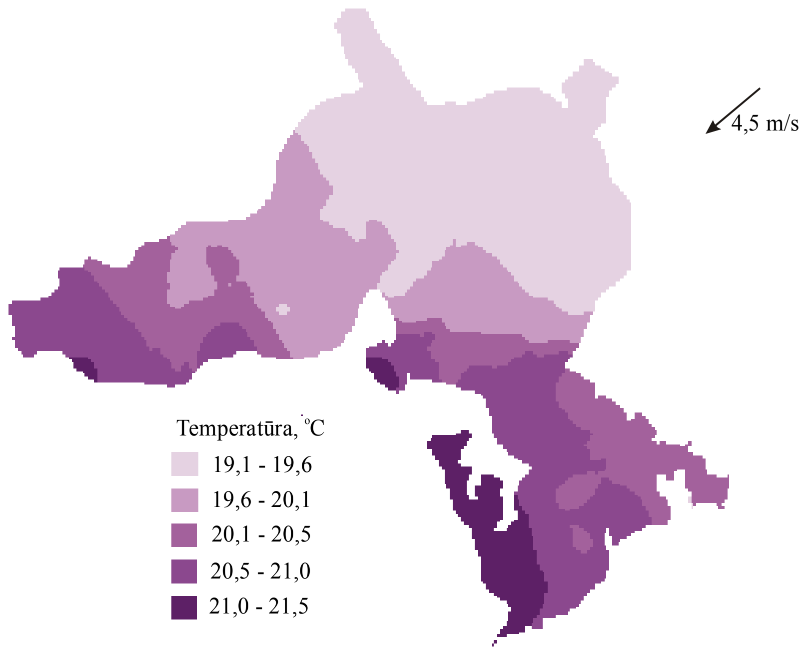


Figure 7.1-32. The natural distribution of surface temperature in Lake Driuksiai (July 9, 1981; before the INNP was taken into operation).

The first unit of the INPP unit was taken into operation in 1984 and since 1988 both units were operating. Their total capacity did usually not exceed 2 500 MW. Approximately 80 m³/s of lake water is used for cooling one INPP unit. For two units the cooling water demand was 135 m^3/s in winter and 160 m^3/s in summer. Water inside the condensers is heated by 9-12 ºC (compared to the input water temperature). Water temperature cools down by 2–3 ºC in the output channels *(Janukeniene, Jakubauskas 1992)*. Figure 7.1-33 presents the thermal state of the lake on August 5, 1984. INPP was operating with 788 MW load. The weather on the investigation day was fine, without wind. Therefore it can be seen how the structure of the lake thermal field was influenced not only by natural factors but also by the cooling water discharge of the INPP. The map shows that the temperature fluctuated from 22.1 ºC in the western (deepest) part of the lake to 27.9 ºC within 1–1.5 km radius from the power plant discharge channel. According to Gailiusis and Virbickas (*1995*) the naturally highest surface temperature in Lake Druksiai fluctuates from 20.4 to 25.5 °C. Hence the lake was heated over the natural maximum temperature. The area with temperature higher than 25.5 °C reached 17 % of total lake surface area. The heated water spread evenly throughout the lake surface, because the wind speed during this period was insignificant.

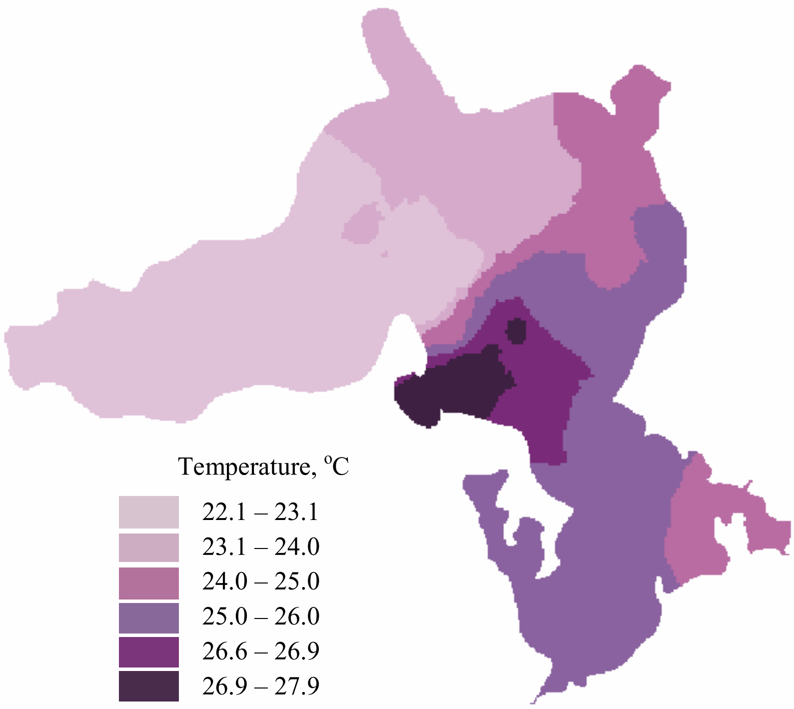


Figure 7.1-33. The distribution of surface temperatures with INPP operation effect of 788 MW. (August 5, 1984).

The response of the lake to the two units operating at a high air temperature (25.9 ºC) and still wind condition is shown in Figure 7.1-34. The average surface temperature reached 30.1 ºC and the maximum temperature 36.6 ºC. This is the highest recorded temperature rise (per area) in the lake (Table 7.1-22). The thermal state of the lake was determined by a combination of unfavourable conditions of low wind and high air temperature. During that day, in 86 % of the area the temperature was higher than 28 °C and in 100 % it was higher than 25.5 °C.

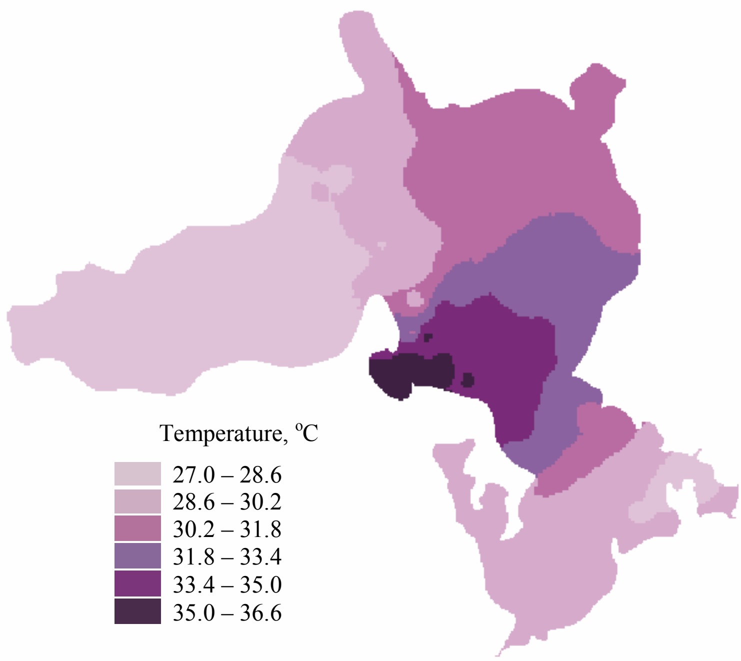


Figure 7.1-34. The lake-cooler state (July 15, 1988); INPP output 2 447 MW.

The form of the hot water field on windy days show, that southern and eastern winds are unfavourable for cooling. The winds from the north and the west turn the stream of hot water to the southern part of the lake and increase cooling.

Table 7.1-22. The database records of the highest overheating of the each year.

Date	Lake surface temperature, °C			% of surface over		INPP operating capacity, MW	Air tempe-rature, °C
	Highest in outlet (point no. 39)	Lowest	Average	>25.5 °C	>28 °C		
August 9, 1984	30.3	23.9	25.4	50	6	796	21.4
June 26, 1985	32.5	21.5	23.5	12	5	1505	19.8
June 18, 1986	33,4	23.6	26.8	66	**24**	1490	25.5
June 23, 1987	27.4	19.6	21.7	3	0	1051	21.1
July 15, 1988	36.6	27.0	30.1	**100**	**86**	2447	25.9
July 12, 1989	32.5	23.1	25.3	34	8	1264	22.5
August 10, 1990	32.6	20.3	21.6	8	4	2500	18.5
August 4, 1991	35.4	23.6	25.5	31	11	1296	25.8
June 1, 1992	30.5	19.2	21.5	11	2	1243	23.6
July 19, 1993	27.3	20.6	21.7	1	0	778	21.8
August 5, 1994	31.1	26.3	27.3	**100**	**38**	759	25.0
August 22, 1995	32.8	24.0	24.4	41	11	1293	21.5
August 23, 1996	35.0	21.3	24.0	13	7	1272	25.5
July 6, 1997	32.5	22.6	24.1	4	3	747	22.1
June 6, 1998	32.1	21.7	22.7	25	17	1306	24.0

The highest surface temperatures are reached during the warm summer months. The cooling water discharge has increased the average monthly temperature of the lake by 3–4 degrees (Figure 7.1-35).

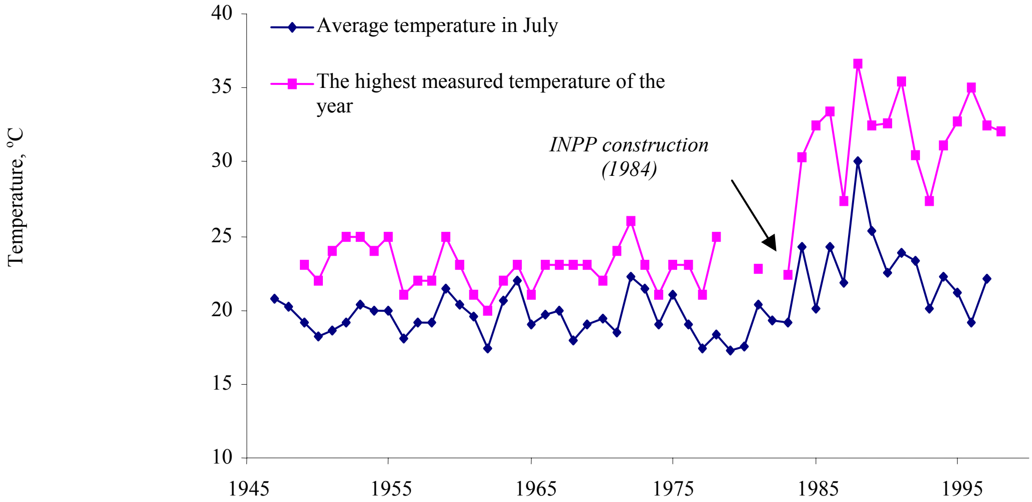


Figure 7.1-35. Surface water temperatures of Lake Druksiai before and after Ignalina NPP construction.

Comparative analysis of average annual temperature of the vertical water layers in Lake Druksiai and some natural lakes for the period 1985–1989 has shown that in Druksiai water temperature at 10 m depth has risen by 4.2 °C and at 30 m depth by 2.2 ^{o}C. Evaluation of the anthropogenic impact on Lake Druksiai is complicated, because the rise of lake bottom temperature is also being observed in other Lithuanian lakes (Dusia, Plateliai, Tauragnas) (*Pernaraviciute, 1998*).

7.1.2 Assessment of impacts on water

7.1.2.1 Raw water consumption

Potable water supply for the present Ignalina NPP is outsourced to the state (Ministry of Economy) owned Visaginas Energija, which serves also the town of Visaginas. Groundwater is used as raw water and it requires only a simple treatment of aeration and filtration to remove excessive iron. The total water production capacity is 31 000 m^3/d, but as one NPP unit has already been closed and a drastic water consumption reduction has taken place in Lithuania, the present capacity in use is only about 10 000 m^3/d, and the daily average output about 6 900 m^3/d. The treated water storage tanks have a capacity of 12 000 m^3, which provides for adequate stand-by supply volume. The potable water supplier has adequate capacity and existing pipeline network to supply all potable water required at the new NPP also.

At the new NPP, potable water is required both for household purposes (e.g. drinking, showers, toilets) and for production of the process water. The potable water demand depends on size of the power plant and the project stage (Table 7.1-23).

During the construction of the plant household water consumption will be at its highest, depending, however, on the phase of construction and the number of workers at that time. The total consumption will, however, be approximately same or slightly less than during the operation period since no process water is needed. The required potable water supply capacity is 650 m^3/d for 1 700 MW power plant and 1 300 m^3/d for 3 400 power plant.

Table 7.1-23. Potable water demand for two plant alternatives.

	Average daily flow m^3/d	
	Alt 1 ≤1 700 MW	Alt 2 ≤3 400 MW
Potable water demand		
Construction period	300-450	600-750
Operation period, for household use	150	300
Operation period, for process water prod.	400-500	800-1 000
Annual maintenance, for household use	250	250
Annual maintenance, for process water	200	600-700
Required potable water supply capacity	650	1300

The quality of the potable water is suitable for household needs and no additional treatment at the NPP is required. For process purposes, however, the water must be demineralised ("removal of salts") in a demineralisation plant at the NPP site. The demineralisation plant will have a capacity of 400-700 m^3/d depending on size and type of the power plant.

In addition to the potable water also water from Lake Druksiai will be used for purposes not requiring such a high quality. These comprise service water and fire protection water. Service water is used for some household purposes, like cleaning and washing floors and surfaces, and for cleaning the cooling water screens and filters (see Section 7.1.2.3). Water from the lake is also used in case of fires. Sufficient supply of fire water is guaranteed with an adequate pumping station and water basins at the NPP site.

7.1.2.2 Waste waters

In the following the non-radioactive waters are described. Treatment of the waste waters originating from the controlled area, i.e. potentially radioactive waters, is described in Section 6.2.2.

Household waste waters

Household waste water treatment for the present Ignalina NPP is outsourced to the state owned company (Ministry of Economy) Visaginas Energija, which serves also the town of Visaginas. The same company will be responsible for household waste water treatment also for the new NPP.

Visaginas Energija operates a municipal wastewater treatment plant (WWTP). The plant capacity is 21 000 m^3/d, but it is in need of rehabilitation. A reconstruction project has started in May 2008 by signing the construction contract. The new plant will have a capacity of 5 500 m^3/d, an activated sludge biological process, and it will be able to meet the current Lithuanian and EU effluent standards. The reconstruction project is financed by the Lithuanian state and EU Cohesion Fund and it is expected to be completed by 2010.

Table 7.1-24 gives the estimated maximum household sewage discharge loads after treatment during NPP operation.

Table 7.1-24. The yearly household waste water loads after treatment in the new WWTP.

Parameter	Alt 1 ≤1700 MW	Alt. 2 ≤3400MW
Flow m^3/d	150	300
BOD_5 at 25 mgO_2/l, kg BOD_5/year	1 370	2 740
COD at 125 mgO_2/l, kg O_2/year	6 850	13 700
Total suspended solids at 35 mg/l, kg TSS/year	1 920	3 830
Total phosphorus at 2 mgP/l, kg P/year	110	220
Total nitrogen at 15 mg/l, kg N/year	820	1 640

The loads from the new NPP will represent either 4 or 8 % of the loads from the municipality of Visaginas. The effluent is discharged through a pond named Skripku to Lake Druksiai.

Process water

The waste waters from the process water production include regeneration effluents and reject water. Regeneration effluents are generated when the ion-exchange resins are treated with strong acid (sulphuric acid, H_2SO_4) and base (sodium hydroxide, NaOH). Approximately 5–10 % of the water flow through the process water treatment will form reject water. These effluents contain mainly cations (e.g. sulphates) and anions (e.g. iron, sodium) originating from the raw water and the treatment. Both the regeneration effluents and the reject are led to a neutralisation basin where the pH will be brought to a range of 5–9 before discharging to the lake. The discharged waste waters mainly contain minerals from the neutralisation.

Approximately 28–56 tonnes of sulphuric acid and 50–100 tonnes of sodium hydroxide (50 % concentration) will be used annually in the process water neutralisation. If the new power plant will be of pressurised water type (PWR), it will also cause a boron load of approximately 2–4 tonnes per year due to the use of this chemical in the process water.

Rain water and drainage water

All the rain and drainage waters from the NPP area will be led trough oil detection wells and along the rain water drains to a settling basin. The basin will be equipped with an automatic oil detection alarm system.

Water streams that potentially may contain oil (e.g. rain water from secondary basins of oil tanks and the oil handling areas) will be led through oil separators before leading them to the lake via the settling basin. A reservoir equipped with oil separator will collect the waste oil for off-site recycling or disposal by a licensed contractor. Water from the separator will be discharged to rain water drains.

7.1.2.3 Cooling water

Lake Druksiai serves as the source of cooling water. The main part of the cooling water is needed for cooling the condensers and a minor part for various rotating devices and some other components. Cooling water is pumped to the power plant via a cooling water intake structure in Lake Druksiai.

Cooling water does not need any treatment. However, coarse organic and other material carried by the water (such as plants, fish, rubbish etc.) are sieved at the cooling water intake by a coarse bar screen and closer to the power plant by denser screens. The screens are regularly washed with lake water to remove the collected material. The collected material is treated according to solid waste management regulations and procedures.

From the condenser the warmed cooling water is led back to Lake Druksiai along the cooling water outlet channel.

When passing through the cooling system of the NPP, the quality of cooling water does not normally change in any other way than that the temperature rises approximately 9 – 11 degrees. However, under certain conditions so called antifouling chemicals like hypochlorites may need to be added to cooling water to prevent biofouling. Biofouling means that bacteria, algae, plants and animals like mussels grow on the surfaces of the cooling system in amounts that would harm the effective functioning of the system. The amount of antifouling chemicals used and quality of the discharged water will be monitored and controlled according to the regulations.

The need of cooling water depends on the produced power, technical features of the plant type (the core thermal output and the gross electrical output differ a little in different NPP types) and on the temperature rise in the condenser. Approximate cooling water needs for different power levels are given in Table 7.1-25. The estimation has been made conservatively by assuming 35 % efficiency of the NPP and an approximate cooling water temperature rise of 10°C degrees.

In the table (Table 7.1-25) the thermal load ($P_{Released}$) is presented for different energy production levels ($P_{Electrical}$).

Table 7.1-25. Produced energy ($P_{Electical}$, P_{Total} and $P_{Released}$) and cooling water demand.

$P_{Electrical}$ MW	P_{Total} MW	$P_{Released}$ MW	Flow m^3/s
750	2 143	1 393	35
1 200	3 429	2 229	55
1 400	4 000	2 600	65
1 700	4 857	3 157	80
2 400	6 857	4 457	110
2 800	8 000	5 200	130
3 400	9 714	6 314	160

The existing cooling water structures have a design capacity of 170 m^3/s. As the maximum need for the new NPP is estimated to be 160 m^3/s, the capacity of the existing structures will be adequate also for the new NPP.

During the spent nuclear fuel removal from the reactor core and storage pools of the existing NPP only one cooling water pump (*IAE letter No. 109-4859* (12-14, dated 2007-08-27)) will be needed. This phase is preliminarily planned to be finished before the end of 2015. The cooling water need during that period is very small (about 1.7 m^3/s) compared to cooling water need of the new NPP. Thus there is no discrepancy in using the same inlet channel for the NNPP.

7.1.2.4 Impacts of waste water load on water quality

Household waste water

Lake Druksiai has undergone an eutrophication development during the last decades and this unfavourable development is still continuing. Household waste waters from

Visaginas waste water treatment plant (WWTP) have been and are still forming the majority of nutrient load to the lake. Improvement of water treatment has led to decrease in nitrogen load but the phosphorus load has not decreased.

At present approximately 80 % of the total phosphorus load and 55 % of the total nitrogen load to Lake Druksiai comes from the Visaginas WWTP. The new WWTP will decrease the total annual load of phosphorus by 60 % and nitrogen by 40 % compared to the present. The nutrient load from the new NPP will comprise only 4 to 8 % of the total nutrient load to be discharged from the Visaginas new WWTP.

The new WWTP is considered as an environmentally best option for treatment of the household waste waters from the NNPP. The nutrient load from the new NPP to Lake Druksiai will be smaller than the present load from INPP due to the new WWTP. The nutrient load from the NNPP will be small compared to the total load to Lake Druksiai coming from the other sources (e.g. Visaginas municipality and natural runoff). Thus the impacts of the new NPP on lake water quality and eutrophication can be considered insignificant and the proposed treatment at the new WWTP adequate.

Process waste water

Process waste waters discharged to the lake contain dissolved salts which are found in small amounts also naturally in lake water. The dissolved salts combined with increased evaporation rate can lead to increase in lake water salinity (which is in lakes often measured as a concentration of total dissolved solids (TDS)).

The process water production at the new NPP will produce approximately 180–450 kg of salts per day which are discharged to the lake. Impacts of the process water to the lake salinity were evaluated based on the amount of salts discharged and the water balance (inflow, evaporation and outflow). According to this rough estimation salt addition would increase the TDS in lake water by 0.1–0.34 mg/l per year. During the plant's operation period (60 years) the total increase would be approximately 6–20.4 mg/l if calculated linearly. This evaluation is, however, very rough and possibly an overestimate, as it takes only the outflow from the lake into account as a way to decrease the salt content. In reality, however, dissolved salts are removed from the water also by organisms, chemical reactions and eventually sedimentation to the lake bottom.

On the other hand, the dissolved salts are probably not distributed evenly to the whole lake volume. The concentration of TDS can rise higher than assumed especially if the process waste waters are not well mixed with the lake water when discharged. The denser and heavier process water may accumulate to water layers close to the bottom. Theoretically, this can intensify lake stratification and decrease water circulation. This can then lead to decrease of oxygen concentration and intensification of sulphate reduction and nutrient release from the bottom in the deep water layers.

During the operation of Ignalina NPP the TDS concentration has risen from 224 mg/l to 264 mg/l. It is clear that the TDS has not increased as much as was expected before the operation started. This is suggested to be mainly due to the growth of zebra mussels and macrophytes which decrease the HCO_3^- and Ca_2^+ concentrations in water. The observed increase in TDS concentration roughly corresponds to an increase from 0.022 to 0.026 % in salinity.

The new NPP will not increase the amount of salts discharged compared to the present situation. The increase in TDS has so far been slow and the new NPP is not expected to significantly change this. As most of the fresh water species can live in salinities lower than 0.5 %, the salinity is not expected to increase to levels harmful for organisms.

Boron is an essential micronutrient but toxic in high concentrations. In case the new NPP will be a pressurised type reactor (PWR) also boron will be released to the environment as it is used in the process. According to WHO (*WHO, 1998*), the environmental no-effect concentration for boron is 1 mg/litre. The concentration of boron is not expected to rise over this value during the operative time (60 years) of the new NPP. Thus no harmful impacts are expected.

As the concentrations of TDS or single ion (e.g. boron, chloride) can, however, rise on some parts of the lake, they should be continuously monitored. If the concentrations are rising to levels causing directly or indirectly adverse effects on the lake ecosystem, additional treatment methods of process waste waters, like evaporation, should be considered.

7.1.2.5 Summary of the water consumption and treatment

The detailed information about the planned water consumption amounts and treatment are summarised in Table 7.1-26, Table 7.1-27, Table 7.1-28 and Table 7.1-29.

Table 7.1-26. Predicted water intake and consumption in two alternative power production options.

No	Water source	Maximum planned water intake capacity			Activity with water consumption	Maximum planned water consumption amount for each activity			Planned water loss	Water amount planned to be delivered to other consumers
		m^3/y	m^3/d	m^3/h		m^3/y	m^3/d	m^3/h	m^3/y	
ALTERNATIVE ≤1700 MW										
1	Lake Druksiai	29x10^{8}	86x10^{5}	360 000	Cooling water	23x10^{8}	69x10^{5}	288000	Insignificant	No
2	The network of Visaginas Municipality	60 000	1 000	70	Household consumption during normal operation	54 750	150	20	Insignificant	No
3	The network of Visaginas Municipality	8 000	1 000	70	Household consumption during annual maintenance	7 500	250	30	Insignificant	No
4	Lake Druksiai	645 000	2 000	180	Service water (rinsing the cooling water screens etc.)	640000	1 900	160	Insignificant	No
5	The network of Visaginas Municipality	170 000	500	30	Process water production	167 500	500	30	Insignificant	No
ALTERNATIVE ≤3400 MW										
1	Lake Druksiai	52x10^{8}	16x10^{6}	648000	Cooling water	46 x10^{8}	14x10^{6}	576 000	Insignificant	No
2	The network of Visaginas Municipality	120 000	1 000	70	Household consumption during normal operation	109 500	300	40	Insignificant	No
3	The network of Visaginas Municipality	8 000	1 000	70	Household consumption during annual maintenance	7 500	250	30	Insignificant	No
4	Lake Druksiai	810 000	2 600	240	Service water (rinsing the cooling water screens etc.)	804000	2 400	200	Insignificant	No
5	The network of Visaginas Municipality	340 000	1 000	70	Process water production	335 000	1 000	60	Insignificant	No

Table 7.1-27. Information about wastewater sources and dischargers.

No.	Wastewater source	Discharger type/technical data	Description of discharge area	Maximum foreseen effluent amount			
				m^3/s	m^3/h	m^3/d	m^3/y
ALTERNATIVE ≤1700 MW							
1	Reject concentrate from process water production	Neutralization	Lake Druksiai	0.002	5	100	33500
2	Household waste water	Sanitary sewage treatment plant of Visaginas	first Lake Skripku, then Lake Druksiai	0.010	15	150	55000
3	Service water	Oil/grease separation	Lake Druksiai	0.1	160	1900	640000
4	Cooling water	Discharge canals	Lake Druksiai	80	288000	$69x10^5$	$23x10^8$
ALTERNATIVE ≤3400 MW							
1	Reject concentrate from process water production	Neutralization	Lake Druksiai	0.004	10	200	67000
2	Household waste water	Sanitary sewage treatment plant of Visaginas	first Lake Skripku, then Lake Druksiai	0.018	30	300	109500
3	Service water	Oil/grease separation	Lake Druksiai	0.1	200	2 400	804000
4	Cooling water	Discharge canals	Lake Druksiai	160	576000	$14x10^6$	$46\ x10^8$

Table 7.1-28. Pollution load planned to be discharged/ forecasted pollution of environment.

No.	Pollutant name	Maximum forecasted pollution of effluent before discharge				Maximum permissible and actual forecasted pollution of planned effluents/ planned pollution of the environment								Foreseen purification effectiveness. %
		inst. [1], mg/l	aver. [2] mg/l	t/d [3]	t/y	MPC inst. [4], mg/l	planned inst. [5], mg/l	MPC aver. [6], mg/l	planned aver. [7], mg/l	MPC 24 h [8], t/d	planned 24 h [9], t/d	MPC annul. [10], t/y	planned annul. [11], t/y	
ALTERNATIVE ≤1700 MW														
	BOD7	na	250	0.038	13.9	na	na	25	20	0.004	0.003	1.37	1.10	92
	Ntot	na	40	0.006	2.2	na	na	15	12	0.0023	0.0018	0.82	0.66	70
	Ptot	na	7	0.001	0.38	na	na	2	1.5	0.0003	0.0002	0.11	0.07	75
	TSS	na	350	0.053	19.2	na	na	35	30	0.0055	0.0045	1.92	1.64	90
ALTERNATIVE ≤3400 MW														
	BOD7	na	250	0.075	27.4	na	na	25	20	0.004	0.003	1.37	1.10	92
	Ntot	na	40	0.012	4.4	na	na	15	12	0.0045	0.0036	1.64	1.31	70
	Ptot	na	7	0.002	0.77	na	na	2	1.5	0.0006	0.00045	0.22	0.16	75
	TSS	na	350	0.105	38.3	na	na	35	30	0.0105	0.009	3.83	3.3	90

1 – Maximum foreseen concentration of pollutant in the instantaneous or average for 24 h effluent sample before purification;
2 – Maximum foreseen average annual concentration of pollutant in effluent before purification;
3 – Maximum foreseen amount of pollutant in effluent before purification generated during 24 hours;
4 – Maximum Permissible Concentration (MPC) in the instantaneous or average for 24 h effluent sample established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
5 – Planned concentration of pollutant in the instantaneous or average for 24 h effluent sample;
6 – Maximum permissible average annual pollutant concentration established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
7 – Planned average annual pollutant concentration;
8 – Maximum permissible average 24 hours pollutant amount established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
9 – Planned average 24 hours pollutant amount;
10 – Maximum permissible annual pollutant discharge amount established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
11 – Planned annual pollutant discharge amount.

Table 7.1-29. Means for minimisation of effluent amount and environmental pollution planned to be used.

No	Effluent source/discharger	Description of a measure and its purpose	Designed characters of the planned means	
			measure unit	value
1	Liquid radioactive waste treatment facility	Evaporation, filtration and bitumization (reducing the radioactivity)	See Section 6.2.2 for detailed description	
2	Sanitary sewage treatment plant of Visaginas	Mechanical and biological treatment (reducing the load of organic and inorganic substances)	m^3/d	5 500
3	Demineralization reject concentrate	Neutralization (HCl, NaOH) (balancing the pH –value)	na	na
4	Oil separation	Grease/oil separation in weirs/basins (separation of the oily substances)	na	na

7.1.2.6 Impacts of thermal load

Thermal modelling

Model computations were carried out using EIA Ltd's flow model, which is a three dimensional hydrodynamic water flow model based on Navier-Stokes equations, specifically designed for modelling lakes and coastal areas (*Koponen et al., 2008*).

The model grid was constructed using depth isoline data (*Depthdata, 2008*) obtained from Ignalina NPP. To construct the model grid, first a depth model with 5 m horizontal resolution was interpolated from the isoline data. The model grid was then constructed from the depth model by averaging 5 m resolution depth data to 50 * 50 m grid boxes. Additionally the intake and outlet channel depths were set to 6.6 m and 2.9 m depths according to the information obtained from the INPP.

Meteorological data from the Dukstas meteorological station was used in the computation. Model calibration and scenario computations were performed using summer periods of selected years. For calibration the years 1981, 1989 and 1991 were selected, using data availability, INPP usage and weather conditions as criteria. Locations of the temperature measurement points used in calibration are shown in Figure 7.1-36 . The year 2002 was selected for the scenario computation, since it had the warmest summer period of the available years. The effect of different levels of thermal load and different NNPP cooling water inlet and outlet locations on Lake Druksiai temperatures was investigated using the calibrated model. Additional simulations were performed to see how change of environmental conditions would affect the results.

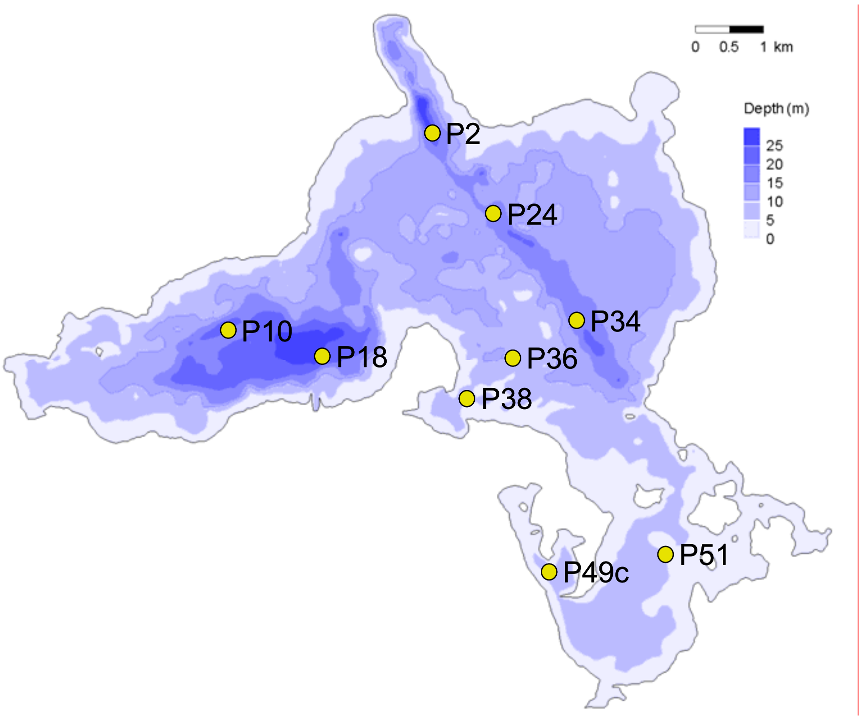


Figure 7.1-36 . Location of measurement points used in model calibration.

Model calibration

In model calibration the computed model results are compared to conducted measurements. Different levels of model fit can be obtained depending on the used boundary condition data, meteorological data, and other model driving data accuracy, the model itself, quality of the measurement data and natural variability of the modelled natural phenomena. If differences are found the empirical and site-dependent model parameters can be adjusted in order to make the computed results fit better to the measurements.

Flow model calibration

The model simulated lake surface temperatures quite well. The average difference of computed and measured lake temperatures were less than ±1.2 degrees in all measurement points, except point P38 near the INPP outlet. In year 1981 (with no NPP) the model slightly overestimated the lake surface temperatures (by 0.2 degrees). In years 1989 and 1991, with two different INPP operation capacities, the model computed the surface temperatures almost correctly for year 1989 (± 0.6 degrees in all points), and underestimated the surface temperatures for year 1991 on the average by about 1 degree (-2 to -0.5 degrees). A summary of the average difference of computed and measured surface temperatures is shown in Figure 7.1-37.

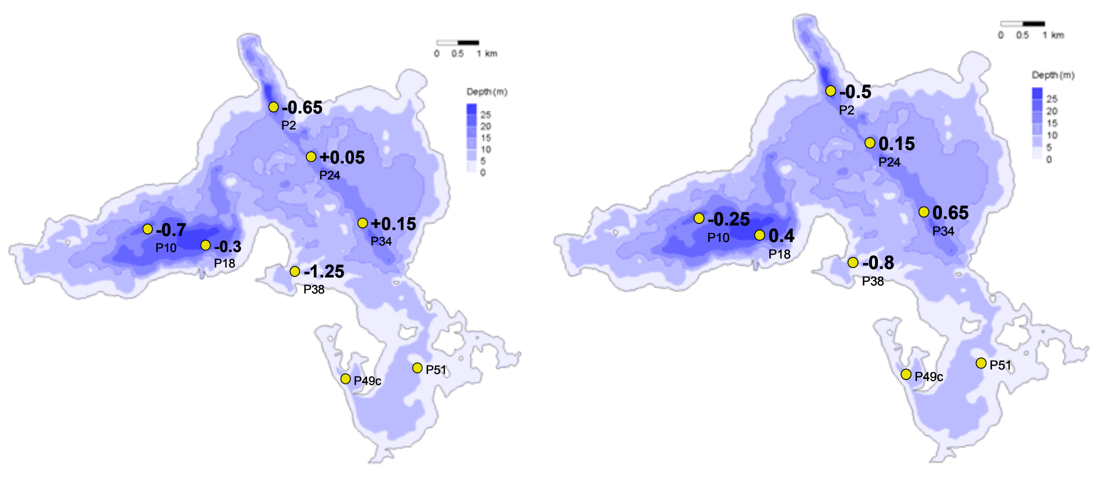


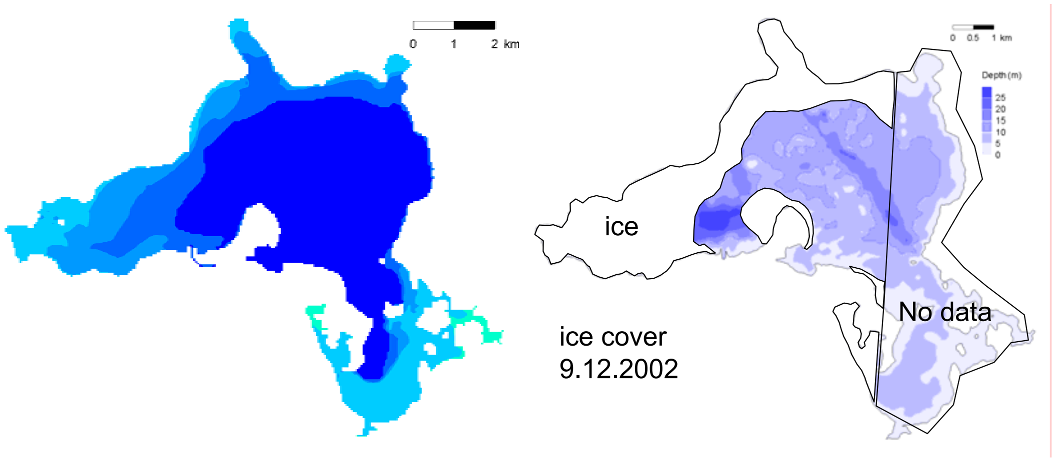
Figure 7.1-37. Average difference of computed and measured (*model result minus measurement*) values at measurement points for years 1989 and 1991 (ºC), for the whole simulation period (*left*), and for warm periods (*right*).

Ice cover computation

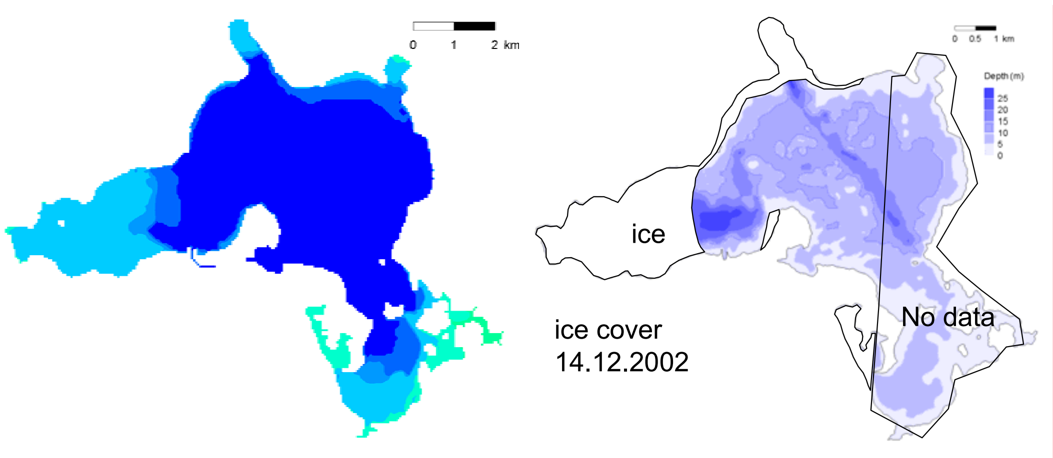
The ice cover computation was calibrated to Digital Globe satellite pictures obtained from Google Earth. There were three pictures available, from 9.12.2002, 14.12.2002 and 6.1.2003. The computed ice cover and corresponding digitized satellite data are shown in Figure 7.1-38.

The winter 2002-2003 used for calibration was cold and started early. The icing started already in November in the shallow southern parts of the lake, and in the end of December most of the lake was covered with ice, except in the front of the INPP outlet

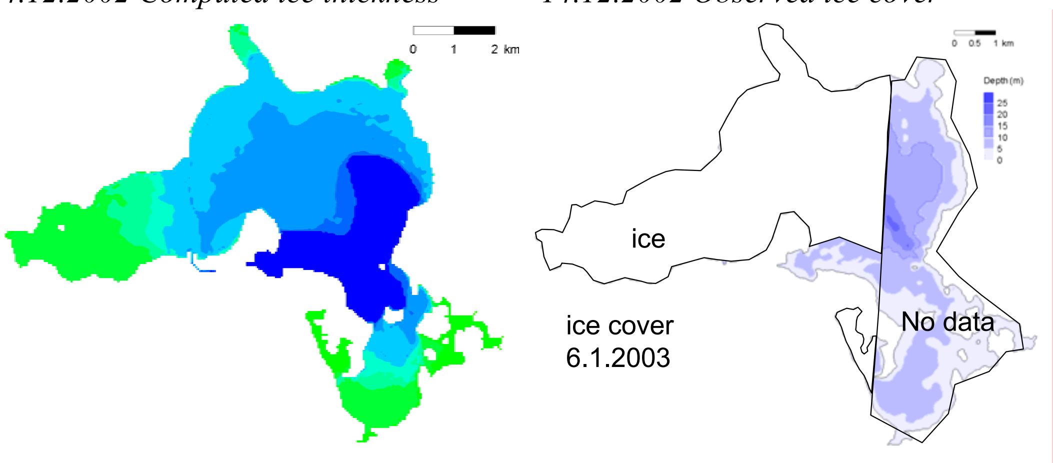
At the start of the computation period the lake temperature was set to 9 degrees in all depths. This initial temperature was estimated from the measured INPP inlet temperature. The average INPP electric power level in November was 2020 MW and cooling water flow average was 92 m^3/s, in December and beginning of January the electric power level was 2 480 MW with an average cooling water flow of 117 m^3/s. On 6.1.2003 the INPP electric power level was 2 650 MW.



9.12.2002 Computed ice thickness *9.12.2002 Observed ice cover*



14.12.2002 Computed ice thickness *14.12.2002 Observed ice cover*



6.1.2003 Computed ice thickness *6.1.2003 Observed ice cover*

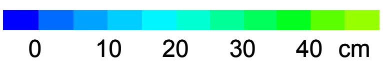


Figure 7.1-38. Computed ice thickness and observed ice cover on 9.12.2002, 14.12.2002 and 6.1.2003.

Scenario computations

The effect of different levels of thermal load and different NNPP cooling water inlet and outlet locations on Lake Druksiai temperatures was investigated using the calibrated model. Additional simulations were performed to see how change of the environmental conditions would affect the computation results.

The scenario computations were done using summer 2002 period weather data measured at the Dukstas station, with the planned NPP working at a steady power throughout the simulation. The time period used in the scenarios was from 1.5.2002 to 1.10.2002. The initial state of the lake was set to a constant temperature of 11 degrees in 1-4 meter layers, and 10 degrees in deeper layers. Steadying of the initial situation took about one month in the beginning of the simulation.

The year 2002 was selected for scenario simulations, since it had the highest monthly average temperatures during the three summer months of June, July and August. Years 2001 and 2003 were also simulated using reduced set of NNPP alternatives, to investigate how the weather in different years affected the lake temperatures.

The NNPP alternatives and corresponding cooling water flows and temperature rises used in the computations are shown in Table 7.1-25. The cooling water flow and temperature rise were estimated using NNPP total efficiency of 35 %, with temperature rise between 9.5 and 10°C.

The different inlet and outlet locations used in the scenarios are shown in Figure 7.1-39. There are three alternative inlet locations: the present location, a location about 2 km west from the present location, and a tunnel from the deeper part of the lake. The two outlet locations are the present location in the middle of the lake, and a southern outlet to the end of a bay guiding the cooling water to the southern part of the lake.

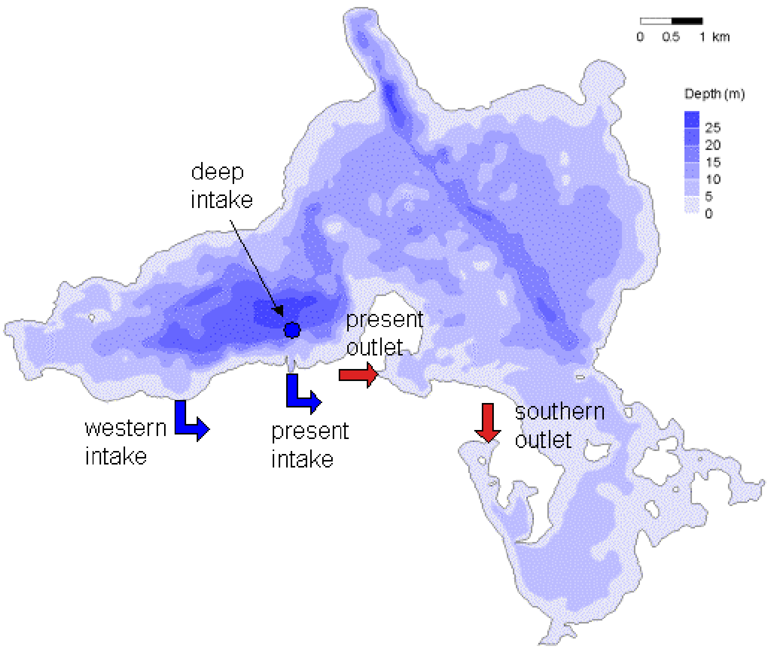


Figure 7.1-39. Alternatives of the NNPP intake and outlet locations used in the computations.

Thermal load scenarios

To investigate the effect of thermal load from NNPP to the lake temperature, six alternative levels of thermal load to the lake ($MW_{released}$) were simulated, using present cooling water intake and outlet locations. The corresponding amount of electrical energy produced assuming direct cooling and plant efficiency of 35 % is presented in brackets (MW_e). The following levels were computed:

- 1 390 $MW_{released}$ (750 MW_e)
- 2 230 $MW_{released}$ (1 200 MW_e)
- 3 160 $MW_{released}$ (1 700 MW_e)
- 4 460 $MW_{released}$ (2 400 MW_e)
- 5 200 $MW_{released}$ (2 800 MW_e)
- 6 310 $MW_{released}$ (3 400 MW_e)

As a result the simulation produced time-dependent 3-dimensional temperature fields for the whole lake. These results are summarized below using two types of visualisations:

- surface temperature fields averaged over July
- percentage of the lake area exceeding the threshold temperatures of 28 and 30 degrees as a function of time

Figure 7.1-40 shows the average temperature distribution during July 2002 for four thermal load alternatives. The shape of temperature distribution remains similar between different thermal load alternatives, but the temperature level rises when thermal load is raised.

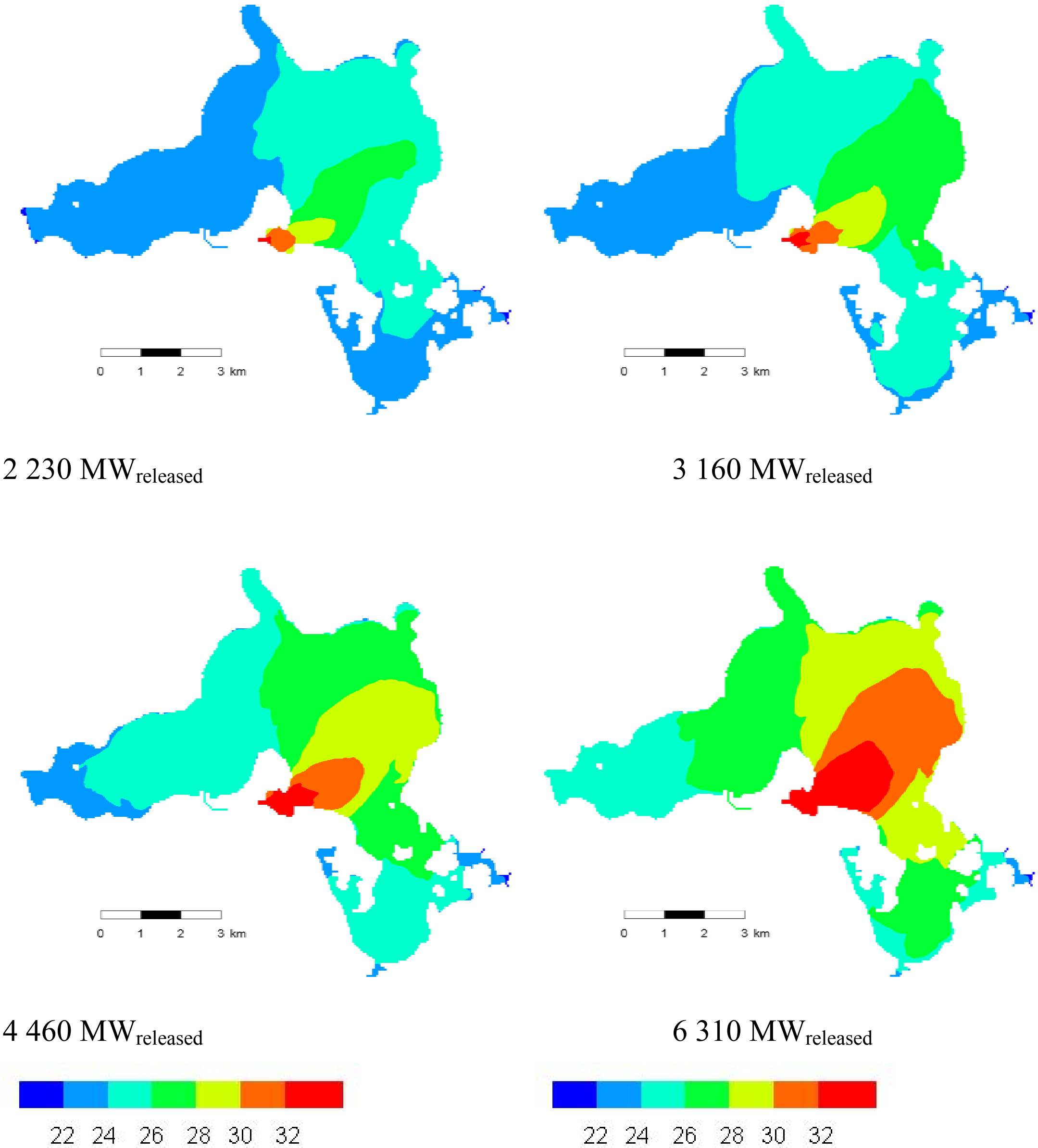


Figure 7.1-40. Average temperature fields (°C) of the lake influenced by different thermal loads in July 2002.

Figure 7.1-41 shows the area of the lake that exceeds a given temperature for the whole simulation period as a percentage of the lake area. For thermal loads of 1 390 MW$_{released}$ and 2 230 MW$_{released}$ the lake area warmed over 28 degrees remains below or near the 20 % limit. For load of 3 160 MW$_{released}$ the limit is exceeded in the second half of June and in the beginning of August 2002. For loads 4 460 MW$_{released}$ or more, over half of the lake warms to over 28 degrees during the warmest summer period.

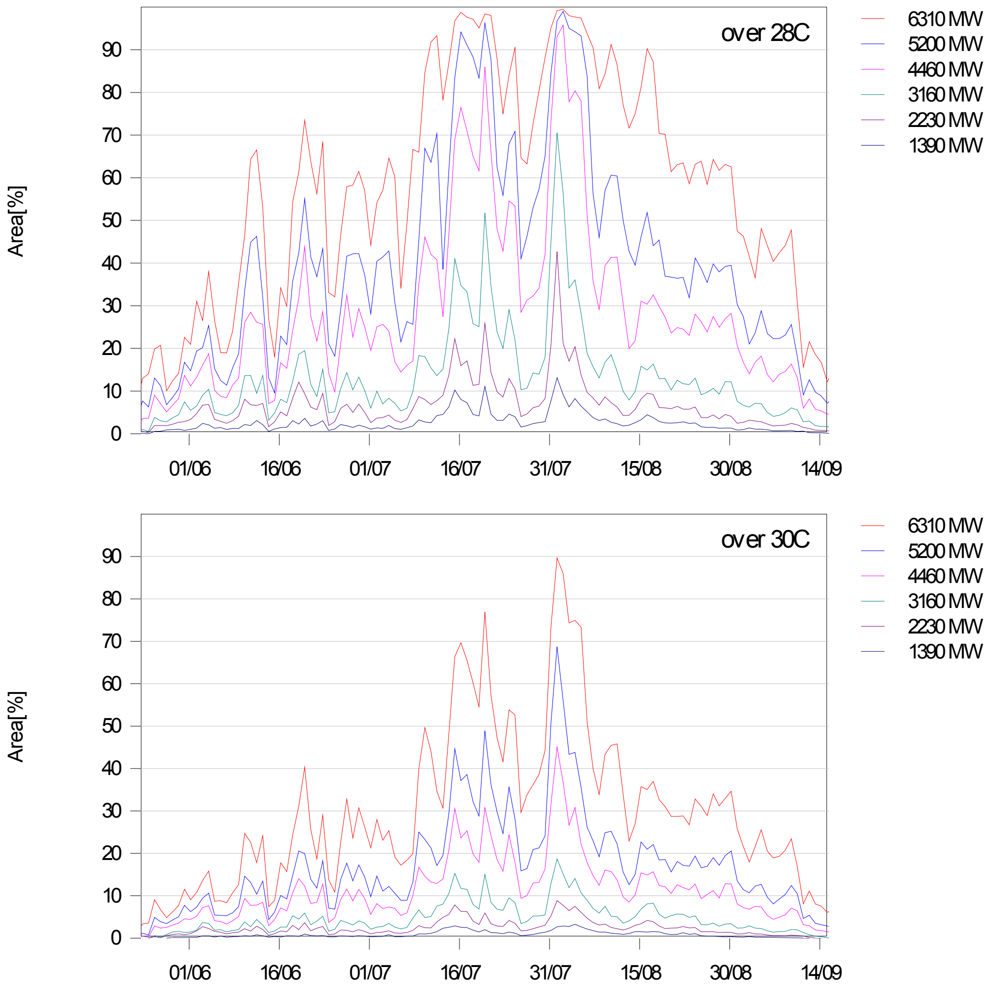


Figure 7.1-41. Proportion of the lake surface area (daily average) heated to over 28 ^{o}C (a) and to over 30 ^{o}C (b) by thermal load from 1 390 to 6 310 $MW_{released}$.

The computed summertime average lake surface temperature in the middle of the lake depends linearly on the thermal load. Figure 7.1-42 shows the computed average temperatures in point P24 as a function of the thermal load. The temperature rises about 2°C for each 2 000 MW of thermal load released to the lake. The above number is computed for year 2002 and for point P24, in other years and in different points the temperature rise may be different, as can be seen from the similar data computed for the point P38 for the same year.

The number of days when the temperature exceeds a given limit is shown as a function of the NNPP thermal load in Figure 7.1-43. For a limit of 28 degrees, the number of days starts to rise steeply after thermal load of 2 000 – 3 000 $MW_{released}$. For a limit of 30 degrees, the steep rise starts at thermal load level of 3 500 – 4 500 $MW_{released}$. The values depend strongly on weather data of simulation year, and these figures are valid for year 2002 only.

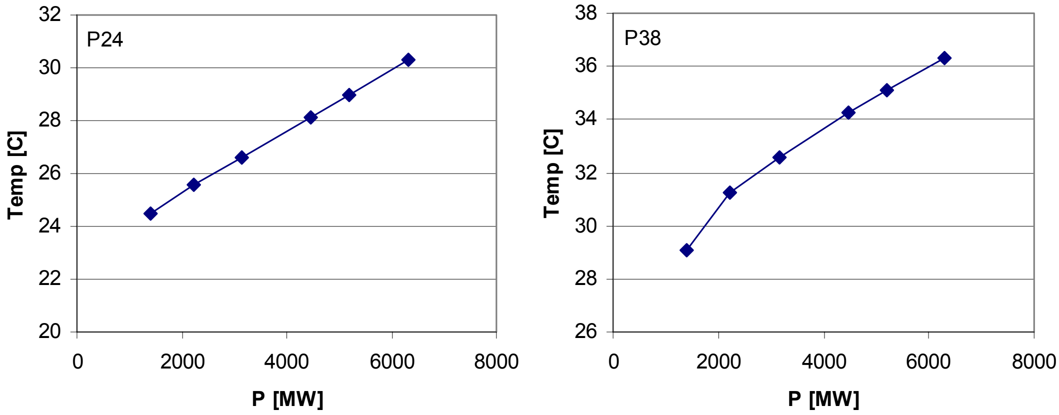


Figure 7.1-42. Dependency of average water temperature at points P24 and P38 on the NNPP thermal load in model simulations. Regression line for P24 is T = 0.00217 P + 22.88, goodness of fit is 0.99. Selected simulation period was 1.6-1.9.2002.

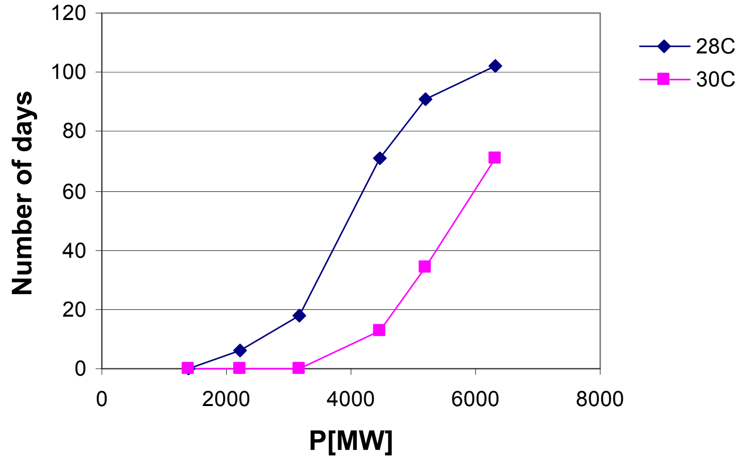
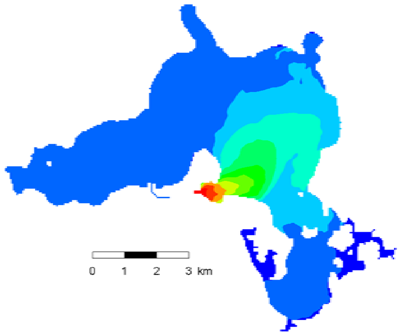
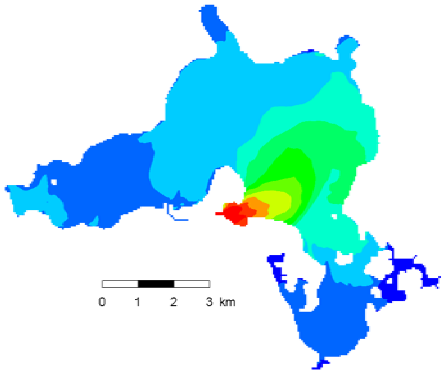


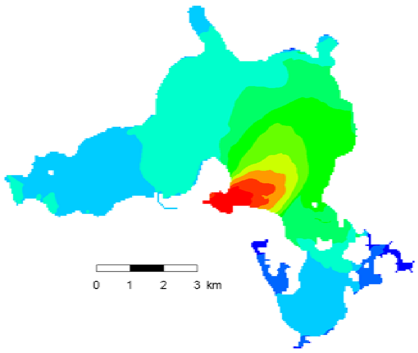
Figure 7.1-43. Dependency of the number of days when 20 % of the lake surface area warms over given temperature limit on the NNPP thermal load, simulation year 2002.

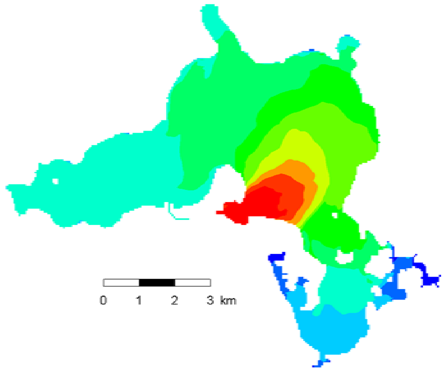
The lake surface temperature rise caused by the NNPP can be approximated by subtracting a reference temperature field computed without the NNPP from a scenario temperature field computed with the operating NNPP. Figure 7.1-44 shows temperature rise fields computed from the average temperature fields for July 2002 for the thermal loads 2 230, 3 160, 4 460 and 5 200 $MW_{released}$. The average lake surface temperature in July 2002 without the NPP was 23.5°C, with minimum values of 22.9 and maximum of 24.5 °C. Figure 7.1-45 shows the size of areas that warmed over a given temperature for different thermal loads.





*2 230 MW*released *3 160 MW*released





*4 460 MW*released *5 200 MW*released

Figure 7.1-44. Average lake surface temperature rise in July 2002 for thermal loads 2 230, 3 160, 4 460 and 5 200 MW$_{\text{released}}$.

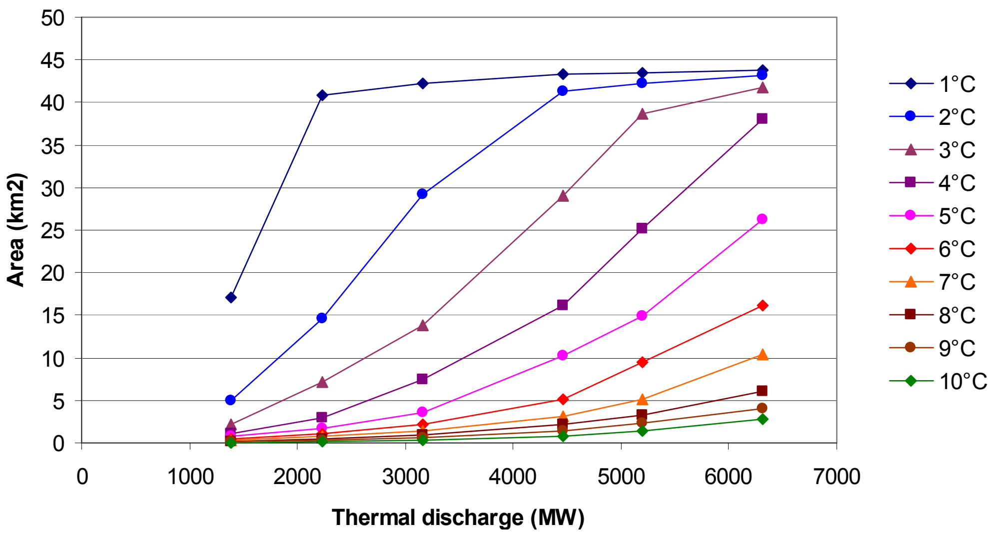


Figure 7.1-45. Area of lake surface temperature rise as a function of the thermal load, average of July 2002 for temperature rises of 1-10°C.

Inlet and outlet scenarios

To investigate the effect of NNPP inlet and outlet locations on lake temperatures, six alternative NNPP inlet and outlet location combination scenario sets were computed. The following inlet and outlet combinations were used:

PP	–	**p**resent inlet and **p**resent outlet
DP	–	**d**eep inlet and **p**resent outlet
PS	–	**p**resent inlet and **s**outhern outlet
WP	–	**w**estern inlet and **p**resent outlet
WS	–	**w**estern inlet and **s**outhern outlet
PD	–	**p**resent inlet and **d**ivided outlet

Western inlet and southern outlet scenarios

Figure 7.1-46 shows the average temperature distribution during July 2002 for scenarios PP, PS, WP and WS with 3 160 $MW_{released}$ thermal load.

Relocating the inlet to the western location has only a small effect on the surface temperature distribution near the inlet location. The western inlet reduces the warmed up areas a little, as the NNPP inlet water is slightly cooler than in the present inlet option.

Relocating the outlet to the southern alternative completely changes the temperature distribution: the western part of the lake remains cooler, while the southern part of the lake and especially the bay to which the outlet discharges, warms up significantly. When using the southern outlet the temperature in the middle of the lake decreases about 1 degree, and at the inlet the decrease is about 0.4 degrees. The southern part of the lake warms up about 4 degrees.

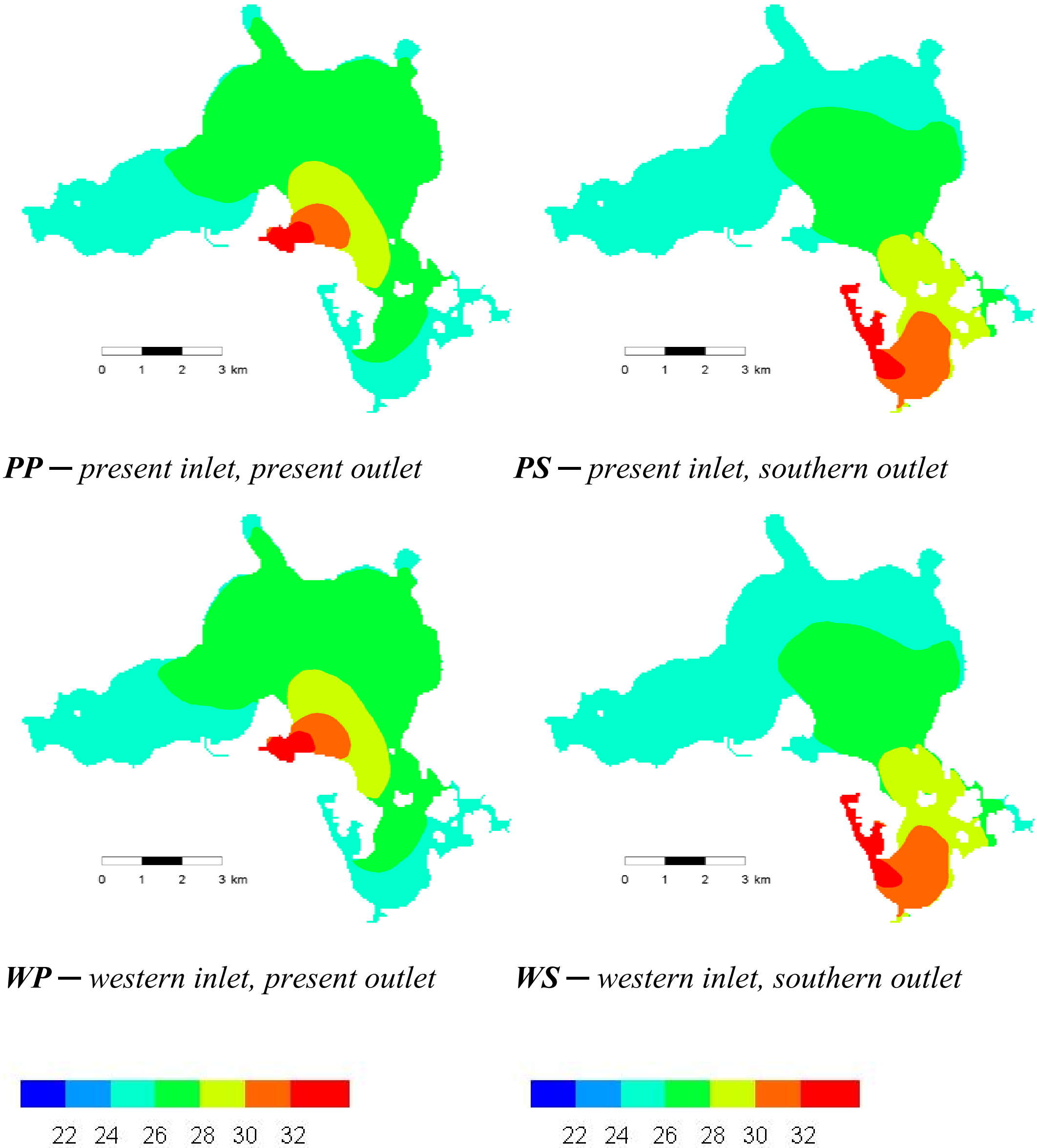


Figure 7.1-46. Average temperature field of the lake with thermal load of 3 160 $MW_{released}$ in July 2002 in different inlet – outlet alternatives.

Deep inlet scenario

Temperature fields of the PP and DP options are shown in Figure 7.1-47. The deep inlet option for 2 230 $MW_{released}$ thermal load warms the lake more than the present inlet option. In the model run the cold water storage of the deeper layer lasts about 1.5 months, after which the inlet temperatures closely resemble the surface inlet temperatures. After this initial period the thermocline no longer exists near the inlet, and the mixing of the warmer surface water to deeper layers becomes more intense. This reduces the lake surface temperature and thus reduces also cooling of the lake to the atmosphere. During hot summer months the lake is already warmed up and therefore also the surface warms to higher temperatures than with the present inlet.

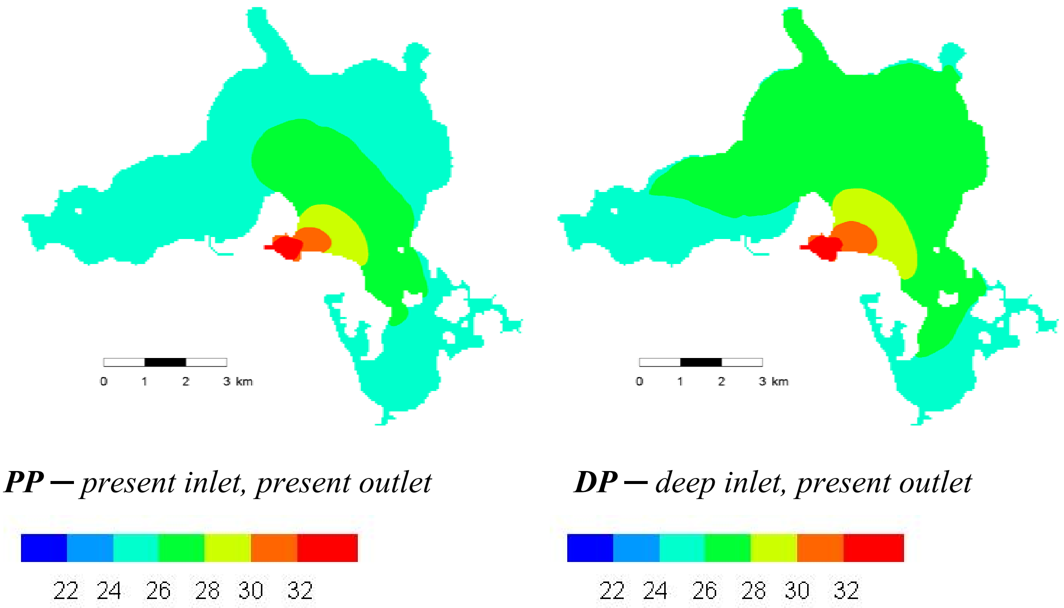


Figure 7.1-47. Average temperature field of the lake with NNPP thermal load of 2 230 $MW_{released}$ in July 2002 in deep and present inlet alternatives.

<u>*Divided outlet scenario*</u>

Dividing the 4 460 $MW_{released}$ cooling water outlet to two locations reduces temperatures in the middle part of the lake. At the same time the bay to which the southern outlet flows, and also the southern part of the lake warms up. This option reduces the area warmed over 28 degrees, and also the temperatures in the eastern part of the lake. The PP and PD scenario temperature fields are shown in Figure 7.1-48. In the divided outlet option the temperatures in the middle of the lake and also at the NNPP inlet are somewhat colder than in the present outlet option.

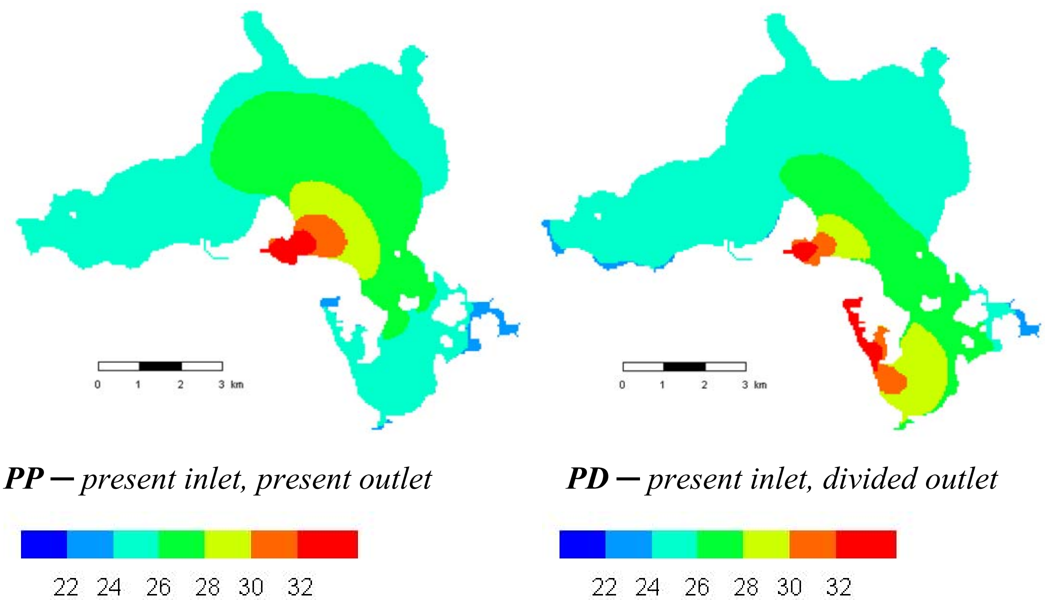


Figure 7.1-48. Average temperature field of the lake with NNPP thermal load of 4 460 $MW_{released}$ in July 2002, in present and divided outlet scenarios.

Impacts on ice cover

Wintertime ice conditions were simulated using four different NNPP thermal load levels, 2 230, 3 160, 4 460 and 6 310 $MW_{released}$. The simulation period was from 1.11.2002 to 6.1.2003.

The temperatures in January 2003 were low, thus these values represent the minimum open water area size (Figure 7.1-49). With a thermal load of 2 230 $MW_{released}$ a water area of 2.4 km^2 stayed free of ice. The ice free area increased to 5 km^2 with 4 460 $MW_{released}$ and respectively to 9 km^2 with 6 310 $MW_{released}$.

On the simulations from December 2002 the effects of different thermal loads on the areas frozen can be seen clearly. With the 2 230 $MW_{released}$ thermal load the ice free area is located close to the NNPP outlet. Thermal loads of 4 460–6 310 $MW_{released}$ keep the main part of the lake open longer from the start of the winter. In general the effect on the ice cover in the southern and western part of the lake is smaller compared to the central parts of the lake.

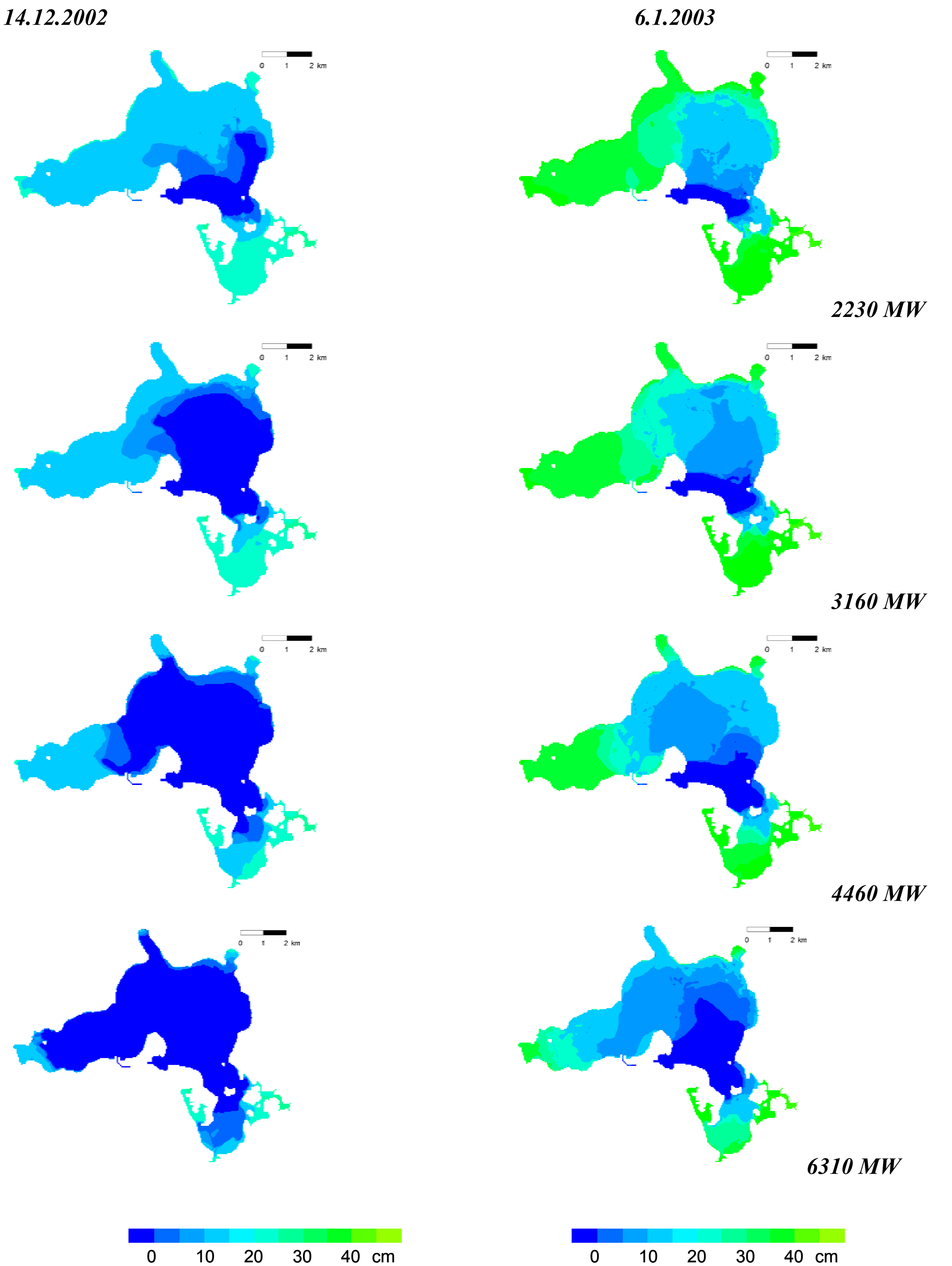


Figure 7.1-49. Computed ice cover on 14.12.2002(*left*) and 6.1.2003 (*right*) using NNPP thermal loads of 2 230, 3 160, 4 460 and 6 310 $MW_{released}$.

Sensitivity to temperature rise and wind data

Sensitivity of the used model to the changes of meteorological conditions was estimated using the following modified input data scenarios:

(1) Air temperature rise +2°C demonstrating climate change with NNPP thermal load of 3 160 MW$_{released}$
(2) Wind data from INPP meteorological station

The air temperature rise scenario reflects predicted conditions from year 2040 onwards as the result of climate warming. The air temperature of the warm period (April-October) is predicted (greatest predicted change) to rise 2,2 ^{o}C in Lithuania by 2040–2069 compared to the temperatures in 1961–1990 (*Bukantis and Rimkus, 2005*).

In the INPP wind scenario the measured wind speed and direction from the INPP meteorological station was used instead of the Dukstas station data. This scenario reflects the effect of possible errors in wind data on model results. The wind measured at the INPP station is likely to be more representative of the actual lake conditions than the Dukstas station data. However, the Dukstas station data was used, because data for all required simulation periods was not available from the INPP station.

Figure 7.1-50 shows the time-dependent effect of the climate change scenario compared to the present inlet and outlet 3 160 MW$_{released}$ scenario. The +2°C increase in air temperature warms the lake water about the same amount. The climate change result curve also resembles closely the curve with 5 200 MW$_{released}$ NNPP thermal load scenario at the present climate (see Figure 7.1-41).

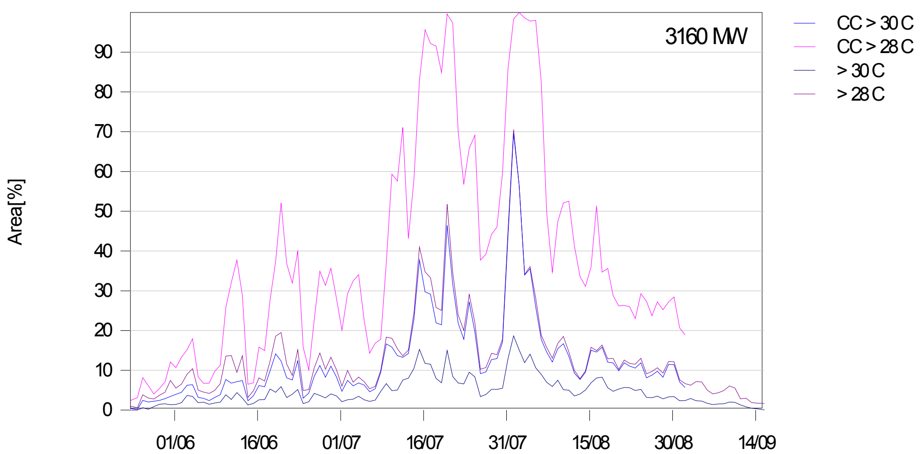


Figure 7.1-50. Proportion of the lake surface area heated to over 28 ^{o}C and 30 ^{o}C by NNPP capacity of 3 160 MW$_{released}$ in year 2002 and in climate change scenario.

Using the INPP wind data causes some changes to the sizes of the areas warmed over 28 and 30 degrees as shown in Figure 7.1-51. There seems to be a period of weaker winds in the beginning of June 2002, that increases the warmed up area size. Peak area size in the beginning of August is somewhat larger than in the simulation using Dukstas station data, but the number of days when the 20 % limit is exceeded is lower. However, the differences caused by using these two wind data sets are generally small.

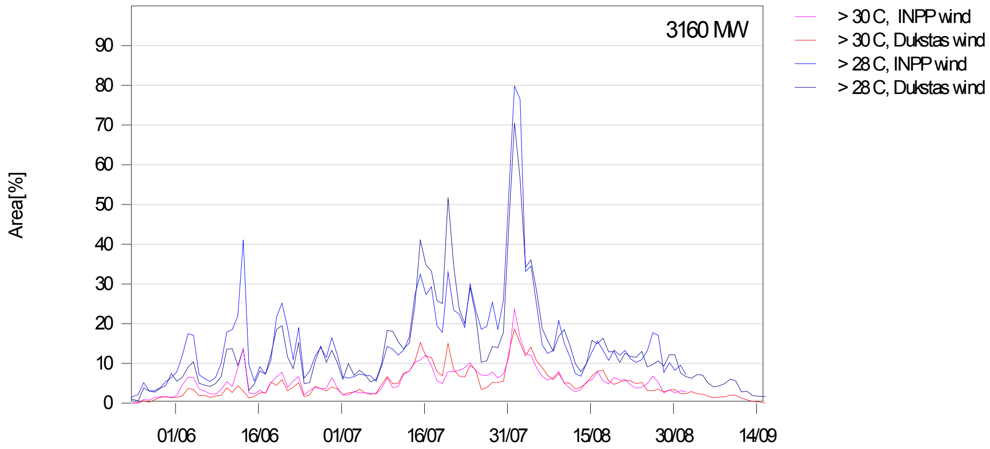


Figure 7.1-51. Effect of using INPP station wind data on the proportion of the lake surface area warming to over 28 °C at NNPP thermal load of 3 160$_{released}$ MW in 2002.

Conclusions

<u>*Thermal load scenarios*</u>

It can be concluded, that if the present criterion for lake warming (maximum 20 % of the lake surface layer warming to over 28 degrees) is used the maximum allowable thermal load to the lake during the summer months will be approximately 1 390 MW$_{released}$.

Respectively, if the criterion for lake warming would be set at 20 % of the lake surface warming over 30 degrees, the maximum allowable thermal load to the lake would be approximately 3 160 MW$_{released}$ during the warmest summer months. These results are calculated using input data from year 2002 and thus describe basically only this single year. In reality the limit for the thermal load may vary between years depending on the weather conditions.

<u>*Inlet and outlet locations*</u>

The current outlet is the best alternative when the area warmed up is used as criteria. However, the different outlet options do not significantly differ from each other. The present NPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water. The southern outlet position is more confined and shallow, which restricts the warm outlet water mixing with cooler lake water thus reducing the surface area where the cooling to atmosphere takes place. Dividing the outlet to two locations was no better than the present outlet option when comparing the average size of warmed up areas. However, the divided outlet option had a small advantage in the warmest day giving a somewhat smaller value for the area exceeding 28 °C, which is explained by higher than 30 °C temperatures near the southern outlet.

Western inlet option had on the average 0.1°C cooler inlet water temperature compared to the present inlet, and the area warmed up was therefore somewhat smaller. Otherwise the behaviour of the scenario was similar to the present inlet option. The temperature difference is explained by a larger distance to the outlet position.

In the deep inlet option simulation, the cold water storage of the deeper part of the lake was depleted in the beginning of the simulation, after which the inlet temperatures did not differ from the present inlet option. Additionally, in the deep inlet option after the thermocline of the lake is destroyed, the mixing of warmer water to deeper layer is increased raising the total heat storage in the lake. As a result, the deep inlet option produces higher surface temperatures during the warmest periods compared to the present inlet option.

Sensitivity computations and model accuracy

Sensitivity analysis computations showed that years 2001 and 2003 had both at least equally warm weather periods compared to year 2002. The climate change scenario with +2.0 °C temperature rise in summer months produced about 2 degree rise in water temperatures.

The possibility of error in the model simulations is mostly related to wind data and surface energy balance computation. Regarding the wind data, the used model does not take into account the possibility that the lake may modify the atmosphere and, for example, generate air movement as a result of warming of the lake. This may give too low values for the lake cooling, especially for situations when the wind speed is low. Therefore the highest peak temperatures, typical for the warm, low wind days, may be somewhat overestimated.

The lake surface energy balance model does not currently take into account the stability of the atmosphere, but uses neutral stability assumption. This may, in case of warm water and cooler air, give smaller values for cooling than in real situations. Also, in the model only one wind speed and direction value is used for the whole lake, whereas in reality the wind is different in different parts of the lake. The representativeness of the meteorological data for Lake Druksiai can also be questioned, as the nearest meteorological station (Dukstas) with weather data available for all the calibration and simulation periods is located 17 km away from the NNPP location.

It should also be noted that during warm summer periods lake water temperatures rise to high values also naturally. For instance 1.8.2002, without the NPP, the average surface temperature of the lake was 26.2 °C, with values ranging from 24.8°C to over 30°C.

Scenarios created for the assessment of impacts on lake ecology

The amount of waste heat discharged to the lake depends on the electricity produced and the cooling system chosen. In direct cooling system all the excess heat is discharged to the lake, whereas when using cooling towers only a very small part of the heat enters the lake and the major part is transmitted to air. The thermal load to the lake from the cooling towers can in this assessment be considered insignificant.

In order to illustrate the impacts of different thermal loads and cooling technology combinations in a concise and still comprehensive way, three scenarios were created based on the modelling results (0) and hydrological, limnological and biological expert assessment of the probable effects. In all the scenarios the electricity production is assumed to be 3 400 MW_e but the cooling system and consequently the thermal load to the lake varies. The following scenarios were chosen to the assessment:

- Scenario T1 – Thermal load to the lake will be at maximum 3 160 $MW_{released}$. This corresponds to approximately 1 700 MW electric energy produced by using direct cooling for heat dissipation. The remaining 1 700 MW_e will be produced using cooling towers. This scenario resembles roughly the conditions when both units of INNP were in operation.
- Scenario T2 – Thermal load to the lake will be at maximum 6 310 $MW_{released}$. This corresponds to approximately 3 400 MW electric energy all produced by using direct cooling for heat dissipation. In this scenario the heat load and the

temperatures in lake will rise compared to the period of INPP operation and to the scenario T1.

- Scenario T3 – Only cooling towers will be used for cooling and the thermal load to the lake will be negligible. In this scenario the lake water temperatures will decrease compared to the period of INPP operation and to scenarios T1 and T2.

Consequently, this assessment can, from the lake point of view, be considered roughly corresponding to production of 1 700 MW_e (T1), 3 400 MW_e (T2) and 0 MW_e (T3) with direct cooling.

In addition, also impacts of different inlet/outlet combinations were assessed.

Impacts on hydrology

The main hydrological impacts of the operation of the new NPP are the evaporative losses created when the heat from the cooling water is transferred to air by evaporation. The total losses depend on the plant effect and the cooling method selection (see Section 4.2. for description of the different cooling alternatives and Sections 7.1.1.2. and 7.1.1.3. for lake hydrology and water balance).

Water supply

The adequacy of the water supply for the new NPP has been assessed for a normal and a dry hydrological year (with a 1-in-20 year return period i.e. 95 % probability; see Section 7.1.1.3.).

According to the study by Janukiene (*1992*; see Section 7.1.13), raising the INPP electrical effect by 1 000 MW increases evaporation by 14.3 million m^3 per year. This corresponds approximately to evaporation rate of 0.45 m^3 per second.

However, it has to be noticed that extrapolation of the results above 1 500 – 2 200 MW, up to 3 400 MW, and the relatively low number of measurements having their own sources of error, creates insecurity to the calculations. Measurements were carried out mainly for the effects of INPP from 0 to 1 500 MW. One single measurement exists corresponding to effect of INPP of approximately 2 200 MW.

The evaporation via cooling tower is also in the order of 0.45 m^3/s per 1 000 MW of electrical power. Thus it can be estimated that the additional evaporation from the lake for 3 400 MW power plant is approximately 1.5 m^3/s regardless of the cooling system. This corresponds to 48 million m^3 per year.

During a normal hydrological year approximately 85.9 million m^3 of water would be available for additional evaporation caused by a NNPP, assuming that lake level is maintained at normal water level 141.6 m and minimum discharge out of the lake is 0.64 m^3/s. Thus, it can be calculated that during a normal hydrological year there are adequate resources available for cooling evaporation in all the alternative scenarios.

During a dry hydrological year, approximately 33.1 million m^3 of water would be available for additional evaporation (with the same assumptions as above). Additionally the regulating volume of the lake (difference between normal water level and minimum allowable water level) of 43.0 million m^3 would be available. The annual input of 33.1 million m^3 and the regulating volume of 43.0 million m^3 would give adequate water supply in all the evaluated scenarios for about three successive dry years (with a 1-in-20 year return period).

Because water supply generally exceeds demand, as indicated above, it is concluded that the water supply from Lake Druksiai is adequate to the water demands except in the case of more than three successive dry years. However, it is quite unlikely that this kind of drought would occur during the operation period of the new NPP. In this kind of a rare case either the operation of the one or more of the NNPP units should be temporarily limited or the water level of Lake Druksiai allowed to lower below the lowest presently allowed level.

Lake level

During normal hydrological years the average lake level is not expected to fall below the normal and thus the hydrological effects on the lake and their ecological consequences are considered minor. During dry years (with a 1-in-20 year return period) the lake level would fall below normal, however staying above the minimum allowed regulation level (for approximately three successive dry years). Thus also the consequences of this kind of events can be estimated to be small.

Downstream river flow

Evaporation of water by cooling the NNPP would reduce the overall volume of water in the lake, thereby impacting the quantity of water discharged to River Prorva. The operation of the new NPP would result in a net decrease of water available to the River Prorva equal to the evaporation caused by the cooling systems.

The discharges out of River Prorva have not been measured during the operation period of INPP. Thus the outflow has been estimated by subtracting the additional evaporation (0.8 m^3/s), estimated to be caused by the INPP with average production[2] of 1 800 MW, from the natural average outflow (MQ=3.3 m^3/s). The estimated present mean discharge to the River Prorva is thus 2.5 m^3/s.

Furthermore, the new mean discharge is calculated similarly (by subtracting the additional evaporation due to the NNPP from the natural MQ).

The evaporation from the new plant (assuming effect of 3 400 MW) would be approximately 0.7 m^3/s higher than at present (corresponding to the increase of 1 600 MW). Consequently the present mean annual discharge to River Prorva would decrease approximately by 28 %.

The decrease of mean flow would impact the approximately 50 km long stretch of River Prorva, flowing through lakes Obole and Bogino before the confluence of River Dysna (MQ=10 m^3/s, observation point below Druksa rivulet). Reduced flows could alter the riparian vegetation and habitat for riparian and wetland species along the river. They could also have adverse impacts on the river water use for e.g. irrigation or cattle watering. However, the minimum discharge in River Prorva will remain at the present level (0.64 m^3/s) in all of the scenarios.

The decrease in the mean discharge in River Dysna is so small (7 % of the mean discharge 10 m^3/s) that after the confluence with River Dysna the impact of NNPP can be considered negligible.

Impacts on aquatic ecology

The impacts on the aquatic ecology were assessed based on the modelling results, the ample available scientific research and monitoring data of the lake and international research of the impacts of thermal discharges.

[2] The average production has been calculated as a yearly average from period 1993–2004 when both units were in operation.

Period between closure of the INPP and the commissioning of the new NPP

The second unit of the Ignalina NPP will be shut down in the end of 2009 and the new NPP will start operating in year 2015. During that period the thermal discharges to Lake Druksiai will be minimal. This will impact the lake ecosystem in several ways. Due to eutrophication the lake has high primary production and consequently quite high decomposition rates. This has already at present led to oxygen depletion in the deeper water layers. During the last few years oxygen content has been lowered already at a depth of 10 meters.

When the lake is not anymore warmed by the thermal discharges after 2009, it will be covered by ice during cold periods. As exchange of oxygen between air and water is thus prevented, it may lead to further weakening of oxygen situation during winters, which again contributes to nutrient release from the sediments and thus accelerates eutrophication development. In the worst case, total oxygen depletion under the ice cover might lead to fish kills, but due to quite short and mild winters of Lithuania and consequent short duration of ice cover, this is unlikely.

As the expected period without thermal loading is quite short, 6 – 8 years, no major changes to the present state of the lake can, however be expected. On the other hand the formation of ice cover might accelerate eutrophication development, but on the other, absence of thermal load decelerates it.

It must be noted, that this period resembles to a large extent the changes expected to occur in the T3-scenario. One important difference is naturally that the conditions in T3-scenario would last the next 60 – 80 years instead of 6 – 8 years. This issue is discussed in more detail later.

Thermal load levels

<u>*General*</u>

Thermal discharges raise the temperatures in the receiving water body. The rise in temperature affects organisms differently depending on their preferences. The impacts can be direct (e.g. longer growth period) or indirect (e.g. sufficient food is no longer available or more food is available). In the beginning of the growth period, i.e. in April-May, the ecological impacts of temperatures higher than natural can be significant even though the temperatures as such would not be harmful.

When ambient water temperature rises over 30–32 degrees it is considered harmful to most aquatic organisms. The effects depend on organisms' tolerance as well as the exposure time. Even in natural watercourses water temperature may occasionally rise over 30 degrees. Hence most of the organisms (e.g. fish) are capable to avoid or tolerate high temperatures for short periods (*Langford, 1990*), but will be affected, if the average temperatures are raised for a longer period of time. Consequently, most of the ecosystem changes are realized only within a longer time period, which can vary from days to several years. The detectable ecosystem changes are generally limited to the areas where the water temperature is continuously more than one degree higher than in the natural situation.

Temperature rise accelerates biological activity. The organisms' metabolic activity is higher in warmer temperatures, which leads to faster growth, presuming that conditions are otherwise favourable (e.g. nutrients/food is available). The level of primary production, i.e. growth and reproduction of phytoplankton and vegetation, generally increases as a result of risen temperature and longer growth period. Furthermore, decomposition accelerates and the nutrients are efficiently recycled. High production will increase sedimentation of organic material, which again leads to acceleration of decomposition. Decomposition consumes oxygen in the water layers near the bottom (hypolimnion). Resulting anoxic or low-oxygen conditions are harmful for bottom fauna and fish living or feeding in the hypolimnion.

The described impacts of thermal discharges in the living conditions of species and the production rates are the basic factors behind the significant changes in species composition and diversity observed in Lake Druksiai during the operation of INPP.

In the T1-scenario the thermal load will be approximately as at present. During the last decades the lake has changed from cold and oligotrophic to warm and eutrophic as a result of both the thermal load from INPP and the nutrient load from municipal and other sources. This has led to changes in species composition and abundance. Hence, the organisms habiting the lake at present are adapted to the prevailing conditions. Since the new NPP would in this scenario not significantly alter the thermal conditions from the present, no significant impacts on the present ecosystem can be expected. However, if the nutrient load to the lake can not be significantly reduced in the near future, the eutrophication development will continue and accelerate.

In the T2-scenario the thermal load will be higher than it has been during the operation of the INPP. Temperatures will rise almost in the whole lake area. The colder western part of the lake, which at present hosts the species preferring cold water, will also be warmed up to some extent. Temperatures close to the outlet (P38) can rise up to 37–38 degrees, to the levels considered lethal for many aquatic organisms. Also the area where temperatures rise to the harmful levels (over 30 – 32 degrees) is larger than at present. Furthermore, the periods with high average temperature will last longer than at present.

Impacts of this scenario will probably roughly resemble those observed in cooling basins or other limited areas, where temperatures are constantly kept several degrees higher than in the surroundings (e.g. in closed biological research basin at Forsmark NPP on the coast of Sweden; *Sandström & Svensson 1990*). The thermal load will intensify the current eutrophication development. The diversity of species can decrease as the still remaining cold-preferring species disappear from the lake. At the same time the biological production of the lake can, however, increase as the higher temperatures accelerate the growth of the remaining warm water species. Locally the effects can be opposite and biological production can decrease in the area close to the outlet due to the harmfully high temperatures.

In the T3-scenario water temperatures will decrease compared to the period of INPP operation, returning to the level of natural water bodies in the same area. This will improve the conditions for the cold preferring organisms. However, as the eutrophication development has been and still is quite intense, it can be estimated that the lake ecosystem will not start to change significantly towards the previous, more oligotrophic state.

The species typical to the eutrophicated waters will still dominate while the stocks of the clear and cold water preferring species will stay at the present low levels or might even continue to decline. Due to the colder water and shorter growth period the rate of primary production may somewhat decrease, but it is likely to remain on high levels typical to eutrophicated waters. In cold winters the lake will be ice-covered. This together with the eutrophication may lead to worsening oxygen situation, since the exchange of oxygen between air and water will be prevented. This leads to increase of nutrient release from the sediments and contributes to the eutrophication development.

<u>*Water quality*</u>

The quality of cooling water does not change when it passes trough a direct cooling system, thus the water quality impact does not depend on the thermal load. When cooling towers are used (T1 & T3) the increase of concentrations of substances in the circulating cooling water must be prevented by continuously taking some water in the system (“make-up water”) and on the other hand discharging some water out of the system (“blowdown water”).

Makeup water will be treated with antifouling chemicals to inhibit growth of organisms on the surfaces within the cooling tower. The amount of added chemicals and quality of the discharged water will be monitored and controlled according to the regulations setting the highest acceptable limits for outlet concentrations and amounts. These limits will be designated in order to protect aquatic communities. Thus concentrations of these chemicals in the blowdown water are not expected have a significant harmful impacts on the aquatic species.

The blowdown water is concentrated lake water. The concentrations of salts and other substances originating from lake water have risen to a level typically about 5–10 times higher than in lake water. Concentrations of the total dissolved solids (TDS) are expected to vary approximately between 1 320-2 640 mg/l. This does not directly increase the TDS concentrations in the lake water since nothing is added, but water is evaporated. This increased evaporation could elevate the concentration of total dissolved solids in the lake water. However, the additional evaporation is relatively small compared to lake volume.

Another mechanism that could cause water quality impacts is the “transport” of lake water from intake area to outlet area when it is used as cooling water. If the water quality in these areas differs, the water quality in both areas may change. This potential impact in various inlet/outlet combinations is evaluated in the following.

Present inlet–Present outlet & Western inlet–Present outlet options: water quality does not significantly differ between the intake and outlet areas. Thus using these combinations will not have an impact on water quality.

Present inlet–Southern outlet & Western inlet–Southern outlet & Present inlet–Divided outlet options: water quality in the western part of the lake is better than in the southern part of the lake where the municipal waste waters are discharged. Leading water from the less nutrient rich western part (*the southern outlet option and the divided option*) could improve water quality somewhat in the southern outlet area. The bay could also benefit from the improved water exchange. Higher temperatures accelerate the denitrification process (nitrogen is released from the lake to the atmosphere) and this natural nitrogen removal could somewhat mitigate the adverse effects of the nutrient load. However, the southern area of the lake is eutrophicated and quite shallow, thus the higher temperatures would probably accelerate the primary production leading to intensification of the eutrophication development. Based on this, the total effects of this option on southern outlet area would most probably be negative.

Deep inlet – Present outlet: at present the water in the deep layers is rich in nutrients, poor in oxygen and would have adverse effects on the water quality in the outlet area. However, as the volume of this deep water area is relatively small and would be totally used in approximately 90 days of power plant operation, the negative water quality impact on the discharge area would be quite short. In addition, the oxygen situation of the deeper areas would improve significantly as a result of the effective water exchange and thus benefit the lake. However, the thermal impacts discussed before make this option worse for the overall state of the lake than other options.

<u>*Plankton and aquatic vegetation*</u>

During the operation of the INPP the diversity of both phytoplankton and aquatic vegetation has decreased. Due to the eutrophication, which has been accelerated by the thermal load, several species have become extinct from the lake (see Section 7.1.1.4 for detailed description). The dominating species are characterised by high tolerance for various environmental hazards (such as high temperature and poor water quality). The primary production, however, has had an increasing trend compared to the time before INPP was in operation. This is likely due to the thermal load and eutrophication which have accelerated growth of the remaining tolerant species. The possible effects on plankton community have most probably been indirect (increase of temperature in receiving water body/ acceleration of eutrophication) since passing trough the power plant has not been observed to impact the plankton communities in the recipient waters (*Langford, 1990, Sandström & Svensson, 1990*).

In the T1-scenario the development of the plankton community and aquatic vegetation would probably resemble the current situation. Eutrophication, which to a large extent does not depend as much on the new NPP as on the external and internal nutrient loads together with the thermal load, would keep the phytoplankton biomass on the levels typical for eutrophicated water bodies. Phytoplankton species composition would probably remain quite similar to what it is at present. Cyanobacteria blooms, which are typical for eutrophicated waters, may still become more common in the future. The aquatic vegetation would probably not change significantly from the present since the most significant changes have already happened during the operation of INPP and the prevailing species are adapted to the warm and eutrophicated conditions. The currently prevailing tolerant species, such as *Myriophyllum spicatum* and *Phragmites australis*, would still be dominating and the total biomass would likely remain roughly on the present level. The zooplankton community is also likely to remain quite similar to what it is at present since the species preferring the cold waters (such as the glacial relict *Limnocalanus marcus*) have already disappeared.

In the T2-scenario the currently observed effects of thermal discharges and eutrophication would be accelerated due to the higher thermal load. The higher temperatures may lead to instability of the plankton community and enhance the conditions for mass development (blooms) of single dominating species of e.g. cyanobacteria or diatoms and these may become more common. In the zooplankton community the species tolerant to the higher temperatures would be dominating.

The high temperatures would be likely to increase biomasses of aquatic vegetation as the warming areas would be bigger. Only in the vicinity of the outlet (zone B) could the aquatic vegetation decrease because of the increased erosion and harmfully high temperatures. Also some remaining less tolerant species, such as charophytes, might become less abundant in the lake.

In the T3-scenario temperature would remain on natural level, which is colder than at present. However, eutrophication due to nutrient load is more dominating factor than the thermal load in affecting the phytoplankton production and aquatic vegetation. Therefore species composition would probably not change much compared to the present. Even cyanobacteria blooms would probably be as common as present or even increase if the current shift towards nitrogen limitation would continue. Also composition and biomass of aquatic vegetation would probably remain quite similar as at the present.

However, the conditions for vegetation in the vicinity of the outlet (zone B) would be improved as the strong current and high temperatures would cease. In this area the growth and diversity of vegetation would increase. In the zooplankton community the cold water preferring species would probably have better living conditions and their numbers might increase, but otherwise no significant impact on zooplankton community could be expected.

Bottom fauna

The thermal discharges are mainly warming the lake surface layer, hence the impacts on bottom fauna below the depth of few meters are mainly indirect. The effects of the scenarios (T1, T2 & T3) are considered almost similar, although in scenario T2 the bigger thermal load with stronger eutrophication and in T3 the ice cover would most likely lead to weaker oxygen conditions in larger areas than scenario T1.

In scenarios T1 and T2, the bottom fauna is reduced or completely absent in the vicinity of the cooling water outlet due to the high velocities removing the sediment, like it is at present. In the upper water layers where good oxygen conditions prevail, the biomass of bottom fauna would most probably increase as a result of improved food situation as a result of eutrophication and elevated temperature.

In the deeper bottom sediments the impact would be rather opposite as a result of the weakening oxygen conditions due to e.g. increased production and decomposition and/or ice-cover (in scenario T3). The bottom fauna would disappear or be replaced with few low-oxygen tolerant species in larger areas than at present.

The cold water preferring relict species dwelling on the deep bottom areas have already disappeared or decreased to very low numbers. Therefore significant negative impacts on them are not expected in any of the scenarios.

Fish stocks and fishing

The thermal discharges of INPP and eutrophication have already changed the fish community of the lake quite significantly. The abundance of species preferring cold and clear waters, such as smelt and vendace, has decreased while abundance of e.g. the cyprinids (like roach and silver bream), typical for warm and eutrophied waters, has increased.

At present, there are no professional fishermen fishing on the lake but domestic and recreational fishing is practised. The adverse effects of the proposed activity are mainly related to the changes in species composition towards less valuable species, increased dirtying and fouling of the fishing gear (nets etc.) and restricted possibilities to fish on the ice.

In T1-scenario the fish community would mainly remain similar as at present. The colder western parts of the lake would probably still act as refuge for cold-preferring species, but their future in the lake would still remain uncertain due to the general eutrophication of the lake. The cyprinids as well as e.g. perch would continue to be the dominating species. Since the fish stock has already adjusted to the prevailing temperature conditions, no significant changes compared to the present state are expected.

In T2-scenario the fish community would be further altered due to the higher temperatures in the whole lake. It is likely that the currently colder western part of the lake would be warmed so much that the area suitable for cold water species would decrease significantly or even too much for survival of some of them, e.g. vendace and smelt. Vendace spawns to the deeper bottoms during autumn, which makes it also vulnerable to oxygen depletion and increased sedimentation. Cyprinids and other tolerant species would become even more dominating in the fish community. Thus, the total fish biomass is likely to stay at present high level or even decrease. On the other hand, the average temperatures might at least in some parts of the lake be so high that even growth of the more tolerant species might start to decline. The changes would be adverse for fishing due to the decline of the more valuable species and fouling of the fishing gear (nets etc.). Ice fishing would become more restricted due to the shorter ice cover period.

In T3-scenario the water would become permanently cooler which would improve the living conditions of e.g. smelt and vendace. Due to the lower temperatures the species preferring cold and oxygen rich waters might somewhat increase their proportion of the fish stock of the lake. The general eutrophication development of the lake and the changes in the fish community has however been so strong that the fish stock would not be restored to the stage before the INPP commissioning. Species characteristic to the eutrophicated waters would still dominate. Permanent ice-cover during the winters combined with general eutrophication development might lead to anoxic or low-oxygen situations, which are harmful for fish as well as roe. This might lead to decrease of vendace, which spawns to the deeper bottoms.

Inlet and outlet location options

Present inlet option does not demand practically any construction work in the lake area so the effects during the construction period are small. In this option no new areas need to be altered by new structures.

Western inlet option will demand construction of new intake structures. The location of physical structures would naturally be altered permanently. Due to dredging, which is probably needed for the inlet structures and in front of them, the concentrations of particulate matter and nutrients would temporarily increase around the construction area. Bottom fauna and vegetation would temporarily be removed from the dredged area. Locally increased sedimentation and nutrient load can have adverse effects on e.g. fish roe and fry present at the shallow areas. Impacts of the construction works are, however, temporary and very local in nature.

In operation phase, due to decreased recirculation of cooling water, this option would lead to in average 0.1 degrees lower surface water temperatures than using the present inlet. This difference is however so small in practice that no ecological differences compared to using present inlet could be observed.

Deep inlet option would demand construction of a large tunnel (in the order of 100 - 160 m^2 cross-section area) and an intake structure on the deepest bottom area of the lake. This would cause more turbidity and related impacts than constructing the western inlet alternative, but these can still be considered temporary.

In the operation phase, the cold water reserve of the deep area of the lake would be depleted in about 1 – 2 months and after that the lake would not have a thermocline and intake water temperatures would approach surface water temperatures. Consequently, the thermal energy would spread more evenly in the lake water and the energy exchange to the atmosphere would be reduced. In average, the lake water would be warmer in the later part of the summer than when using surface inlets. This would reinforce the eutrophication development.

A benefit would be that the oxygen conditions in the deep part of the lake would improve as the water would circulate more efficiently. This would benefit the bottom fauna and other biota living in deeper water layers.

Present outlet option does not demand practically any construction work since the existing structures can be used. The area around the present outlet is strongly affected both by the current induced by the cooling water and the thermal load caused by it. Since the area has already changed due to the INPP, using the present channel for the new NPP would not significantly change the present state.

Southern outlet and divided outlet options would demand construction of new southern outlet channel and outlet structures. The impacts for constructing a new outlet channel are similar to the construction of the new inlet structure (see the description above). The major impacts are however related to the operation phase and discharge of the warm waters. The southern area of the lake is currently quite little impacted by the thermal discharges but affected by the waste water nutrient load. Discharging cooling waters to the nutrient-richer southern area would lead to acceleration of the eutrophication of that area. Primary production would increase and cyanobacteria blooms would most probably increase since the shallow, warm and nutrient rich conditions would favour the development.

The temperatures close to the outlet can rise to over 30 degrees in larger area during the warm days, since the mixing of the warm waters is more restricted due to the shallow and confined area. The conditions around the present outlet could improve somewhat as a result of the decreased or removed cooling water discharge, but these positive impacts would remain small compared to the adverse effects of this option. In general, the adverse effects of the option are evaluated more significant than the positive effects.

Conclusions

Ecological impacts of thermal load scenarios

The effects of the different scenarios resemble somewhat each other due to the general eutrophication development of the lake, which plays a major role in the ecosystem changes. The magnitude of the impacts, however, varies between the different scenarios. However, the planned new NPP does not significantly affect the trophic state of the lake since nutrient load from the NNPP is small and its impacts can not be distinguished from the general eutrophication development of the lake.

In the T1-scenario the impacts are roughly similar to what they have been while INNP has been operating. During the operation period of INPP the lake ecosystem has been altered to resemble the present thermal and trophic conditions. Consequently no significant changes in the ecosystem are expected in this scenario and it is considered acceptable from environmental point of view.

In the T2-scenario warming would comprise the whole lake area, periods of high temperature would last longer than at present and the area were temperatures exceeds the harmful 30–32 degrees would be larger. In general, it can be assumed that the species diversity would decrease but the total biological production would increase. Hence in this scenario the adverse effects on the lake ecosystem can be significant.

In the T3-scenario the lake temperatures will resemble the natural state more and this can somewhat improve the living conditions of the cold preferring species. However, recovery of the previous conditions or species composition is not expected. If the general intensive eutrophication development continues this alternative may also lead to low-oxygen conditions during periods of ice-cover. From this point of view, moderate warming of the lake can be even environmentally advantageous. This option has somewhat diverse effects on the lake ecosystem. It is the best option when the warming of lake is considered but may result also in adverse effects due to the oxygen depletion.

Ecological impacts of different inlet and outlet location options

From environmental point of view the present inlet and outlet options are the best alternative. Building a new western surface inlet would only bring marginal benefits from the thermal impact point of view. However, this option can be considered acceptable despite the small construction-time negative impacts.

The relatively small positive impacts achievable by building and operating a new deep inlet or new southern outlet structures can be considered insignificant compared to the adverse effects of these options.

7.1.2.7 Radiological impact

Like any nuclear power plant, the new NPP will discharge a small, strictly controlled amount of liquids which contain radionuclides into the environment. Estimated liquid releases from different reactor types assuming that total power of units does not exceed 3400 MW_e are summarized in Table 7.1-30. Data provided in the Table 7.1-30 is derived from the design control documentation (DCD) of different types of reactors. The releases are conservatively calculated values and thus the actual releases will most probably be significantly smaller.

Table 7.1-30. Estimated maximum annual liquid releases (MBq/year) into environment during normal operation of NPP.

	BWR		PWR			HWR
Reactor type	ABWR	ESBWR	EPR	APWR	AP-1000	CANDU-6
Number of units	2	2	2	2	3	4
Nuclide						
Ag-110m	2.44E+01	na	3.26E+01	1.33E+02	1.17E+02	na
Ba-140	5.04E+01	6.06E+01	3.11E+02	4.29E+02	6.13E+02	na
C-14	1.18E+01	na	na	na	na	na
Ce-141	8.88E+00	5.18E+00	3.70E+00	2.15E+01	9.99E+00	na
Ce-144	1.41E+02	na	9.62E+01	4.14E+02	3.51E+02	na
Co-58	6.66E+00	3.26E+01	1.11E+02	7.25E+02	3.73E+02	2.67E+03
Co-60	6.74E+02	6.66E+01	1.33E+01	1.04E+03	4.88E+01	3.14E+02
Cr-51	5.70E+02	9.62E+02	7.40E+01	4.44E+02	2.05E+02	8.62E+02
Cs-134	4.52E+02	5.04E+01	1.92E+02	8.88E+02	1.10E+03	na
Cs-136	2.36E+01	3.04E+01	2.29E+01	1.63E+03	6.99E+01	na
Cs-137	6.58E+02	1.33E+02	2.59E+02	1.33E+03	1.48E+03	na
Fe-59	7.40E+00	5.18E+00	na	1.70E+02	2.22E+01	na
H-3	4.44E+06	1.04E+06	1.50E+08	1.18E+08	1.12E+08	7.80E+08
I-131	2.36E+02	3.10E+02	2.52E+03	1.48E+02	1.57E+03	na
I-132	1.92E+02	6.06E+01	8.88E+01	2.29E+01	1.82E+02	na
I-133	7.40E+02	1.55E+03	2.59E+03	5.99E+01	7.44E+02	na
I-134	1.26E+02	2.96E+00	na	6.59E+00	8.99E+01	na
I-135	5.56E+02	4.00E+02	1.11E+03	5.77E+01	5.52E+02	na
Y-91	8.14E+00	1.04E+01	na	6.66E+00	na	na
La-140	1.26E+01	na	5.62E+02	5.92E+02	8.25E+02	na
Mn-54	1.92E+02	1.18E+01	4.00E+01	3.33E+02	1.44E+02	1.04E+04
Mn-56	2.82E+02	9.62E+01	na	na	na	na
Mo-99	6.14E+01	2.22E+02	na	1.26E+02	6.33E+01	na
Na-24	2.08E+02	3.78E+02	4.51E+02	3.48E+02	1.81E+02	na
Nb-95	7.40E+01	1.48E+00	7.40E+00	1.48E+02	2.33E+01	8.37E+03
Np-239	2.30E+02	8.14E+02	4.29E+01	3.92E+01	2.66E+01	na
Pr-143	9.62E-02	6.66E+00	3.70E+00	5.85E+00	1.44E+01	na
Ru-103	1.33E+01	2.96E+00	1.85E+02	2.52E+02	5.47E+02	na
Ru-106	1.26E+01	na	2.29E+03	3.48E+03	8.16E+03	na
Sr-89	8.14E+00	1.63E+01	3.70E+00	1.11E+01	1.11E+01	na
Sr-90	2.60E+00	1.48E+00	na	1.33E+00	1.11E+00	na
Te-132	2.96E-01	1.48E+00	3.55E+01	3.48E+01	2.66E+01	na
Zn-65	6.66E+00	3.34E+01	1.26E+01	1.63E+01	4.55E+01	na
Zr-95	6.22E+01	1.48E+00	9.62E+00	9.62E+01	2.55E+01	na
TOTAL (H-3 excluded)	5.65E+03	5.27E+03	1.11E+04	1.30E+04	1.76E+04	2.26E+04

na – information about activity of releases nuclide is not available

For comparison the actual annual average releases during years 2004–2006 from two existing nuclear power plants in Finland are presented in Table 7.1-31 (*STUK 2005, STUK 2006, STUK 2007*). In the Finnish plants the annual discharges of tritium have been approximately 10 % and the annual discharge of other activation products about 0.002-0.003 % of the site specific discharge limit values.

Table 7.1-31. Annual amount of radioactive releases to water (MBq/year) from two Finnish NPPs and site specific limit values.

Liquid radioactive releases (MBq/y)	Loviisa 1 & 2 2x860 MW PWR	Limit	Olkiluoto 1 & 2 2x860 MW BWR	Limit
Tritium (H3)	1.60E+07	1.50E+08	2.17E+06	1.83E+07
Other fission and activation products (total)	8.00E+02	8.90E+05	6.00E+02	2.96E+05

Radioactive substances may be released into environment only after the permission to do this has been obtained. This permission is issued by the Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2001 “On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring” (*State Journal, 2001, No. 13-415; 2005, No. 142-5136*). In the permission the limits for the liquid radioactive releases will be set. According to the regulations, the protection measures ensuring an adequate safety for human are sufficient to protect both the environment and natural resources.

The radioactivity of the monitored nuclides in the aquatic environment around INPP has been continuously decreasing during the last years (see Section 7.1.1.5 for releases from the INNP). The releases have been and are so small that no negative impacts on environment have been observed. The new NPP will be constructed and operated using the best available techniques and practises to ensure low radioactive releases. Consequently the liquid radioactive releases of the new NPP will not have any negative impacts on environment or natural resources.

Annual exposure of the critical group members of population due to liquid releases into the environment from different types of power reactors is estimated in chapter 7.10. Radiological impact of new NPP on downstream water system in terms of effective dose is estimated in chapter 8.

7.1.3 Mitigation measures

7.1.3.1 Waste water treatment

Waste water originating from process and technical use will be treated depending on the quality of the waste waters by mechanical, chemical or biological means according to the regulations and laws. Waste waters from process water production will be neutralized. Possible oil traces will be removed. Waste waters from the controlled area will be processed in the liquid waste treatment plant. The impacts of the treated waste waters on the lake are estimated to be minor and acceptable. However, these impacts will be monitored and if unacceptable consequences occur, the treatment of waste waters will be improved.

The household waste waters of the new NPP will be treated at the new waste water treatment plant of Visaginas town. The loads from the new NPP represent only 4 - 8 % of the loads discharged to the lake from the new waste water treatment plant and naturally even smaller part of the total load to the lake. Thus treatment of the sanitary waste waters at the new waste water treatment plant can be considered adequate.

The liquid radioactive releases are reduced by applying the best available techniques in treatment and monitoring of the possible sources of the radioactivity. All the waste waters from the controlled area will be treated in the liquid waste water treatment plant (detailed description in Section 6.2.2). The radioactivity of all waste waters is constantly monitored and if the activity exceeds the limit activity determined in regulations, the water in question will be transferred to further treatment.

Even though the amount of radioactive releases to the aquatic environment is very small, the equipment and practices are constantly developed and maintained to continuously reduce the releases.

7.1.3.2 Cooling method

When selecting the type or combination of cooling systems for new NPP units, the following issues have to be taken into consideration:

- the amount of thermal load to the lake,
- the impacts of the thermal load on the aquatic environment as well as
- the hydrological impacts in the lake and watercourse below.

With the present regulation (see the next Section) the maximum thermal load to the lake especially during July and August is very limited. During the rest of the year the lake can, however, tolerate substantially higher thermal load. Consequently the environmentally and economically best option may be to limit the thermal load to the lake mainly during the warmest months.

The NNPP can be constructed in a way that it relies mainly on direct cooling during the colder periods. When the impacts of the thermal load on the lake are starting to become ecologically significant in spring and summer, the power plant can then switch totally or partially to other cooling techniques.

The environmentally and technically best cooling technology will be selected later in the design phase of the new plant. There are several available technologies and their combinations. For example, the cooling can be carried out by combining direct cooling and wet cooling towers.

The different cooling technologies are discussed in more detail in Section 4.2 Cooling water systems.

7.1.3.3 Timing of the yearly maintenances

The average length of the annual maintenance break is 2 to 6 weeks per one unit. In case of two or more units the maintenance periods are carried out successively. During this period the thermal load is lower than normally since one unit is out of operation. In case of one-unit NPP, the thermal load is practically zero during the maintenance period.

Other factors allowing, by timing the maintenance periods to the warmest summer months (July and August) impacts of the thermal load could be significantly decreased during this ecologically most critical period.

7.1.3.4 Possibilities to utilize thermal energy

When using direct cooling the temperature of the water led to the lake has increased about 10°C. The thermal energy led to the lake varies according to the power production (see Table 7.1-25) and cooling technique. For example, in case of a 1 700 MW_e unit running 8 000 hours per year the annual energy amount led to lake is approximately 90 900 TJ = 25 260 GWh. For comparison, this amount is about 4 times the annual district heating energy used in Helsinki (500 000 inhabitants) or about 2.8 times the annual district heat delivery in the country of Lithuania (*Helsingin Energia 2008, IEA 2005*) or about 80 times the use of district heat in Visaginas town (compared to year 2004).

In order to produce heat or steam in a nuclear power plant, it must be designed for this purpose from the beginning. The heat or steam that the NNPP could produce for heating or industrial purposes can be transported only relatively short distances, some tens of kilometres, for it to be economically viable. The INPP has produced heat to the district heating system of the town Visaginas. It is also possible to produce district heat at the new NPP. However, the demand of Visaginas town covers only approximately one percent of the waste heat produced. This comparison makes it understandable that there does not exist such a utilization possibility for the waste heat, which would significantly reduce the need for heat dissipation either into the air or into the lake.

Other possible ways to utilize the excess heat in the cooling water would be to use it to heat the ground like football fields for recreational purposes. Utilization in greenhouses or in fish farming would also be possible. However, only a very small amount of heat could be used for these activities and thus no remarkable reduction in the amount of thermal energy led to Lake Druksiai could be achieved. In addition, other impacts e.g. nutrient load from the fish farming could be more harmful to the lake than the achieved benefits by small heat load decreases.

An additional factor making utilization of the waste heat difficult is the relatively low temperature of the discharged cooling water.

7.2 CLIMATE AND AIR QUALITY

7.2.1 Present state of the environment

7.2.1.1 Climate

The region concerned is located in the continental East Europe climate area. One of the main features of the climate in the region is the fact that no air masses are formed over this area. Cyclones are mostly connected with the polar front and determine continuous movement of air masses. The cyclones formed over the medium latitudes of the Atlantic Ocean move from the west towards the east through Western Europe and the new NPP region is often located at the intersection of the paths of the cyclones bringing humid maritime air. The variation of maritime and continental air masses is frequent, therefore the climate of the region can be considered as a transient climate from the maritime climate of Western Europe to the continental climate of Eurasia.

In comparison with other Lithuanian areas, the new NPP area is characterized by big variations of air temperature over the year, colder and longer winters with abundant snow cover, and warmer, but shorter summers. Average precipitation is also higher.

7.2.1.2 Precipitation and snow cover

Monthly averages of precipitation for the new NPP region are given in Table 7.2-1. Average annual amount of precipitation in the new NPP region is 638 mm. About 65 % of all precipitation takes place during the warm period of the year (April–October), and about 35 % during the cold period (November–March).

Table 7.2-1. Monthly averages of precipitation (mm) for the new NPP region.

Meteorological station and observation period	Month (s)												Total for months		
	01	02	03	04	05	06	07	08	09	10	11	12	01-12	11-03	04-10
Dukstas, 1961–1990	32	25	28	43	58	69	75	66	64	50	42	40	592	167	425
Utena, 1961–1990	39	31	37	47	53	69	73	75	66	50	57	53	650	217	433
Zarasai, 1961–1990	45	36	39	42	59	72	75	66	66	55	60	56	671	236	435
INPP, 1988–1999	41	41	46	33	55	84	60	64	70	66	58	57	676	244	432
INPP, 2000–2005	46	46	36	40	52	92	78	68	38	75	59	46	676	233	443

The snow cover in the region lasts about 100–110 days per year. Average thickness of the snow cover is 16 cm, and the maximum is 64 cm. Density of snow cover gradually increases from 0.2 to 0.5 g/cm^3 in the middle of March. Absolute maximum of recorded weight of snow cover is 120 kg/m^2.

7.2.1.3 Wind

Western and southern winds dominate. The strongest winds have western and south-eastern directions. The average annual wind speed is about 3.5 m/s, and maximal (gust) speeds can reach 28 m/s. No-wind conditions are observed on, on the average, 6 % of the time and last no more than one day (24 hours) in the summer, and no more than two days in the winter. The wind rose of the new NPP region is based on local wind measurements and is presented in Figure 7.2-1.

Winds with speeds below 7 m/s dominate – recorded events constitute more than 90 % of the total number of observations. Recorded events with wind speeds above 10 m/s are not frequent – less than 10 events per year.

Calculated average wind pressure is 0.18 kPa and pulsation component of wind load is 0.12 kPa. With a reliability coefficient of 1.4 the calculated value of uniform wind load is 0.42 kPa and extreme wind load (with frequency 1 per 10 000 years) is 1.05 kPa with the reliability overloading coefficient 2.5 (*Almenas et al., 1998*).

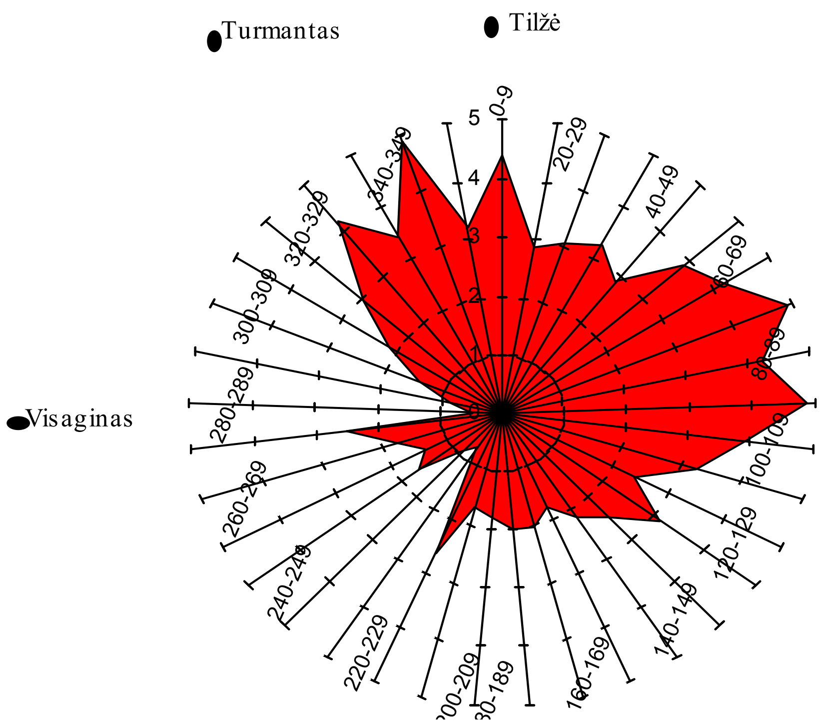


Figure 7.2-1. Wind rose at the new NPP region (wind direction off the new NPP).

Extreme events (spouts) are rare in the vicinity of the Ignalina site. During a storm in 1998 a wind speed of 33 m/s was recorded. Spouts in the vicinity of the new NPP have not exceeded class F-2 according to Fujita classification. The season of spouts begins at the end of April and ends in the first half of September. The direction of spout motion is from south-west to north-east in 75 % of the cases. The average length of spout shift trajectory is 20 km and the length varies from 1 to 50 km. Average width of the spouts is 50 m with variations from 10 to 300 m. Calculated maximum spout velocity with a frequency of 1 in 10 000 years is 39 m/s (*Almenas et al., 1998*).

According to the data of Lithuanian Hydrometeorological Service under the Ministry of Environment (*http://www.meteo.lt*) the maximal wind speed of 40 m/s measured in Utena on June 1986 is a Lithuanian meteorological record. The maximal speed of spout of about 70 m/s has been observed in Sirvintos on May 29, 1981. Spout of such speed is classified as class F-2 according to Fujita classification.

7.2.1.4 Insolation

Average annual duration of sunshine in the region is about 1710 hours (42 % of the maximum possible duration of the earth's surface insolation by the sun). June is the sunniest month: the amount of sunshine in June is about 280 hours (58 % of the possible duration). The shortest period of sunshine because of cloudy weather is observed in December, which is about 20 hours (12 % of possible duration).

Average annual cloudiness in the region is about a force 7. In December it increases to a force 8.5 and in May it decreases to a force 6.5. The average annual amount of cloudy days (175) is considerably larger than the clear ones (*Almenas et al., 1998*).

7.2.1.5 Temperature

Monthly average temperatures in the new NPP region are given in Table 7.2-2.

Average calculated air temperatures of the coldest five-day period are –27 ºC. Absolute maximum of recorded temperature is 36 ºC and absolute minimum is –40 ºC. Absolute maximum of calculated temperature with a frequency of 1 in 10 000 years is 40.5 ºC and absolute minimum of calculated temperature with a frequency of 1 in 10 000 years is –44.4 ºC (*Almenas et al., 1998*).

Table 7.2-2. Monthly average temperatures (°C) for the new NPP region.

Meteorological station and observation period	Month												01–12
	01	02	03	04	05	06	07	08	09	10	11	12	Average
Dukstas, 1961–1990	-6.8	-5.9	-1.9	5.2	12.1	15.5	16.8	15.9	11.2	6.2	0.9	-3.8	5.5
Utena, 1961–1990	-6.0	-5.2	-1.2	5.5	12.2	15.6	16.8	15.9	11.4	6.6	1.4	-3.2	5.8
INPP, 1988–1999	-2.5	-2.2	0.3	6.6	12.4	16.5	17.9	16.5	11.3	6.0	-0.1	-3.1	6.6
INPP, 2000–2005	-3.6	-4.4	0.7	7.4	12.4	15.2	19.1	17.3	11.8	6.4	1.6	-3.3	6.7

7.2.1.6 Atmospheric pressure

Normal range of atmospheric pressure is 994 hPa. The greatest values of twenty-four-hour atmospheric pressure are usually in winter and vary from 1010 to 1027 hPa. The smallest values of twenty-four-hour atmospheric pressure are observed in summer and vary from 970 to 985 hPa. The oscillations of twenty-four-hour amplitude of atmospheric pressure vary from 15 to 25 hPa.

7.2.1.7 Humidity

Average relative humidity of air reached 80%, and about 90% in winter. A minimum relative humidity (53–63%) is observed in June, and a maximum – in January.

7.2.1.8 The frequency of storms with lightning

The average number of storms with lightning is 11 per year. Four storms monthly are usually observed in July–August and 1–2 storms in other relatively warm months.

Average duration of the storms is 2 hours and the maximum is 4 hours. Average duration of storms with lightning in the course of a year is about 22 hours.

7.2.1.9 Fogs

Fog can be observed any day of the year in the new NPP region. The average number of foggy days is 45. Fog absorbs different impurity (noxious gases, smoke, dust) and, combined with high humidity, increases corrosion intensity, aggravating visibility and impeding transportation. Average duration of fog in the course of a month is from 4 to 29 hours and in the course of year about 173 hours. During the cold period total duration of fog varies between 92 to 106 hours, and during the warm period it is about half of that, which is 49–68 hours.

7.2.1.10 Black ice, hoarfrost, ground freezing

There are about 15 days with glazed frost or ice-crusted ground, 14 days with hoarfrost and 18 days with blizzard per year. The length of hoarfrost threads reaches 50 mm.

The freezing of the ground usually begins in the first part of December and lasts to the middle of April. The average depth of the frost line reaches about 50 cm, and the maximum depth extends to 110 cm depending on the composition of the ground and its humidity.

7.2.1.11 Background contamination of the ambient air and greenhouse gases

Present background contamination

Information on environment background contamination provided in this chapter is based on the reports on the analysis of concentrations of contaminants in the atmosphere presented in the website of the Environment Protection Agency (*http://aaa.am.lt/*).

Analysis of concentrations of atmospheric contaminants in Lithuania is performed in the Integrated Monitoring (IM) stations in Aukstaitija (LT01), Zemaitija (LT03), and Preila. Automatic air quality monitoring stations are located in the biggest cities of Lithuania (the closest station is in Panevezys); however, they reflect air situation in the big cities only. Air quality in the region of the NNPP may be evaluated based on measurements of concentration of contamination in the atmosphere at Aukstaitija (LT01) station, which is to the north-west from the INPP at a distance of about 80 km. At this station concentrations of gaseous (SO_2, NO_2), aerosol (SO_4^{2-}) and total ΣNO_3^- (sum of gaseous NO_3 and aerosol particles NO_3^-) and ΣNH_4^+ (sum of gaseous NH_3 and aerosol particles NH_4^+) contaminants are measured. Table 7.2-3 presents values, measured for atmospheric contaminants at Aukstaitija station (LT01) in 2006.

Table 7.2-3. Statistical values of concentrations of contaminants in air at the station LT01 in 2006 (*Data from Environment Protection Agency*).

Component	Measure-ment unit	Concentrations of contaminants								
		Min.			Max.			Annual average		
		LT01	LT03	Preila	LT01	LT03	Preila	LT01	LT03	Preila
SO_2	μgS/m^3	0.07	0.04	0.01	5.64	4.10	7.59	0.85	0.89	0.47
NO_2	μgN/m^3	0.15	0.08	0.23	2.29	2.89	5.33	0.70	1.10	1.30
SO_4^{2-}	μgS/m^3	0.16	0.26	0.02	2.84	2.76	2.00	0.84	0.79	0.39
ΣNO_3^-	μgN/m^3	0.14	0.20	0.01	1.49	1.17	3.27	0.52	0.58	0.69
ΣNH_4^+	μgN/m^3	0.46	0.32	0.17	2.96	3.27	5.06	1.26	1.51	1.71

Limit values for ambient air pollution according to the Lithuanian regulation "Ambient air pollution standards" (*State Journal, 2001, No. 106-3827*) are given in Table 7.2-4.

Table 7.2-4. Limit values for ambient air pollution established for protection of human health, ecosystems and vegetation.

Pollutant	SO_2	SO_2	SO_2	NO_2	NO_2	NO_x	SP_{10}	$SP_{2.5}$	CO
Averaging time-span	1 h	24 h	1 y, ½ y	1 h	1 y	1 y	24 h	24 h	8 h
Limit value, µg/m^3	350 (24 t)	125 (24 t)	20 E	200 (18 t)	40	30 V	50 (35 t)	40 (14 t)	10 mg/m^3

SP – Solid Particles

(24 t), (18 t), (35 t), (14 t) – allowable overrun per year

E – for protection of ecosystems

V – for protection of vegetation

It can be seen that measured values do not exceed limit values. Comparing the annual average values of concentration of atmospheric contaminants in 2006 in IM stations and Preila, it can be noticed that concentration of SO_2 and SO_4^{2-} in Preila are almost half of the concentrations in IM stations. However, annual average concentration of NO_2 in Preila is almost twice as big as at LT01 and slightly (about 18 %) greater than at LT03. In Aukstaitija (LT01), the annual average values of concentrations of all measured contaminants in 2006 are less than in Zemaitija (LT03). Annual concentrations of NO_2, ΣNO_3^- and ΣNH_4^+ in Zemaitija are by 12–57 % greater than in Aukstaitija.

Change of concentrations of SO_2 and NO_2 has a significant seasonal character. The highest, exceeding several times the average value in every analysis location in 2006, concentrations of sulfur dioxide at LT01 and LT03 stations in Preila occurred in January–March. In Aukstaitija (LT01), from April till the end of the year, the concentration of SO_2 was less than 0.85 μgS/m^3, with the exception of several weeks in August. In Zemaitija (LT03) and Preila less than average concentrations of SO_2 were measured during April–October 2006, and cases of greater than annual average concentrations of SO_2 were observed in some weeks of November–December. High concentrations of NO_2 (up to 2.5–3.7 μgN/m^3) at stations LT01 and LT03 were frequent in January–February and December. However, from March till mid-October concentrations of NO_2 were less than average in 2006 both at LT01, and LT03. In Preila, as at IM stations, change of NO_2 concentrations is significant. The greatest concentrations prevailed in January, November and December. From March to November concentrations of NO_2 were usually less than average in 2006. However, also in summertime there were days, when concentration of NO_2 reached 2–3 μgN/m^3. Level of atmosphere contamination with sulfur and nitrogen compounds above Lithuania is conditioned by emissions of these contaminants from local contamination sources and, mostly, from Western and Southern European states.

In change of concentrations of SO_4^{2-} in all locations of monitoring of atmospheric contamination, it is observed that the episodes of the highest concentrations are measured during weeks (IM stations) or days (Preila) of winter months and they co-occur with the episodes of high concentrations of SO_2. In change of concentrations of ammonium compounds ΣNH_4^+ a greater reoccurrence of smaller than in 2006 average concentrations is observed in summer months in comparison to winter months. The episodes of higher and as well lower ΣNH_4^+ concentrations co-occur with the episodes of high and low concentrations of SO_4^{2-}.

At both IM stations and in Preila more frequent reoccurrence of higher concentrations of ΣNO_3^- than average in 2006 was obtained in January–April. Concentrations less than 0.4 μgN/m^3 ΣNO_3^- usually occurred from May till October.

Taking into consideration the change of average annual concentrations of SO_2 during the period of 13 years, their significant decrease can be observed in all monitoring locations from 1994 to1997: at LT01 it decreased about three times, at LT03 and Preila – about two times. The concentrations of SO_2 in past 10 years changed in a relatively small range with no significant increase or decrease tendency. The concentrations of SO_2 in past 10 years and their standard declinations are as follows: LT01 – 0.74 ± 0.16 μgS/m^3, LT03 – 0.76 ± 0.24 μgS/m^3 and Preila – 0.93 ± 0.26 μgS/m^3.

The average annual concentrations change of SO_4^{2-} is similar to SO_2. The concentrations of SO_4^{2-} in past 10 years changed in a relatively small range and average concentrations of this period and their standard declinations are as follows: LT01 – 0.89 ± 0.15 μgS/m^3, LT03 – 0.83 ± 0.18 μgS/m^3 and in Preila – 1.06 ± 0.28 μgS/m^3.

Annual average concentrations of NO_2 in 1999–2006 in Aukstaitija (LT01) changed from 0.66 to 0.70 μgN/m^3 with no significant increase or decrease tendency, with the average of 0.66 μgN/m^3 at this period and standard declination ±0.03 μgN/m^3, and in Zemaitija (LT03) an insignificant increase of average annual concentrations from 0.69 μgN/m^3 (1999) to 1.1 μgN/m^3 (2006) is observed. In Preila till 2000, average annual concentrations of NO_2 decreased from 2.20 to 1.18 μgN/m^3, and in their further course there is no single change tendency with the average concentration 1.26 μgN/m^3 and standard declination ±0.07 μgN/m^3

Data from the Environment Protection Agency show that at the IM stations annual concentrations of ΣNO_3^- change in a small range and values of average concentrations and standard declinations of the entire period are as follows: LT01 – 0.49 ± 0.07 μgN/m^3, LT03 – 0.56 ± 0.10 μgN/m^3, Preila – 0.75 ± 0.15 μgN/m^3.

Change of concentration of ΣNH_4^+ in the air is quite similar to the change of concentration of SO_4^{2-}: in Aukstaitija it decreases to 1.44 μgN/m^3 (1997), in Zemaitija to 1.56 μgN/m^3 (1998), in the further course of concentrations there is no general tendency for increase or decrease.

Greenhouse gases emission

Lithuania signed the United Nations Convention on Climate Change (UNFCCC) as an Annex I Party in 1992 and ratified it in 1995. The Kyoto Protocol was signed in 1998 and ratified in 2002. Lithuania undertook to reduce its greenhouse gas emissions by 8 % below 1990 level during the first commitment period 2008–2012. The total emissions in

1990 were about 49 million tonnes equivalent CO_2 so during the years 2008–2012 the annual greenhouse gases (GHG) amount should be at the level 45 million tonnes CO_{2eqv}/year. *(National Inventory Report, 2008)*

Aggregated emissions of GHG expressed in CO_2 equivalent (without CO_2 removals and emissions from the LULUCF sector) have decreased by approximately 53 % during the period 1990–2006 (Figure 7.2-2). The abbreviation LULUCF is used for Land Use, Land-Use Change and Forestry.

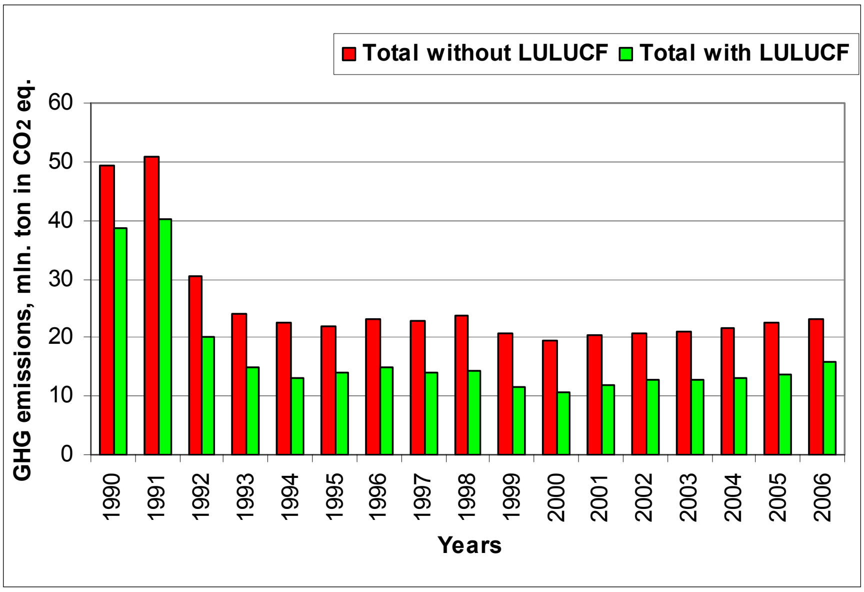


Figure 7.2-2. Emission trends for aggregated GHG (million tonnes in CO_2 equivalent) in Lithuania.

A rapid decrease of GHG emissions has followed the decline of the national economy in the 1990s. The reduction of GHG emissions from 1990 to 2000 was over 60 %. Towards the mid 1990s, Lithuania's GDP began to rise and the reduction in emissions slowed down. The annual increase of GHG emissions in 2000–2006 was approximately 4 % annually.

The decline in the emissions of the main greenhouse gases between 1990 and 2006 is shown in Figure 7.2-3.

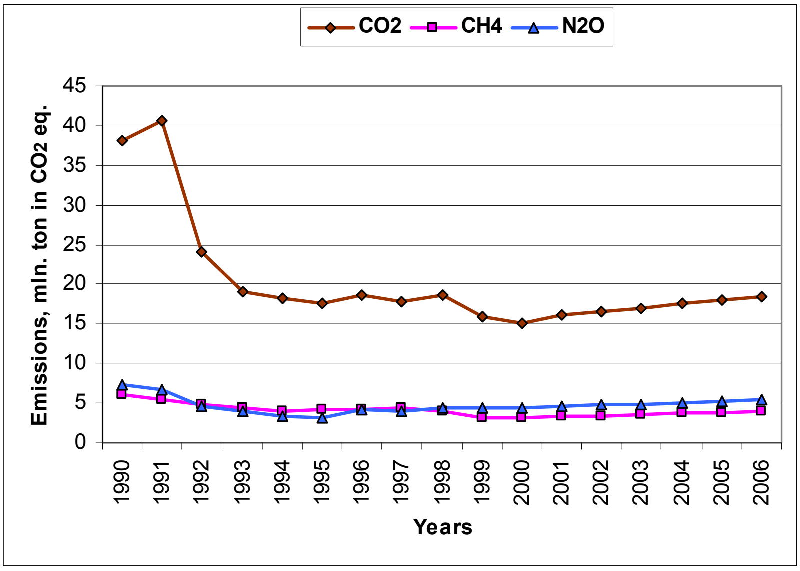


Figure 7.2-3. Trends of GHG emissions by gas in CO_2 equivalent, million tonnes.

Emissions of all three gases were increasing continuously from 2000 to 2006. This increase mainly follows the growth in industrial output as reflected by the growth of GDP. The largest amounts of carbon dioxide emissions resulted from fuel combustion processes in various sectors.

In 1996, CO_2 emissions from transport continued to increase with increasing car fleet. CO_2 emissions from biomass have increased more than 2.5 times since 1990. The government via the promotion of the use of renewable energy sources facilitated consumption of biomass as fuel. It was also regarded as a cleaner and cheaper fuel source. In addition, a number of boiler houses have switched from heavy fuel oil to biomass as a result of a programme of Activities Implemented Jointly mainly with Scandinavian countries. *(National Inventory Report, 2008)*

Methane emissions have decreased from approximately 6.1 to about 3.2 mln. tonnes in CO_2 equivalent from 1990 to the year 2000 but remained fairly constant since the year 2000 changing within the limits of approximately 3.2 to 3.4 mln. tonnes in CO_2 equivalent.

The major part of methane emissions is generated in agricultural sector and the decrease was caused mainly by restructuring of agricultural sector after regaining independence resulting in substantial decline in the number of cattle. The second major source of methane emissions is waste management comprising about 40 % of the total where emissions have also decreased but less dramatically. Though methane emissions in energy sector were decreasing continuously throughout the whole 1990–2006 period, emissions from the year 2000 remained stable because of stabilisation of the agricultural sector.

N_2O emissions have decreased roughly by half from 1990 to 1995 but then started increasing again reaching 5.2 mln. tonnes in CO_2 equivalent in 2006 compared to 7 mln. tonnes in CO_2 equivalent in 1990.

From 1990 to 1996 N_2O emissions were decreasing in all sectors (energy, industry, agriculture and waste). The increase in emissions from 1995 was mainly caused by very substantial growth of N_2O emissions in industry – industrial emissions in 2006 exceeded 1990 level approximately 3 times. As a result, the share of industrial emissions in the total N_2O emissions increased from 11 % in 1990 to 42 % in 2006 while the share of agricultural N_2O emissions decreased from 84 % in 1990 to 54 % in 2006. *(National Inventory Report, 2008)*

The greenhouse emission grows more rapidly than it was foreseen in the National Sustainable Development Strategy. However, this doesn’t make cause difficulties for Lithuania to keep the Kyoto protocol requirements. The difficulties may arise after the year 2010, when Ignalina NPP Unit 2 will be shut down and without a new NPP part of the demand of energy would have to be compensated by burning fossil fuels.

Potential changes in background contamination due to shut down of INPP

Unit 2 of Ignalina NPP will be shut down at the end of 2009 and therefore before start up of the new NPP replacement capacity will be needed. The production of unit 2 is about 20 TWh annually. This amount of electricity will be replaced by production of thermal power plants in Lithuania and by imported electricity. Unlike nuclear power plants, thermal power plants produce emissions of pollutants like nitrogen oxide, sulphur dioxide and particles into the air. These pollutants have an impact on the ambient air quality in the vicinity of the power plants. The magnitude of the impact and the area affected depends on the size and type of thermal power plant, and on the mitigation measures applied. The amounts of the different pollutants and thus also their impacts on ambient air quality vary according to the fuel used by the thermal power plants.

If fossil fuels are used for electricity production greenhouse gases will be produced, whereas nuclear power plants, hydropower plants and thermal power plants using biofuels do not produce greenhouse gases.

7.2.1.12 Radionuclide emissions to the atmosphere

Ignalina NPP is the only source of radionuclide emissions to the atmosphere in Lithuania. Permission to release radionuclides from the nuclear installations into the environment is issued by the Ministry of Environment according to the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring" (*State Journal, 2007, No. 138-5693*). According to the existing order, the Ministry of Environment issues permissions for Ignalina NPP for releases of radioactive material into environment. Radioactive emissions from Ignalina NPP to the atmosphere are continuously monitored. The information on radionuclides and activities that have been actually released from existing Ignalina NPP is presented in Table 7.2-5, Table 7.2-6 and Table 7.2-7 (*INPP Report ПТОот-0545-14, 2007*).

It should be noted that these existing releases of certain radionuclides are 100 or more times less than permissible values indicated in the valid permission of Ministry of Environment (Table 7.2-8).

Table 7.2-5. Activity (10^5 Bq) of aerosol radionuclides released from Ignalina NPP to the atmosphere during 2000–2006.

Nuclide	Year							Annual limit value
	2000	2001	2002	2003	2004	2005	2006	
Na-24	0	14.8	15.2	529	1840	0	0	463
Cr-51	0	312	124	190	86.2	0.02	365	682000
Mn-54	3120	1790	949	1430	1090	333	560	96200
Co-58	55.6	98.9	42.0	112	64.4	27.7	39.7	73400
Fe-59	441	599	238	318	52.5	105	226	491000
Co-60	4680	2990	1920	2260	2320	1030	1020	2880000
Zn-65	0	27.0	4.74	18.5	1.92	160	234	8320
As-76	0	0	0	0	0	0	0	103000
Sr-89	438	332	483	587	618	553	287	61100
Sr-90	450	421	587	453	597	559	592	53800
Sr-91	0	0	0	0	0	0	0	25900
Zr-95	486	325	87.9	120	91.2	0	2.62	733000
Nb-95	902	1430	421	458	431	13.4	140	487000
Mo-99	0	0	0	0	44.4	44.4	41.2	146000
Ru-105	0	0	0	0	0	0	0	125000
Sb-122	0	0	0	0	0	0	0	27700
Sb-124	0	0	0	0	0	0	0	147000
I-131	20.5	166	671	138	281	49.9	1240	9870000
I-132	0	0.40	12.3	0	0.41	0		9580
I-133	0	15.2	0.16	342	104	1430	1100	19800
Cs-134	127	178	279	147	133	12.2	22.7	13300
I-135	0	0	0	0	0	0	0	86700
Cs-136	0	0	0	0.40	0.25	0.05	0	14800
Cs-137	1320	1770	1170	925	661	1280	1020	1390000
Ba-140	0	0	0	0	0	0	0	10800
La-140	0	2.70	0	0	0	0	0	77200
Ce-144	0	0	0	0	0	0	0	78600
W-187	0	0	0	0	0.04	0	0	56400
Total	12000	10500	7010	8030	8420	5590	6910	

Table 7.2-6. Activity of noble gas radionuclides (10^{10} Bq) released from Ignalina NPP to the atmosphere during 2000–2006.

Nuclide	Year							Annual limit value
	2000	2001	2002	2003	2004	2005	2006	
Ar-41	3630	6180	3780	3220	1430	1340	961	900000
Kr-85m	52.9	61.1	200	196	90.3	145	49.6	45000
Kr-87	106	25.9	120	22.6	45.1	28.1	0	21500
Kr-88	43.7	27.4	117	57.4	34.8	24.8	0	14700
Xe-133	1530	2640	4550	2740	4090	5110	1780	360000
Xe-133m	7.40	2.60	17.4	11.8	15.5	175	0	2730
Xe-135m	195	56.2	143	0	33.7	0	0	8000
Xe-135	219	552	719	470	369	625	332	30600
Xe-138	343	94.7	430	0	45.1	0	0	6810
Total	6130	9640	10100	6720	6160	7440	3120	

Radioactive emissions from the existing Ignalina NPP and caused doses to population are summarized in Table 7.2-7 (*INPP Report ПТОот-0545-14, 2007*). The actual annual dose to critical group members of the population due to operation of the Ignalina NPP is about 1 % of the established limit value of 0.1 mSv/year = 100 μSv/year.

Table 7.2-7. Annual dose to critical group members of the population (during 2000–2006) due to radioactive emissions from Ignalina NPP.

	Annual dose to critical group members of the population, μSv			
Year	Noble gases	Aerosols & I-131	Total dose, μSv	% of dose limit (0.1 mSv)
2000	0.041	0.196	0.237	0.24
2001	0.065	0.154	0.219	0.22
2002	0.047	0.172	0.219	0.22
2003	0.035	0.110	0.145	0.15
2004	0.017	1.878	1.894	1.89
2005	0.016	1.109	1.126	1.13
2006	0.011	1.377	1.388	1.39

Table 7.2-8. Limited activity of radionuclides in releases from Ignalina NPP.

Nuclide	Limited activity *Aj*, Bq per annum	Nuclide	Limited activity *Aj*, Bq per annum
^{3}H	5.5×10^{16}	^{131}I	1.8×10^{12}
^{14}C	2.3×10^{14}	^{132}I	4.2×10^{15}
^{24}Na	7.7×10^{14}	^{133}I	5.3×10^{13}
^{41}Ar	1.0×10^{17}	^{134}I	1.4×10^{16}
^{51}Cr	6.3×10^{15}	^{135}I	6.7×10^{14}
^{54}Mn	3.1×10^{13}	^{131m}Xe	1.5×10^{19}
^{59}Fe	7.7×10^{13}	^{133m}Xe	4.5×10^{18}
^{58}Co	9.1×10^{13}	^{133}Xe	4.2×10^{18}
^{60}Co	1.8×10^{12}	^{135m}Xe	4.0×10^{17}
^{65}Zn	1.2×10^{12}	^{135}Xe	1.6×10^{18}
^{85m}Kr	8.3×10^{17}	^{137}Xe	1.1×10^{18}
^{85}Kr	2.2×10^{18}	^{138}Xe	1.4×10^{17}
^{87}Kr	1.5×10^{17}	^{134}Cs	1.2×10^{12}
^{88}Kr	5.9×10^{16}	^{136}Cs	2.3×10^{13}
^{89}Kr	1.2×10^{17}	^{137}Cs	8.3×10^{11}
^{88}Rb	1.3×10^{17}	^{138}Cs	3.4×10^{16}
^{89}Rb	5.6×10^{16}	^{140}Ba	1.1×10^{14}
^{89}Sr	8.3×10^{13}	^{140}La	1.7×10^{15}
^{90}Sr	1.4×10^{12}	^{141}Ce	1.4×10^{15}
^{91}Sr	5.9×10^{15}	^{144}Pr	7.7×10^{17}
^{95}Zr	1.6×10^{14}	^{152}Eu	2.7×10^{14}
^{95}Nb	2.8×10^{14}	^{154}Eu	2.3×10^{12}
^{99}Mo	2.3×10^{15}	^{155}Eu	6.3×10^{13}
^{103}Ru	1.3×10^{14}	^{239}Np	5.9×10^{15}
^{106}Ru	1.3×10^{13}	^{239}Pu	2.6×10^{11}
^{132}Te	3.4×10^{14}	^{240}Pu	2.6×10^{11}
^{129}I	8.3×10^{10}		

Note. Since radionuclides may be released from power plant to the ambient air via ventilation stacks of reactor units (150 m height) and via ventilation tubing of the rooms with the radioactive waste treatment equipment (8–13 and 75 m height), calculations have been performed for three different height cases: 150, 75 and 10 m. Calculation results for emissions at the height of 150 m are presented in the Table 7.2-8. In case of emission at the height 75 m value F_{ij} is multiplied and value A_{ij} is divided by index 3.4. In case of emissions at the height of 13 m, this index is 37.

Summarizing the presented results, it can be seen that greatest releases of radionuclides into the atmosphere in 2006 were as follows (*INPP report ПТОот-0545-14, 2007*):

- Radionuclides of inert gases: 1.5×10^{12} Bq/day (about 1.0 % from limited day activity);
- Aerosol radionuclides: 4.5×10^{7} Bq/day (about 0.5 % from limited day activity);
- I-131: 1.30×10^{8} Bq/day (about 1.3 % from limited day activity).

7.2.2 Assessment of impacts on air quality

7.2.2.1 Pollutants released to the atmosphere during construction and operation

Amounts of pollutants

During construction of the new NPP the main source of emissions into the air will be traffic which produces exhaust gases and dust. Construction of a nuclear power plant requires a large number of workers and heavy transportation. The need of workers is at its largest during the fourth year of construction when about 1 800 cars and 60 buses are driving daily from Visaginas to Ignalina NPP and back. In addition about 100 trucks will be needed daily.

During construction dust is raised also from land building work, on-site traffic and some separate operations such as concrete mixing stations.

During operation of the new NPP the emissions will mainly be produced from the operation of the back-up engines and from traffic. The amount of cars commuting daily to the new power plant will be about 1 000 and there will also be 30-35 buses. In addition some 40 trucks will drive to the power plant daily.

Exhaust gas emissions from traffic are presented in Table 7.2-9. The figures include the traffic related to the decommissioning project of the INPP.

Table 7.2-9. Estimated traffic emissions during construction and operation stages of the NNPP.

	Construction stage, t/year	Operation stage, t/year
Nitrogen oxides NO_x	30	14
Sulphur dioxide SO_2	0.1	0.1
Particles PM	1	0.2
Carbon monoxide CO	98	44
Carbon dioxide CO_2	3549	1593

Back-up engines are used in emergency situations when connection to the power grid is not available. During normal operation back-up engines are used for monthly functional test only. Emissions from the back-up engines of the NNPP are presented in Table 7.2-10. In the calculation it is assumed that engines use diesel oil as fuel and that the annual operation time is about 200 hours.

Table 7.2-10. Estimated emissions of back-up engines.

	t/year
Nitrogen oxides NO_x	1
Sulphur dioxide SO_2	0.2
Particles PM	0.5
Carbon dioxide CO_2	500

Heat for the new NPP will most likely be supplied by the existing recently built gas-fired heat boiler which also provides district heat to the city of Visaginas. Steam will most likely be provided by the existing recently built gas-fired steam boiler. The environmental impacts of these boilers have been studied in the EIA's of each boiler (*Ignalina NPP Decommissioning project management unit, 2004a* and *Ignalina NPP Decommissioning project management unit, 2004b*).

Impacts on air quality

Road traffic will increase emissions into the air during the construction of the new NPP. While the number of workers is at it's largest at the fourth year of construction also significant emission produced by traffic are limited to that time. During other time of the construction the traffic emissions into the air are smaller. Thus traffic emissions during construction are not assessed to have significant long-term impacts on the local air quality.

Sources of dust are usually located quite low and the amount is small so the impact is local and dusting will not have significant impact on the air quality outside the construction site.

During operation of the new NPP the traffic amounts are almost the same as they have been during the operation of the INPP so the NNPP project will not have significant negative impacts on the air quality.

The emissions of back-up engines during normal operation are quite low and therefore there will be no significant impact on air quality from these.

As a conclusion the construction and commissioning of the NNPP will not have a significant detrimental impact on the ambient air quality of the Visaginas region taking the background contamination into account. Only very local adverse impacts are expected during the construction phase, mainly at the construction site.

7.2.2.2 Avoided flue gas emissions

Flue gas and green house gas emissions avoided because of the NNPP have been estimated assuming that the amount of electricity equal to the production of the new NPP would be partly produced in Lithuania in thermal power plants and part of it would be imported. According to the zero-option description in chapter 4.4, the majority of energy in Lithuania would be produced with natural gas if the new NPP will not be constructed. As there are targets in the Lithuanian Energy Strategy to increase the use of biomass, also biomass-based electricity production is assumed to be included in the zero-option. Imported electricity is assumed to be produced in thermal power plants using coal and oil as a fuel and in hydro and nuclear power plants as well. In the calculation of the avoided emissions the emission factors used are in accordance with EU directive of the Large Combustion Plants (*2001/80/EC*).

The estimated emissions in the zero-option are presented in Figure 7.2-4. These amounts of emissions would be produced in Lithuania (natural gas and biomass) and in the country exporting electricity to Lithuania if the new NPP would not be built.

The estimate of emissions in the zero-option also describes the situation before start up of the new NPP when unit 2 of Ignalina NPP has been shut down. It is possible that in that time the share of import will be higher if new capacity will not be built in Lithuania.

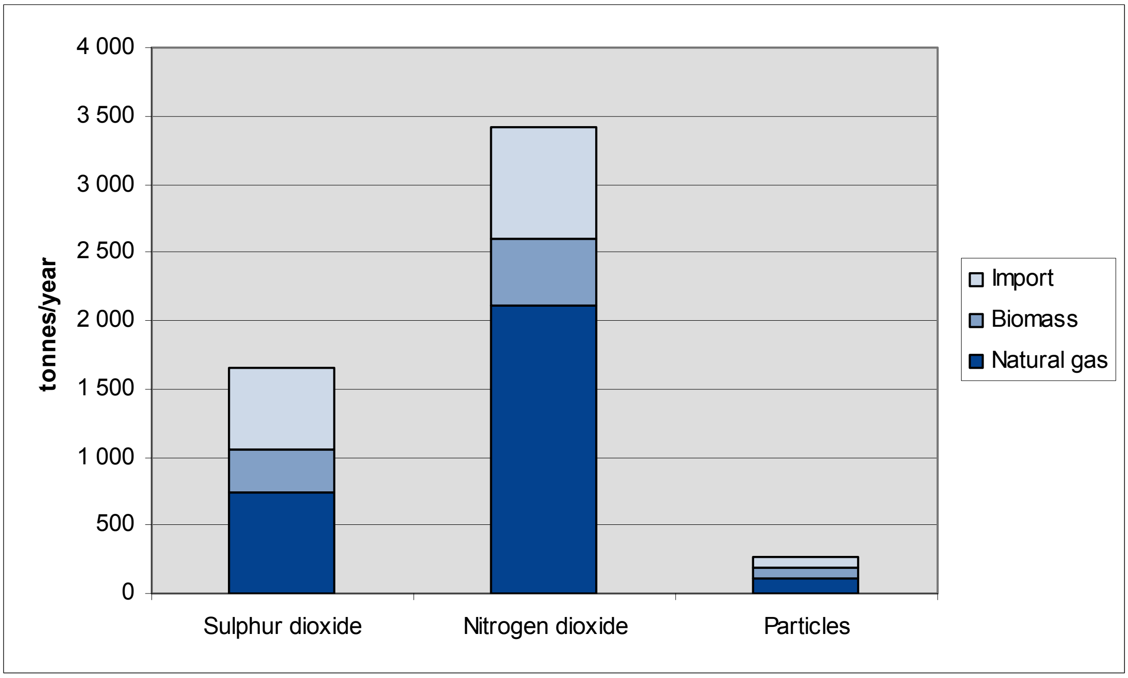


Figure 7.2-4. Avoided emissions (tonnes/year) when NNPP replaces production according to the zero-option.

Figure 7.2-5 illustrates the carbon dioxide emissions in the zero-option. Burning of biomass is not considered to produce CO_2 emissions so the emissions from biomass power plants are zero. The total amount of CO_2 produced in the zero-option would be about 5.8 million tonnes of which about 3.8 million would be produced Lithuania. This corresponds to 45 % of Lithuania's total CO_2 emissions from fuel combustion in the energy sector in 2006 (*National Inventory Report 2008*).

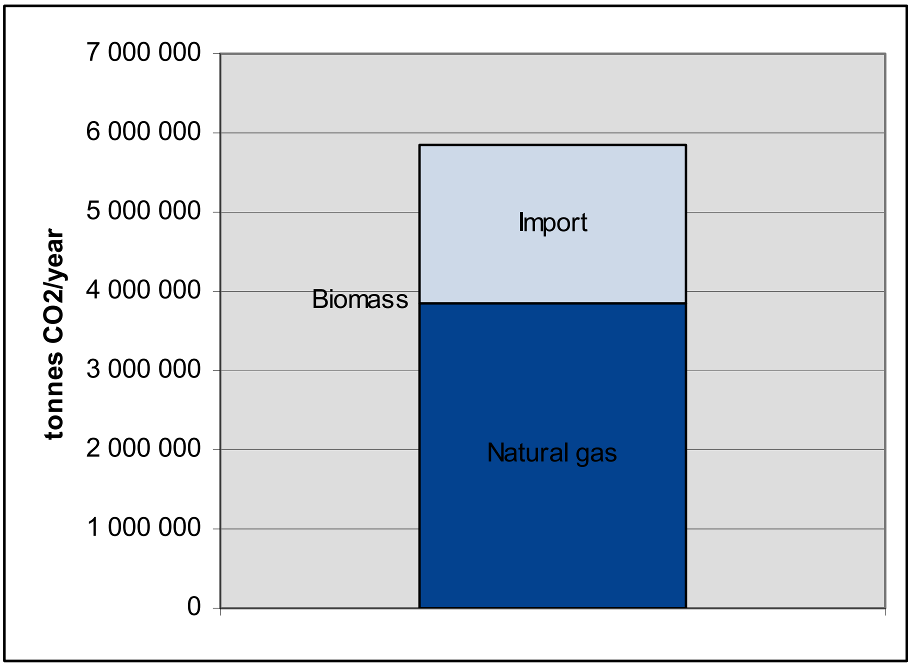


Figure 7.2-5. Carbon dioxide (CO_2) emissions (tonnes/year) in zero-option.

7.2.2.3 Radiological impact

All nuclear power plants during operation cause certain radioactive releases to the atmosphere. Usually, these releases contain noble gases, iodine, aerosols, tritium and carbon-14. According to Lithuanian legislation radioactive materials may be released into the environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring" (State Journal, 2007, No. 138-5693).

Present gaseous releases into the environment from Ignalina NPP are described in Section 7.2.1.12. Possible gaseous releases from different reactor types assuming that total power of units does not exceed 3 400 MW_e are summarized in Table 7.2-11. Data provided in Table 7.2-11 is derived from the design control documentation (DCD) provided for different types of reactors. DCD are freely available on the website of US Nuclear Regulation Commission (www.nrc.gov).

Annual exposure of the critical group members of population due to gaseous releases into the environment from different types of power reactors is estimated in Section 7.10.2.2.

Table 7.2-11. Annual gaseous releases (MBq/year) into environment during normal operation of one reactor Unit.

	BWR		PWR			HWR
Reactor type	**ABWR**	**ESBWR**	**EPR**	**APWR**	**AP-1000**	**CANDU-6**
Number of units	**2**	**2**	**2**	**2**	**3**	**4**
Ar-41	5.00E+05	5.70E+02	2.52E+06	2.52E+06	3.77E+06	n/a
Ba-140	2.00E+03	1.56E+03	3.11E-01	3.11E+01	4.66E+01	n/a
C-14	6.80E+05	7.08E+05	5.40E+05	5.40E+05	8.10E+05	4.20E+06
Ce-141	6.80E+02	5.32E+02	9.62E-01	3.11E+00	4.66E+00	n/a
Co-58	1.78E+02	7.40E+01	3.55E+01	1.70E+03	2.55E+03	n/a
Co-60	9.60E+02	6.36E+02	8.14E+00	6.51E+02	9.66E+02	n/a
Cr-51	2.60E+03	1.55E+02	7.18E+00	4.51E+01	6.77E+01	n/a
Cs-134	4.60E+02	3.56E+02	3.55E+00	1.70E+02	2.55E+02	n/a
Cs-136	4.40E+01	2.94E+01	2.44E+00	6.29E+00	9.44E+00	n/a
Cs-137	7.00E+02	5.38E+02	6.66E+00	2.66E+02	4.00E+02	n/a
Cs-138	1.26E+01	1.70E-01	n/a	n/a	n/a	n/a
Fe-59	6.00E+01	3.88E+01	2.07E+00	5.85E+00	8.77E+00	n/a
H-3	5.40E+06	5.60E+06	1.33E+07	1.33E+07	3.89E+07	6.60E+08
I-131	1.92E+04	3.02E+04	6.51E+02	3.11E+02	1.33E+04	8.00E+01
I-132	1.62E+05	1.18E+05	n/a	n/a	4.44E+04	n/a
I-133	1.26E+05	9.76E+04	2.37E+03	4.74E+03	n/a	n/a
I-134	2.80E+05	2.12E+05	n/a	n/a	n/a	n/a
I-135	1.78E+05	1.23E+05	n/a	n/a	n/a	n/a
Kr-85m	1.56E+06	1.30E+06	1.11E+07	n/a	4.00E+06	n/a
Kr-87	1.86E+06	2.90E+06	3.92E+06	n/a	1.67E+06	n/a
Kr-88	2.80E+06	4.36E+06	1.33E+07	n/a	5.11E+06	1.96E+08
Kr-89	1.78E+07	2.80E+07	n/a	n/a	n/a	n/a
La-140	1.34E+02	2.58E+00	n/a	n/a	n/a	n/a
Mn-54	4.00E+02	2.94E+02	4.22E+00	3.18E+01	4.77E+01	n/a
Mo-99	4.40E+03	3.32E+03	n/a	n/a	n/a	n/a
Na-24	3.00E+02	1.08E+00	n/a	n/a	n/a	n/a
Nb-95	6.20E+02	4.88E+02	3.11E+00	1.85E+02	2.78E+02	n/a
Np-239	8.80E+02	1.66E+01	n/a	n/a	n/a	n/a
Pr-144	1.40E+00	2.70E-02	n/a	n/a	n/a	n/a
Rb-89	3.20E+00	4.02E-02	n/a	n/a	n/a	n/a
Ru-103	2.60E+02	2.08E+02	1.26E+00	5.92E+00	8.88E+00	n/a
Ru-106	1.40E+00	2.70E-02	5.77E-02	5.77E+00	8.66E+00	n/a
Sr-89	4.20E+02	2.96E+02	1.18E+01	2.22E+02	3.33E+02	n/a
Sr-90	5.20E+00	1.53E+00	4.66E+00	8.88E+01	1.33E+02	n/a
Sr-91	7.40E+01	1.34E+00	n/a	n/a	n/a	n/a
Te-132	1.40E+00	2.82E-02	n/a	n/a	n/a	n/a
Xe-131m	3.80E+06	2.20E+05	n/a	1.92E+07	2.00E+08	n/a
Xe-133	1.78E+08	6.22E+07	6.36E+08	n/a	5.11E+08	n/a
Xe-133m	6.40E+03	1.72E+02	1.33E+07	1.48E+05	9.66E+06	n/a
Xe-135	3.40E+07	4.86E+07	8.88E+07	1.48E+05	3.66E+07	n/a
Xe-135m	3.00E+07	4.54E+07	1.04E+06	2.96E+05	7.77E+05	n/a
Xe-137	3.80E+07	5.80E+07	n/a	2.96E+05	n/a	n/a
Xe-138	3.20E+07	4.64E+07	8.88E+05	7.40E+04	6.66E+05	n/a
Zn-65	8.20E+02	5.60E+02	n/a	n/a	n/a	n/a
Zr-95	1.18E+02	8.98E+01	7.40E-01	7.40E+01	1.11E+02	n/a

n/a – information about activity of released nuclide is not available

7.2.3 Mitigation measures

Non-radiological mitigation measures

Dusting caused by traffic can be reduced by paving the roads that are leading to the site. Also reduction of speed limits on dirty roads and work sites as well as cleaning the roads regularly will reduce dust emissions.

The amount of commuting cars during construction can be reduced by organizing accommodation areas for construction workers near to the site so that they don't need daily transportation.

Radiological mitigation measures

The collection and releases of gaseous radioactive materials is made via the ventilation system of the NNPP. In principle the ventilation system is designed so that the air circulation is carried out from low contamination areas to high contamination areas and finally, after filtering, the air is exhausted through a ventilation stack to the atmosphere. Certain height of the stack provides a better dispersion of the released radioactive isotopes. This results in the reduction of their concentration in the air and the radiation dose for the public due to the releases is less.

Typical technical measures installed in a NPP for the mitigation of radiological impacts due to gaseous releases are as follows:

- Gaseous radioactive releases via stack are continuously monitored for radioactive aerosols, radioactive iodine, noble gases, tritium, carbon-14;
- Filtering of exhaust air. There are different filtering stages:
  - High-efficiency filtering for retaining the contaminant particles;
  - Retention of the radioactive iodine existing in the contaminated air;
  - Retention of the possible active coal particles driven by the air stream.
- Periodical inspection and maintenance of components of the ventilation system

The actual impact mitigation measures will be analyzed and justified in the Safety Analysis Report considering Technical Design aspects.

7.3 GROUNDWATER

7.3.1 Present state of the environment

7.3.1.1 The new NPP site No. 1

In the new NPP site No. 1 (Figure 7.3-1) the first hydrogeological zone from the earth surface is the unsaturated zone, the thickness of which is up to 8.7 m (*Hidroprojektas Report, 2006a; Hidroprojektas Report 2006b*). This zone is composed of various Quaternary deposits and sediments. The prevailing deposits in the site are sandy and clayey loam (till) characterized by different hydraulic properties (Table 7.3-1).

Figure 7.3-1. Alternative sites (1 and 2) for the new NPP with locations of boreholes. The blue dots represent geological-hydrogeological boreholes and the brown dots represent geotechnical boreholes.

Table 7.3-1. Hydraulic conductivity of unsaturated soil estimated *in situ* (by water level drawdown in infiltrometer).

No	Place	Date	Depth, m	Hydraulic conductivity, m/d
1	Excavation No 1 close to borehole No 1	2006-08-27	0.3	0.14
2	Excavation No 2 close to borehole No 1	2006-08-28	0.3	0.45
3	Excavation No 2 close to borehole No 2	2006-08-28	0.3	0.44
4	Excavation No 1 close to borehole No 3	2006-08-26	0.3	0.24
5	Excavation No 1 close to borehole No 4	2006-08-23	0.2	0.06
6	Excavation No 2 close to borehole No 4	2006-08-04	0.5	0.08
7	Excavation No 1 close to borehole No 5	2006-08-25	0.3	0.34

Bog deposits (peat) are distributed locally in lowest landscape depressions close to the north-eastern margin of the site. In this area the groundwater level merges with surface water level in local wetland and the unsaturated zone forms only temporarily in summer dry-time. In general the thickness of the unsaturated zone reduces towards north – north-east.

Other hydrogeological bodies of the site are distinguished and characterized according to the data from borehole No.1, which is located in the central part of the site (Figure 7.3-1).

Unconfined groundwater is spread in the entire area of the site and is related to several lithological layers – peat in small spots, sand and sandy loam in prevailing area of the site. Groundwater is mostly spread in interlayers of glaciofluvial and glaciolacustrine sand and gravel, located in the first from the top till body (marginal till of last glaciation, which is locally named Baltic glacial). These aquiferous layers are in the interval of 0.8 m until 24 meter depth. Groundwater flow direction is to the north and north-east towards Lake Druksiai. Annual amplitude of groundwater level range is 1.5 – 2.0 m, the highest water level is in the months of December-February and the lowest in July-August. Hydraulic characteristics of water permeable layers depend on soil matrix composition. Based on pumping tests the hydraulic conductivity of different deposits is as follows: fine silty sand – $2.3 \cdot 10^{-6}$–$6.9 \cdot 10^{-6}$ m/s; fine sand – $1.9 \cdot 10^{-5}$–$2.8 \cdot 10^{-5}$ m/s; coarse sand with gravel – $5.6 \cdot 10^{-5}$–$1.3 \cdot 10^{-5}$ m/s; gravel – $9.1 \cdot 10^{-5}$–$1.9 \cdot 10^{-5}$ m/s. The groundwater is of calcium-magnesium bicarbonate type, according to carbon acid content weakly aggressive for concrete.

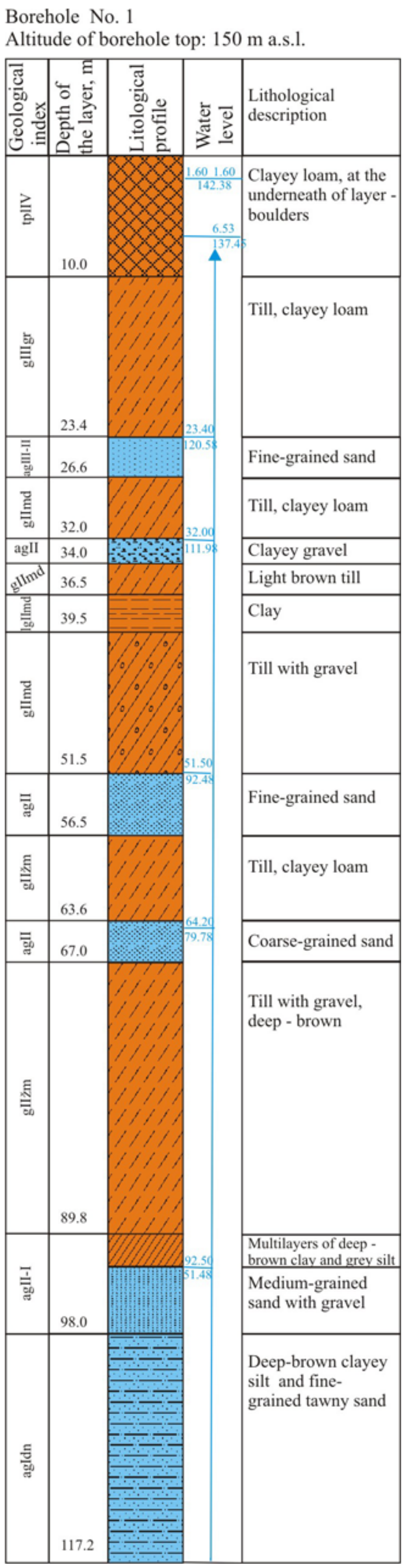


Figure 7.3-2. Generalized (simplified) hydrological section of the new NPP alternative site No. 1 (in blue – confined aquifers, in brown – confining layers).

Confined aquifers are separated from unconfined groundwater by till layers with low and very low permeability. The hydraulic conductivity of confining tills (clayey loam and sandy loam) are varying from $3 \cdot 10^{-9}$ up to $9 \cdot 10^{-9}$ m/s. Therefore, even taking into consideration inhomogeneities of layers, they may be considered as soil of very low permeability (aquitards) with a hydraulic conductivity of 10^{-8} m/s.

At the site a more detailed analysis was carried out for three Quaternary confined aquifers which are from the surface: first aquifer aqIII-II (attributed to intertill deposits that a named in local stratigraphical scheme as Gruda–Medininkai), second aquifer aqII (Medininkai–Zemaitija) and third aquifer aqII-I (Zemaitija–Dainava) (Table 7.3-2).

Table 7.3-2. Hydraulic conductivity of aquifers estimated by pumping tests.

Bore-hole No	Aquifer	Lithology	Aquifer screening interval (filter length), m	Hydraulic conductivity K based on pumping test, m/day		Averaged K value, m/day
				Drawdown of water level	Rise of water level	
1	Devonian	Fine sand	131-136 (5)	19.1	28.0	23.6
2	Quaternary (agII)	Medium coarse sand, silty	62-65 (3)	3.5	4.5	4.0
3	Quaternary (agII)	Medium coarse sand, very clayey	50-53 (3)	0.4	0.5	0.45
4	Quaternary (agII)	Medium coarse sand, silty	54-57 (3)	0.8	0.8	0.8
5	Quaternary (agII)	Medium coarse sand	31-34 (3)	15.1	10.9	13.0

The first confined aquifer (aqIII-II) is spread in the entire site and is attributed to the layers of fine sand with gravel. Prevailing altitude of the aquifer is at about 130 m a.s.l. The hydraulic head is up to 15 m above the top of the aquifer. Main direction of groundwater flow is from south to north; groundwater discharges in Lake Druksiai. Content of TDS in groundwater is 0.2–0.4 g/l. Groundwater is of magnesium-calcium bicarbonate type, according to carbon acid content it is not aggressive to concrete. Yield of pumping wells is 8–9 l/s, specific yield – 0.1–1.2 l/s.

The second confined aquifer (aqII) is spread almost throughout the entire site and is composed of coarse sand. Its thickness is about 3 m. Highest altitude of hydraulic head of this aquifer is in the southern part and the lowest in the northern part of the territory. This shows that the main direction of groundwater flow is from south to north towards Daugava River, which is the discharge area of the aquifer. Hydraulic conductivity of the aquifer ranges from $8.4 \cdot 10^{-6}$ to $1.5 \cdot 10^{-4}$ m/day, hydraulic transmissivity ranges from $2.5 \cdot 10^{-4}$ to $2.9 \cdot 10^{-3}$ m^2/s. Groundwater is of calcium-magnesium bicarbonate type, content of TDS in groundwater is 0.2–0.4 g/l. The features of other Quaternary confined aquifers are similar. Usually they are spread only in palaeoincisions.

7.3.1.2 The new NPP site No. 2

In the new NPP site No. 2 (Figure 7.3-1) the first hydrogeological zone from the earth surface is the unsaturated zone, the thickness of which is up to 13 m (*Report No. 33978DSP, 1986; Hidroprojektas Report, 2006c*). This zone is composed of various Quaternary deposits and sediments. The prevailing deposits in the site are peat, sandy and clayey loam (till) characterized by different hydraulic properties as indicated in Table 7.3-1.

Bog deposits (peat) occur in the western part of the site and occupy almost half of the site area. In this area the groundwater level merges with the surface water level in local wetland and the unsaturated zone forms only temporarily during dry summer time. In general the thickness of the unsaturated zone reduces to the north – north-west towards

Lake Druksiai and a wetland which in Holocene time was a bay of Lake Druksiai. Surface altitude at the bog area is 143–144 m, and in the other parts 143–153 m.

Other hydrogeological bodies of the site are distinguished and characterized according to the data from boreholes No. 3-R and 20627 (Figure 7.3-3), which are located in the eastern part of the site (Figure 7.3-1).

Unconfined groundwater is spread in the entire area of the site and is related to several lithological layers – peat in the western part, sand and sandy loam in the remaining area of the site. In the bog sediments (bIV) the level of groundwater depends on the amount of precipitation. The peat is well or medium decomposed. The thickness of the peat layer varies from 0.1 to 8.6 m. There is often technogenic soil above the bog sediments. Lacustrine sediments (lIV), the thickness of which is 0.5–2.9 m, are also spread in the western part of the site and occur under bog deposits. Lacustrine sediments consist of sandy loam with organic matter, clayey loam and gray sand.

Groundwater in the site is mostly spread in interlayers of glaciofluvial and glaciolacustrine sand and gravel, located in the first from the top till body (marginal till of last glaciation, which is locally named Baltic glacial). The thickness of these aquiferous layers is from several centimetres to 3 m in the south-eastern part of the site. Groundwater flow direction is to the north and north-west towards Lake Druksiai. Annual amplitude of groundwater level variation is 1.5–2.0 m, the highest water level occurs in the months of December-February and the lowest in July–August. Hydraulic characteristics of water permeable layers depend on soil matrix composition and are similar to that of site No 1. The groundwater is of calcium-magnesium bicarbonate type, according to carbon acid content weakly aggressive for concrete.

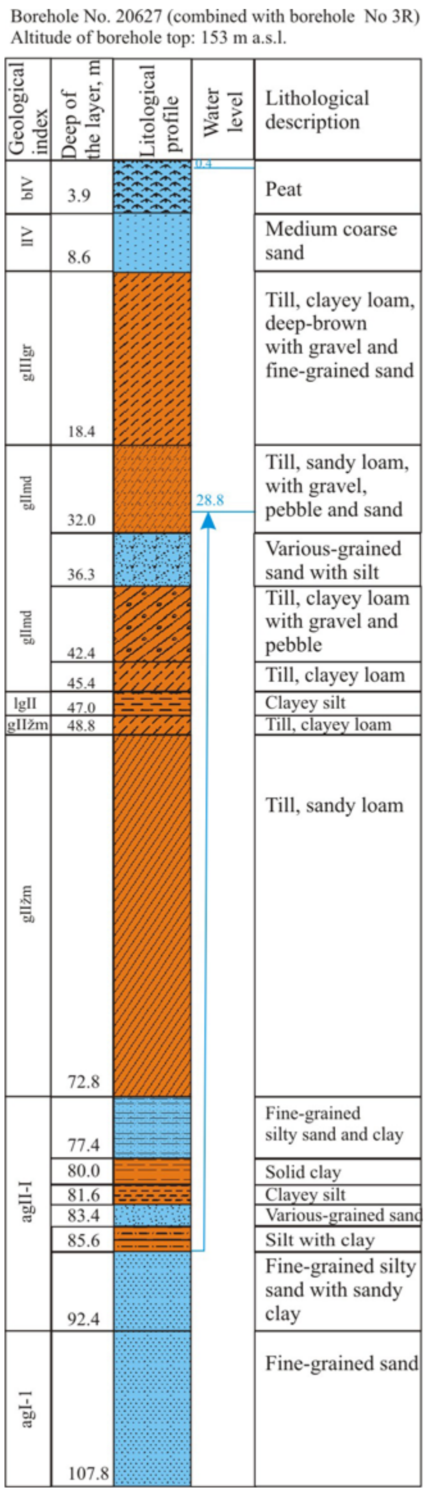


Figure 7.3-3. Generalized (simplified) hydrological section of the new NPP alternative site No. 2 (blue – aquifers, brown – confining layers).

Confined aquifers are separated from unconfined groundwater by till layers with low and very low permeability. The hydraulic conductivity of confining till (clayey loam and sandy loam) varies from $3{\cdot}10^{-9}$ up to $9{\cdot}10^{-9}$ m/s. Therefore, even taking into consideration differences between the layers, they may be considered as soil of very low permeability (aquitards) with a hydraulic conductivity of 10^{-8} m/s.

In the site No 2 the first aquifer (aqIII-II), which was observed in the site No 1, is not present. This aquifer is spread westwards behind the limits of site No 2 and its thickness increases westwards. Three confined Quaternary aquifers are distinguished at the site:

first aquifer aqII (attributed to intertill deposits that a named in local stratigraphical scheme as Medininkai–Zemaitija), second aquifer aqII-I (Zemaitija–Dainava) and third aquifer aqI-1 (Dainava–Dzukija). In palaevalleys, which are spread westward from the site, also the aquifer aqI-2 (underlayered till body Dzukija) occurs.

The first confined aquifer (aqII) is spread in the entire site and is attributed to the layers of sand with gravel. Its thickness is 3–40 m. Prevailing altitude of the aquifer is at about 120 m a.s.l. The hydraulic head is up to 20 m above the top of the aquifer and water level sets up at the depth of 10–12 m from the earth surface. Groundwater flow direction is from south to north; discharge area of the aquifer is the Valley of Daugava River. Hydraulic conductivity ranges from $8.4 \cdot 10^{-6}$ to $3.2 \cdot 10^{-4}$ m/s, hydraulic transmissivity – $2.5 \cdot 10^{-4}$–$2.9 \cdot 10^{-3}$ m^2/s. Content of TDS in groundwater is 0.2–0.4 g/l. Groundwater is of magnesium-calcium bicarbonate type.

The features of other deeper laying aquifers are similar and less characterized. Usually deeper Quaternary aquifers are spread only in palaeoincisions where they may make up to 100–200 m thick aquifer systems composed of various sand, gravel and pebble. Hydraulic conductivity of the aquifer aqII-I ranges from 0.8 to 4.8 m/day. Content of TDS in groundwater is 0.2–0.4 g/l. Groundwater is of magnesium-calcium bicarbonate type.

7.3.2 Assessment of impacts on groundwater

The alternative sites (No. 1 and 2) are practically equal in sense of the groundwater characteristics. Possible impacts will therefore be discussed together for both sites in the following chapters.

Unconfined groundwater: Most important natural factors affecting the shallow unconfined groundwater vulnerability are the following: composition and thickness of the unsaturated zone, hydraulic and sorption properties of unsaturated soil, sources, rate and seasonal distribution of infiltration recharge. It is generally assumed that in the case of lower hydraulic conductivity of unsaturated soil and the deeper groundwater table the shallow groundwater vulnerability is based on surface contamination. Taking this into consideration it may be stated that shallow unconfined groundwater in both sites is weakly protected from surface contamination and has potential risk to be impacted by the new nuclear power plant construction and operation.

However, during the entire INPP operation period no cases of radionuclides originating from INPP spreading in groundwater close to the industrial site have been established. Only the mobile radionuclides ^{3}H and ^{14}C have been recorded in groundwater of the site of INPP (in the closed industrial area). Effective doses due to these events are lower than the dose constraint (*Mazeika, 2002*). Gamma ray emitting radionuclides in groundwater can hardly be detected even in sites close to the radioactive waste storage area. Sometimes traces of ^{137}Cs, ^{60}Co and ^{54}Mn are detected in groundwater. Based on INPP operation there is no expected significant impact even on shallow unconfined groundwater, however, taking into account the high vulnerability of shallow unconfined groundwater a early warning groundwater monitoring system should be installed.

Confined aquifers: Vulnerability of confined aquifers depends on the thickness of confining layers (aquitards) and on the water travel time from recharge point to point of interest.

Within a radius of 15 km from the sites for the new NPP, within the territory of Lithuania, there are five aquifers that could be used for centralized water supply. Two main aquifers for water supply are the Quaternary aquifer aqII (attributed to intertill deposits) and the Devonian aquifer (D_3+D_2).

The most important of them is the Devonian aquifer which is used for centralized water supply for Visaginas town and for the needs of INPP. The average groundwater extraction rate from the Visaginas water field is about 8 800 m^3/day. The new NPP site No. 1 is located at 1 km distance from the 3rd sanitary protection zone of Visaginas water field. The southwestern part of the new NPP site No 2 is contiguous with the 3rd sanitary protection zone of Visaginas water field. Besides Visaginas water field, within the radius of 15 km, about 30 separate operational wells for water supply of small settlements and private entities are operated. Groundwater extraction rates from them are mostly only up to 10 m^3/day. All separate operational wells installed in the Quaternary and Devonian aquifers are located further from the surroundings of the new NPP than Visaginas water field.

Within a radius of 10 km from the sites for the new NPP at the territory of Belarus there are no water fields for centralized water supply. Within the radius of 10 km from the sites for the new NPP, in Belarus, seven separate groundwater extraction wells are operated. In the territory within the radius of 30 km from the new NPP sites, about 50 separate operational wells for groundwater extraction are operated.

Within a radius of 10 km from the sites for the new NPP within the territory of Latvia, there are no water fields for centralized water supply; likewise, there are no separate operational wells for groundwater extraction. In the territory of Latvia within a radius of 30 km from the surroundings of the new NPP, about 50 separate operational wells for groundwater extraction are operated.

The groundwater of the Devonian aquifer system, which supplies for the needs of Visaginas town and INPP, is at a distance of 4 km from the sites. This aquifer system is of very low vulnerability from surface contamination. This was assessed by modeling methods that showed that water particles from the nuclear area could never travel to the aquifer in Visaginas water field in not disturbed (natural) groundwater flow conditions; if the groundwater extraction rate from the aquifer in the water field area is very high (40 000 m^3/day), the particle travel time from the nuclear area takes 300–400 years (*Jakimaviciute et al., 1999*). This period is considerably longer than the time of NNPP operation even based on a conservative approach (very high groundwater extraction rate).

Based on this any confined aquifers have no risk of being impacted by construction or operation of the new nuclear power plant. This is also supported by the experiences from INPP operation and therefore impacts on confined aquifers are not expected. Both sites are therefore considered suitable for construction and operation of the new NPP from groundwater point of view.

7.3.3 Mitigation measures

The potential risks for contamination of groundwater and water wells will be prevented by applying the technically best practises during both the construction and operation phases of the new plant. This will be done both by minimising the risk for leakages or other contamination as well as by installing an early warning system.

There are several suitable technical solutions for groundwater protection. During the construction and operation of the new NPP all potential sources of harmful substance leaks (e.g. oil containers, transformers etc.) will be constructed into secondary protection basins. The contamination of the groundwater will be prevented by leading all the surface and groundwaters from the constructed area to the drainage system. Also the groundwater level around the deep reaching structures will be permanently lowered to prevent possible contamination of surrounding groundwater.

An early warning groundwater monitoring system can be installed. This system should be implemented according to groundwater monitoring programs for each 3-5 years based on the Lithuanian normative document (*State Journal, 200, Nr. 101-4578*). This system shall include unconfined groundwater aquifer and may be first from top confined aquifer.

7.4 SOIL

7.4.1 Present state of the environment

According to Lithuanian Hygiene Standard HN 60:2004 (*State Journal, 2004, No. 41-1357*) fertile soil is defined as an upper loose layer of earth crust, which is formed from the native rock under influence of soil formation processes (a complex of impacts from water, air, bio organisms) and is characterized by its potential productivity. The territory of the new NPP area has been affected in the past because of industrial activity (INPP). The construction of the INPP Unit 3 was started at the end of the 1980´s. Construction materials and some equipment foreseen for INPP Unit 4 have been stored at Site alternative No. 1. Now the structures of INPP Unit 3 have been dismantled, the uncompleted buildings have been demolished and the stored materials have been taken away. Recently the territory was levelled and covered with man-made soil, thus natural fertile soil in this area is almost totally absent.

According to the Technical Construction Regulation STR 1.04.02:2004 (*State Journal, 2004, No. 25-779*) soil is defined as naturally or artificially compacted or loosened sediments, deposits or other type of the earth particles, and this naturally or artificially formed layer is an object of investigation, evaluation and application for construction purposes – as a foundation for existing or projected building or underground medium of the construction; or as an object of underground construction activities or ground construction; or as medium of the geological events and processes important for construction activities.

The natural fertile soil was not investigated at the alternative sites for the NNPP. It could be described only according to regional mapping and investigations. Eutric podzoluvisoils (PDe) and haplic arenosoils (ARh) are characteristic to the area of Ignalina NPP *(Kadunas et al., 1999)*. Eutric podzoluvisoils have been formed above the glacial loamy and clayey sediments. Haplic arenosoils are sandy. Terric histosoils (HSs) are characteristic for the wet areas. Loamy and clayey soils are about 2 g/cm^3 dense. The density of sandy soils is about 1.2 g/cm^3. Terric histosoils are looser (density is about 1.1 g/cm^3).

Generally the topsoil of Eastern Lithuania is relatively infertile and has low humus content (about 1–2 %). Histosoils are an exception and have higher humus content. The pH value is about 6.4 in sandy soil, 7.4 in loamy soil and about 6.5 in peaty soil. Land and soils have not been used for agriculture in the vicinity of Ignalina NPP. Topsoil usually contains similar chemical components as the sediments of soil matrix. The mineral part comes to the soil from the soil matrix and comprises more than 90 % of soil weight. Chemical elements occur in different compounds in the topsoil. The organic part comprises less than 10 % of soil weight and consists of vegetative and animal leftovers, humus. Humus contains specific groups of organic compounds – humic acid, fulvic acid, humatic melanin acid, bitumen, vax, resin, lipoids. Phosphorus, potassium, nitrogen, sulphur and calcium are the most important elements in the mineral part of the soil. Background content of trace elements according to the Geochemical atlas of Lithuania *(Kadunas et al., 1999)* is presented in Table 7.4-1.

Table 7.4-1. Content of trace elements in the soil of NNPP region.

Trace element	Content in different types of soil, ppm		
	Sandy	Loamy	Peaty
Ag	0.065	0.064	0.058
As	2.8	3.7	1.7
B	27.2	32.7	19.8
Ba	291	370	231
Co	4.4	6.0	3.3
Cr	24.2	42.5	20.5
Cu	6.5	11.3	8.7
Ga	5.1	7.5	4.0
Y	20.7	28.8	16.4
Yb	2.5	2.4	2.5
La	18.2	26.5	19.2
Li	10.7	16.3	7.5
Mn	502	600	466
Mo	0.65	0.8	0.71
Nb	14.5	13.6	9.8
Ni	10.1	16.9	11.9
P	598	527	680
Pb	14.8	14.6	18.1
Rb	58	76.6	38.5
Sc	2.5	7.7	4.2
Sn	1.3	2.3	1.1
Sr	68.3	91.2	67.6
Th	4.2	7.5	3.8
Ti	1916	3075	1870
U	1.7	3.0	1.4
V	27.5	45.3	31.4
Zn	24.7	32.9	29.4
Zr	282	363	192

Water in the topsoil can occur in 4 forms. The first form is hygroscopic water which is caged by soil particles and can be removed only by heating (till 100 °C). The second form is filmy water (semi combined). It occurs around the soil particles and migrates very slowly. Plants can hardly reach this water. The third form is capillary water which occurs in very thin cracks of the soil. The last fourth form is gravitational water which can fill all the openings in the soil and which migration is affected by gravitation. Vertical moisture migration in the soil causes the possibility for different substances from the land surface to reach the underground. Moisture content in the soil and its plasticity is presented in the Table 7.4-2.

The new NPP sites are almost totally covered by man-made soil (tplIV). There are only a few locations at Site No. 2 where the natural fertile soil still remains. At locations of former buildings there are a lot of technogenic formations (tIV) consisting of construction scrap and abandoned underground communication cables. Man-made soil consists of clayey loam with pebble and gravel, sand at places with organic remains. Layer thickness is 2–10 m (*UAB "Hidroprojektas", 2006*).

Table 7.4-2. Moisture content and plasticity of man made soils at the proposed sites.

Lithology	Moisture content	Liquid limit	Plastic limit	Plasticity index	Liquidity index
	w_n	wL	wp	Ip	I_L
Silty clay	0.166	0.316	0.147	0.169	0.112
Clay loam	0.151	0.263	0.133	0.130	0.138
Clay loam	0.151	0.265	0.130	0.135	0.156
Sandy and clayey silt	0.174				
Clay loam	0.159	0.262	0.138	0.124	0.169

Man-made soil was poured here from the beginning of the construction of the Ignalina NPP. Soil was poured from trucks, without compaction. This soil represents a mix of clay loam, sandy loam, sand, and construction scrap. At certain places of the sites the thickness of the man made soil reaches 9 meters. The soil was poured in place of excavated peat and often into lower places of the relief without excavation of peat. Hence, there are places, where peat lays under a layer of man made soil.

The man-made soil is in most places without vegetation. Some parts of Site No. 2 (wet places between the knolls) are scrubby. Chemical composition of the man-made soil depends on the sediments it is made from. Man-made soil of the 2 proposed sites for the new NPP is made most of all from silty and clay loam. These sediments contain silicates, carbonates, spars, plagioclases and clay minerals (montmorilonite, kaolinite, hydromica). Permeability and hydraulic conductivity of the soil depends on particle size. The bigger the particles are the higher the permeability is. The share of silt and clay particles reaches 20–30 % in the loamy soil of the proposed sites.

If the loamy soil has no cracks or fissures its permeability is quite low. In natural conditions many small fissures occur in the loamy soil. Hydraulic conductivity, the parameter that characterises soil permeability, could be evaluated during field tests. The hydraulic conductivity of the man-made soil at the particular sites has been evaluated during the geological mapping and applied investigations. Hydraulic conductivity of clay loam determined by field tests varies in the ranges of 0.14–0.24–0.34 meters per day. Hydraulic conductivity of silty and sandy soils is about 0.45 m/d (*Marcinkevicius et al., 1995; Kerasevicius & Kropas, 2006)*.

Hydraulic conductivity characterises the saturated flow. However the upper part of the soil is not fully saturated by water and forms the vadose (unsaturated) zone above the shallow groundwater level. Water or moisture migration goes on according to the laws of capillary and soil pressure. Many scientific investigations *(Klimas, 1988; Mazeika, 1993)* prove that the velocity of moisture migration is between 1 and 2 meters per year in unsaturated zone. The lower velocity (1 m/y) is characteristic to clayey soils and the higher one to sandy soils. The thickness of the unsaturated zone varies from 1 to 5 meters at the proposed sites.

The sorption capacity of the soil depends on the amount of clay particles and organic material. This parameter was not investigated at the proposed sites. However it is known from the results of many former investigations of Lithuanian soils that sorption capacity of glacial loamy deposits is quite high. For example, loam sorption capacity for oil (petrol) products is about 15 mg/kg.

Usually soil pollution is detected in the upper part of the topsoil (0–10 cm deep) or in the arable layer (0–25 cm deep). Natural purification of the soil varies depending on the soil type, climate conditions and the kind of pollutant. Pollutants quickly migrate through the sandy soils and clayey soils sorb them. In wet and warm climate the pollutants leach from the soil quicker than in cold and dry conditions. Some toxic heavy metals will never degrade and can only be accumulated in soil, water, stream sediments, plants and animals.

According to the Ignalina NPP monitoring program, samples of the soil in the region of Ignalina NPP are continuously monitored. The information on detected radionuclides and their radioactivities is presented in Table 7.4-3 (*INPP Report ПТОот-0545-14, 2007*).

Table 7.4-3. Specific activity of the radionuclides in the soil of Ignalina NPP region.

Year	Specific activity in the soil, Bq/kg								Total (except Ra, Th, K)	
	Cs-137	Cs-134	Mn-54	Co-60	Sr-90*	Ra-226	Th-228	K-40	Bq/kg	Bq/m^2
1999	7.89	1.28	0.17	0	<20.0	21.9	33.1	807	9.35	170
2000	5.10	1.50	0.10	0	<20.0	31.4	30.2	618	6.70	339
2001	4.89	1.36	0.08	0	<20.0	42.6	31.9	606	6.34	320
2002	7.02	1.65	0	0	<20.0	45.9	45.2	850	7.36	154
2003	3.70	1.03	0	0	<1.53	22.9	29.3	596	6.26	131
2004	4.98	0.43	0.08	0	2.08	34.2	26.8	549	7.47	158
2005	3.38	0	0	0	1.49	13.8	18.6	462	4.87	31.3
2006	3.38	0	0	0.05	0	22.0	25.6	613	3.43	74.8

* since 2003 detection methodology of Sr-90 has been improved.

Before the start of operation of the new NPP a comprehensive monitoring programme should be prepared. During the preparation of this programme the environmental geological investigations should be carried out and possible ambient pollution should be evaluated.

7.4.2 Assessment of impacts on soil

The proposed sites for the new NPP are located in the industrial area of the operating Ignalina NPP. The soil surface and natural soil of the sites have been changed during the Ignalina NPP construction period. This is why substantial impacts on soil already took place about 30 years ago and the current state of the soil is not natural.

The main impacts on soil will occur during the construction stage and will be typical to any construction project. These include excavation works, relocation of soil, generation of dust from the movement of heavy vehicles and also from soil movements (dust clouds can develop especially during dry periods). These impacts will be mainly temporary. However, some of the soil needs to be permanently relocated.

The depth of the NNPP construction site will vary from 8 to 16 meters and a large volume of soil needs to be removed from the site. The area of the construction works of the NNPP is about 30–32 ha. About 1 400 000 m^3 of soil will be excavated from the NNPP construction site in case two large NPP units will be built. The excavated soil will be transported to soil dumping areas. The preliminary locations of these dumping areas are presented in Figure 7.4-1. The soil dumping area A will be used in case of site 1 and the soil dumping area B in case of Site No. 2. The soil will be transported by road vehicles via a gravel access road from the construction site to the dumping site. Both of the soil dumping sites have the same area, about 24 ha, and their storage capacity is 700 000 m^3 of soil each. The soil will be stored in piles. Some of the removed soil will be moved back to the NNPP construction site and the rest will be left for final storage. It is estimated that about 1 300 000 m^3 of different soil material is needed as fill materials at the construction site in case of two NPP units. The soil that now covers the sites and will be excavated is not valuable and does not contain humus or plants.

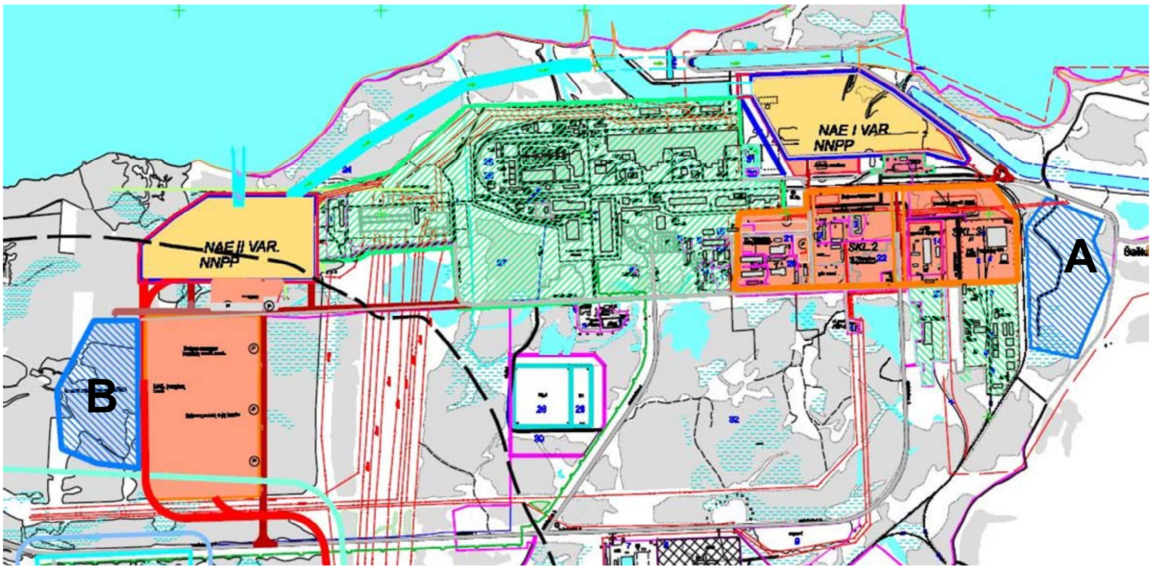


Figure 7.4-1. Preliminary locations of the soil dumping areas during construction of the NNPP: area A for Site No. 1 and area B for Site No. 2.

Cars and other vehicles, materials used for construction and sewage from the temporary buildings could be identified as sources of soil pollution during the construction stage of the new NPP. Possibly polluted atmospheric air, sewage from the reactor building and administrative buildings and storages of different materials could be sources of soil pollution during the operation of the new NPP.

Content of zink, lead and oil products in the soil at the site can increase during the construction stage of the new NPP. However, the duration of the construction stage is about 5–7 years, which is too short a period for substantial changes to occur in the soil chemical composition.

Possible soil pollution caused by polluted air will be very small during the construction stage and neglible during operation. In case of some soil pollution its migration will be prevented by soil properties described above.

After the removal of weak soils the deeper natural soils will occur at the land surface. Deeper soils are clayey and relatively clean. Due to the static load of buildings these soils will be compacted. The value of the compaction is predictable and can be calculated according to the soil compression test results.

It is expected that during normal operation of the new NPP the radiation doses due to radionuclides in the soil will be negligible.

The planned economic activity will not cause soil erosion or other negative processes.

7.4.3 Mitigation measures

Construction will be performed using techniques designed to minimize the potential erosion of the topsoil and to prevent leaking of harmful substances like fuel and oils from the machines. Materials used for the construction will be stored in buildings or on the ground (for example on concrete blocks) isolated from the environment. Sewage from the temporary buildings will be collected and transported to the waste water treatment plant.

Removed soil will be stored for a relatively short period. The storage area will be as small as possible to decrease the physical impact on the environment. After the construction stage, the removed soil that is not used as filling material in the NNPP site can be used to improve the scenery of the new NPP area. Small hills can be formed using the removed soil. The landscape will be designed according to the special project.

To prevent possible soil pollution the new NPP site will be covered by impermeable material where needed. Other open areas will mainly be covered by grasslands. Small amounts of pollutants could be taken from the soil by plants.

The new NPP will be designed to avoid chemical and radiological pollution of the environment. All technological units and objects for sewage removal will be constructed using appropriate materials. All the chemicals used will be stored in a correct manner to prevent any leaks to the environment. All the sewage from the buildings during operation will be collected and transported to the waste water treatment plant. During normal operation significant pollution of soil will be impossible.

For the mitigation of possible changes in the quality of the environment comprehensive monitoring of the new NPP site will be carried out. Soil quality will be monitored during the new NPP operation. If some changes will be detected the suitable technical measures will take part. Possibly polluted soil will be changed mechanically to clean soil material. Polluted soil will be treated in situ using specific physical processes (electrolysis, etc.) or materials (sorbents).

7.5 GEOLOGY

7.5.1 Present state of the environment

The last comprehensive geological mapping performed in 1995, at a scale of 1:50 000, also covered part of the territory of the Latvian Republic and part of the Republic of Belarus. The geological structure, described below, characterizes also the geology of these neighboring countries.

7.5.1.1 Precambrian crystalline basement in the region

The new NPP area is located in the western margin of the East European Platform. It is located in the junction zone of two major regional tectonic structures: the Mazur-Belarus Rise and the Latvian Saddle that makes the structural pattern of the area rather complicated. The contemporary relief of the crystalline basement reflects movements over a period of 670 million years. Several tectonic structures (blocks) of the lower order are distinguished in the surface of the Precambrian crystalline basement: the North Zarasai Structural terrace, the Anisimoviciu Graben, the East Druksiai Uplift, the Druksiai Depression (Graben) and the South Druksiai Uplift. The North Zarasai Structural terrace, the Anisimoviciu Graben and the East Druksiai Uplift are related to the Latvian Saddle. The South Druksiai Uplift belongs to the Mazur-Belarus Rise and the Druksiai Depression (Graben) is located within the junction zone of the two aforementioned regional structures (*Marcinkevicius et al. 1995*).

The crystalline basement is buried at a depth of about 720 m from the Earth's surface. It is comprised of the Lower Proterozoic rocks predominantly of biotite and amphibole composition: gneisses, granite, migmatite, etc. The thickness of the sedimentary cover in the region of the new NPP varies in a range of 703–757 m. Pre-Quaternary succession is represented by the Upper Proterozoic Vendian complex, overlain by sediments of the Paleozoic systems. The Vendian deposits are represented by a succession of gravelstone, feldspar-quartz sandstone of different grain size, siltstone and shale. The Paleozoic section comprises the successions of the Lower and Middle Cambrian, the Ordovician, the Lower Silurian and the Middle and Upper Devonian sediments (Figure 7.5-1 and Figure 7.5-2).

The Lower Cambrian is represented by quartz sandstone with inconsiderable admixture of glauconite, siltstone and shale. The sandstone is of different grain size with the fine-grained and especially fine-grained sandstone predominating. The Middle Cambrian comprises the fine-grained and especially fine-grained sandstone. The Ordovician is composed of interbedded marlstone and limestone. The Lower Silurian is composed of dolomitic marlstone and dolomite. The Middle Devonian – of gypsum breccia, dolomitic marlstone and dolomite as well as interbeds of fine-grained and very fine-grained sand and sandstone, siltstone and claystone; the Upper Devonian – of fine-grained and very fine-grained sand and sandstone, interbeds of siltstone and claystone. The Vendian deposits vary in thickness from 135 to 159 m; the total thickness of the Lower and Middle Cambrian succession reaches 93–114 m, the thickness of the Ordovician varies in a range of 144–153, the Silurian in a range of 28–75 m and the total thickness of the Devonian sediments reaches 250 m (*Marcinkevicius et al., 1995*).

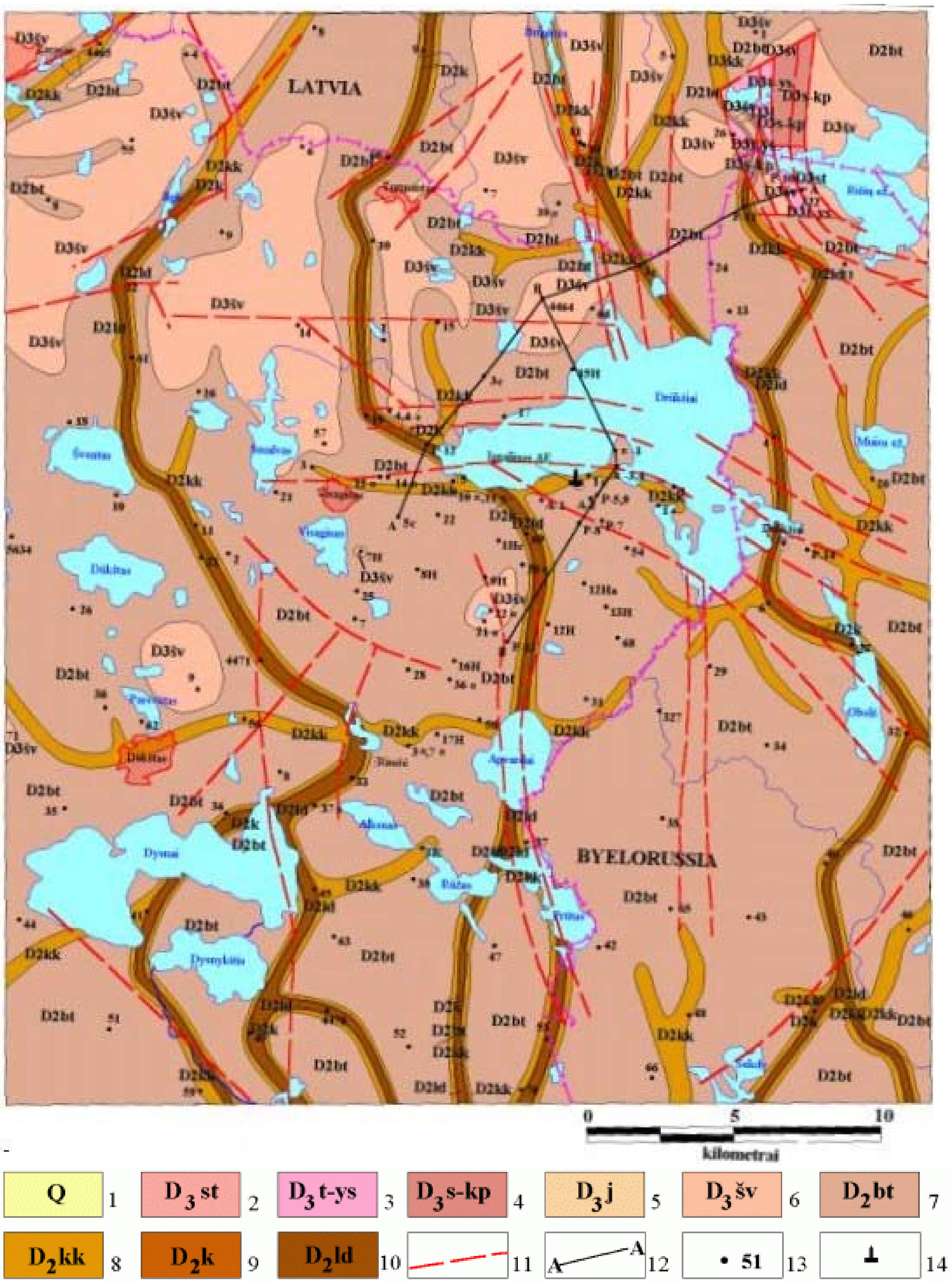


Figure 7.5-1 Pre-Quaternary geological map of the new NPP region (*Marcinkevičius at al., 1995*): 1 – Quaternary deposits (on the sections); Upper Devonian formations: 2 – Stipinai; 3 – Tatula–Istra; 4 – Suosa–Kupiskis; 5 – Jara; 6 – Sventoji; Middle Devonian formations: 7 – Butkunai; 8 – Kukliai; 9 – Kernave; 10 – Ledai; 11 – Fault; 12 –Line of geological-tectonical cross-section; 13 – Borehole; 14 – INPP and the new NPP.

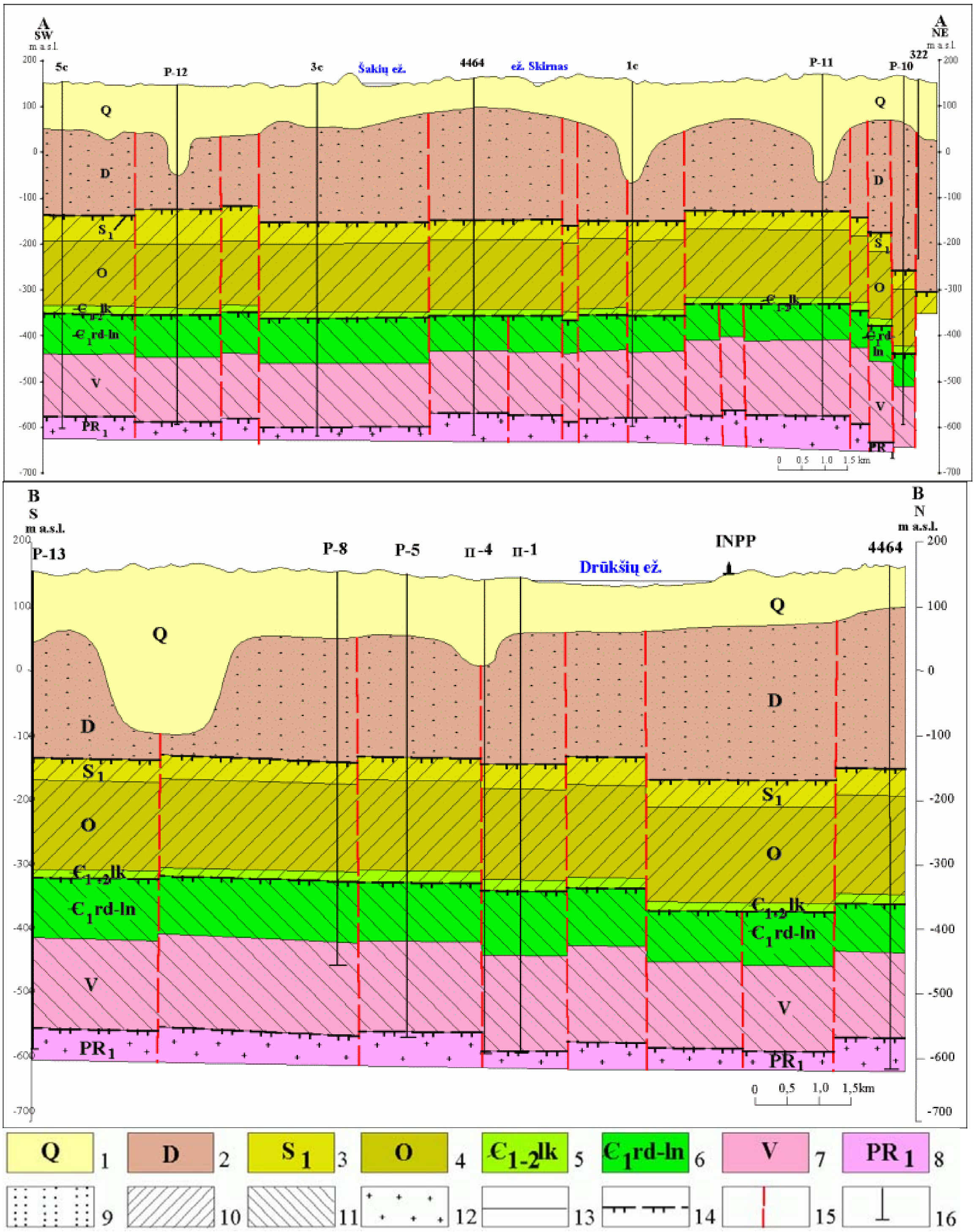


Figure 7.5-2. Geological-tectonic cross-sections of the new NPP region (*Marcinkevičius at al., 1995*): 1 – Quaternary: till, sand, silt and clay; 2 – Middle and Upper Devonian: sand, sandstone, siltstone, clay, domerite, dolomite, breccia; 3 – Lower Silurian: domerite, dolomite; 4 – Ordovician: limestone, marl; 5 – Lower and Middle Cambrian Aisciai Series Lakajai Formation: sandstone; 6 - Lower Cambrian Rudamina–Lontova Formations: argillite, siltstone, sandstone; 7 – Vendian: sandstone, gravelite, siltstone, argillite; 8 – Lower Proterozoic: granite, gneiss, amphibolite, mylonite; Structural complexes: 9 – Hercynian; 10 – Caledonian; 11 – Baikalian; 12 – Crystalline basement; 13 – Border between systems; 14 – Border between complexes; 15 – Fault; 16 – Borehole.

7.5.1.2 Quaternary cover of the region

The Sub-Quaternary relief of the area is highly dissected by paleoincisions (Figure 7.5-3). The thickness of the Quaternary cover varies from 62 to 260 m.

The Quaternary deposits are of Pleistocene and Holocene age. The area is made up of glacial deposits (till) of the Middle Pleistocene Dzukija, Dainava, Zemaitija and Medininkai Formations, and of the Upper Pleistocene Upper Nemunas Formation (Gruda and Baltija). Intertill glaciofluvial (sand, gravel, cobble, pebble) and glaciolacustrine (fine-grained sand, silt, clay) sediments are detected in the area. The thickness of the intertill deposits varies from 10–15 m to 25–30 m (Figure 7.5-4). The interstadial deposits are composed of very fine-grained and fine-grained sand, silt and peat (Figure 7.5-6 and Figure 7.5-7). The Holocene deposits are represented by alluvial, lacustrine and bog sediments. Alluvial sediments are variously grained sands with 1–1.2 m thick organic layers. The lacustrine sediments (fine-grained sand, clay, silt) reach a thickness of 3 m. The thickness of the peat is 5–7 m (*Marcinkevicius et al. 1995*).

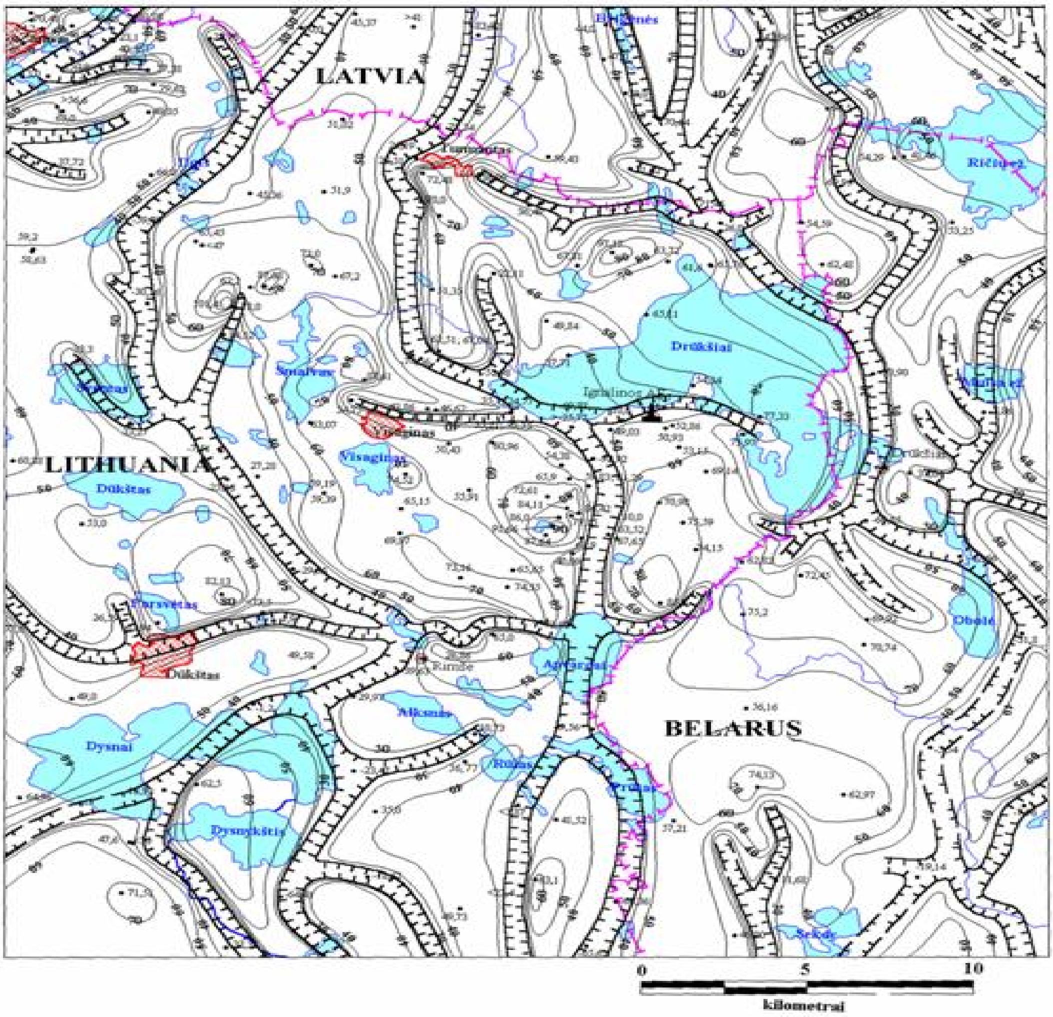


Figure 7.5-3. Scheme of sub-Quaternary surface of the new NPP area (*Marcinkevičius at al., 1995*): 1 – Paleoincision; 2 – Isohypse of pre-Quaternary surface, m; 3 – Boreholes and the absolute depth of the pre-Quaternary surface: 4 – INPP and the new NPP.

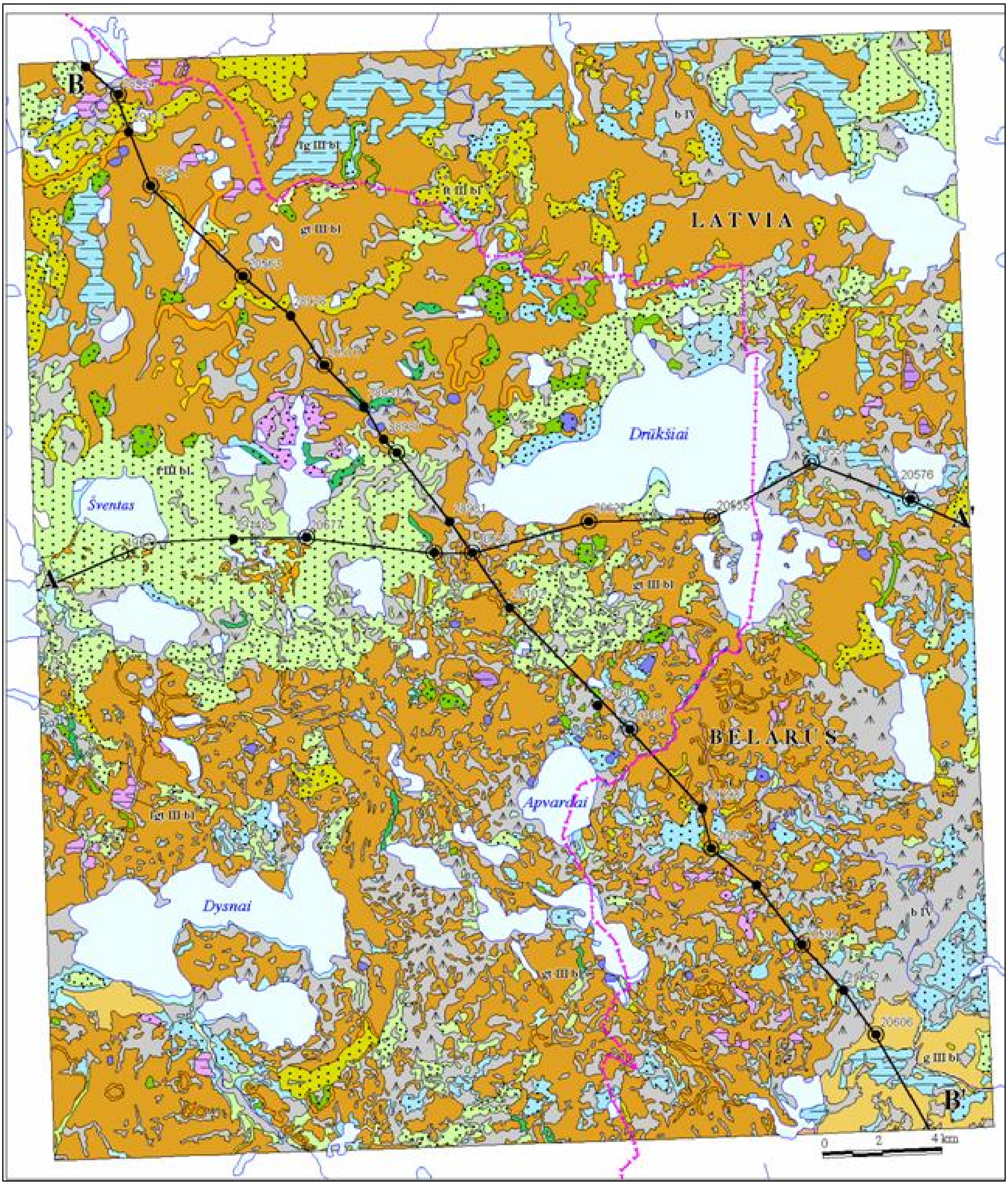


Figure 7.5-4. Quaternary geological map of the new NPP area (original scale 1:50 000, author: R. Guobyte (*Marcinkevicius et al. 1995*)); legend see in Figure 7.5-5.

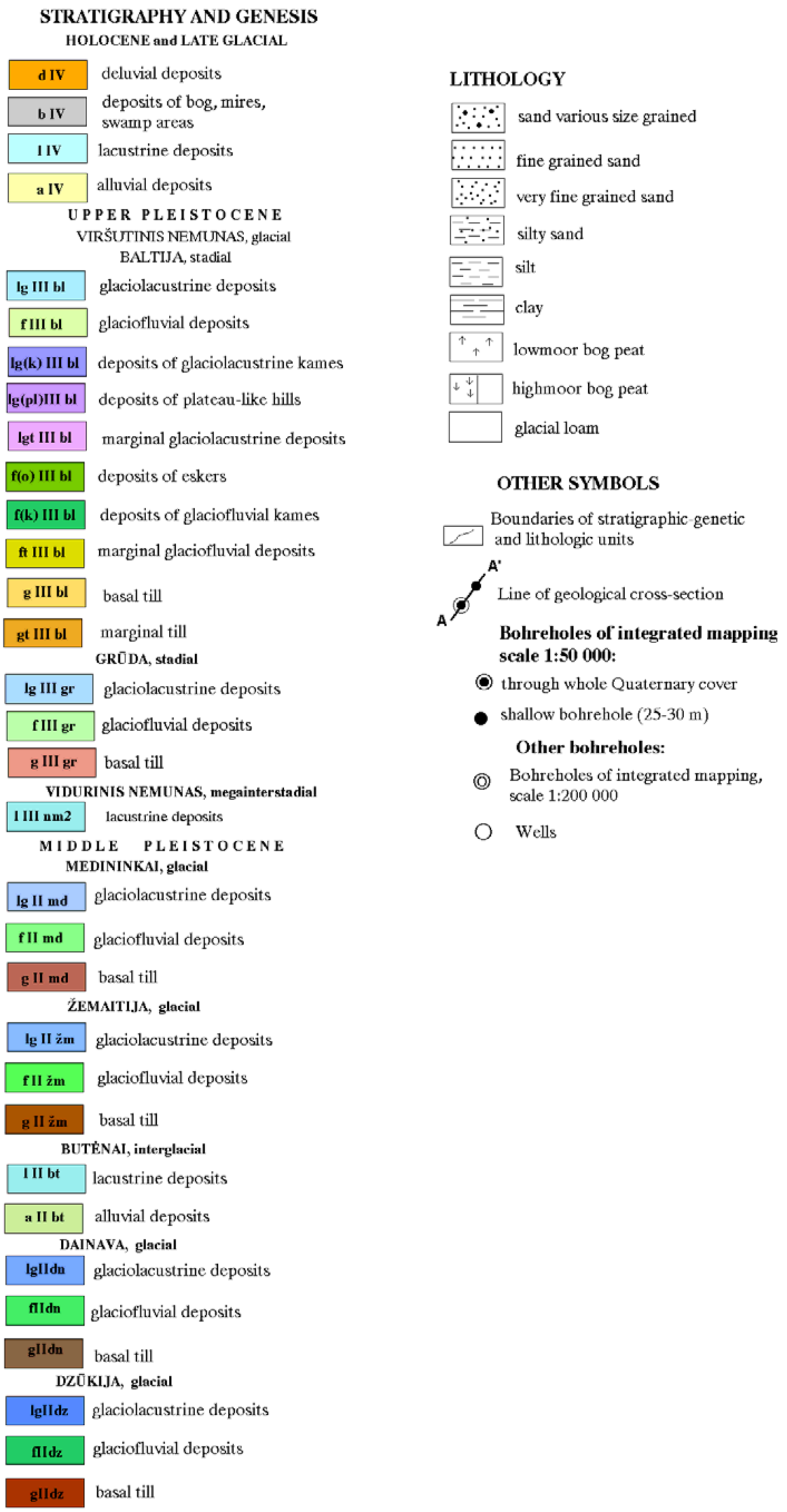


Figure 7.5-5. Legend for Quaternary geological map and geological cross-sections of the new NPP region.

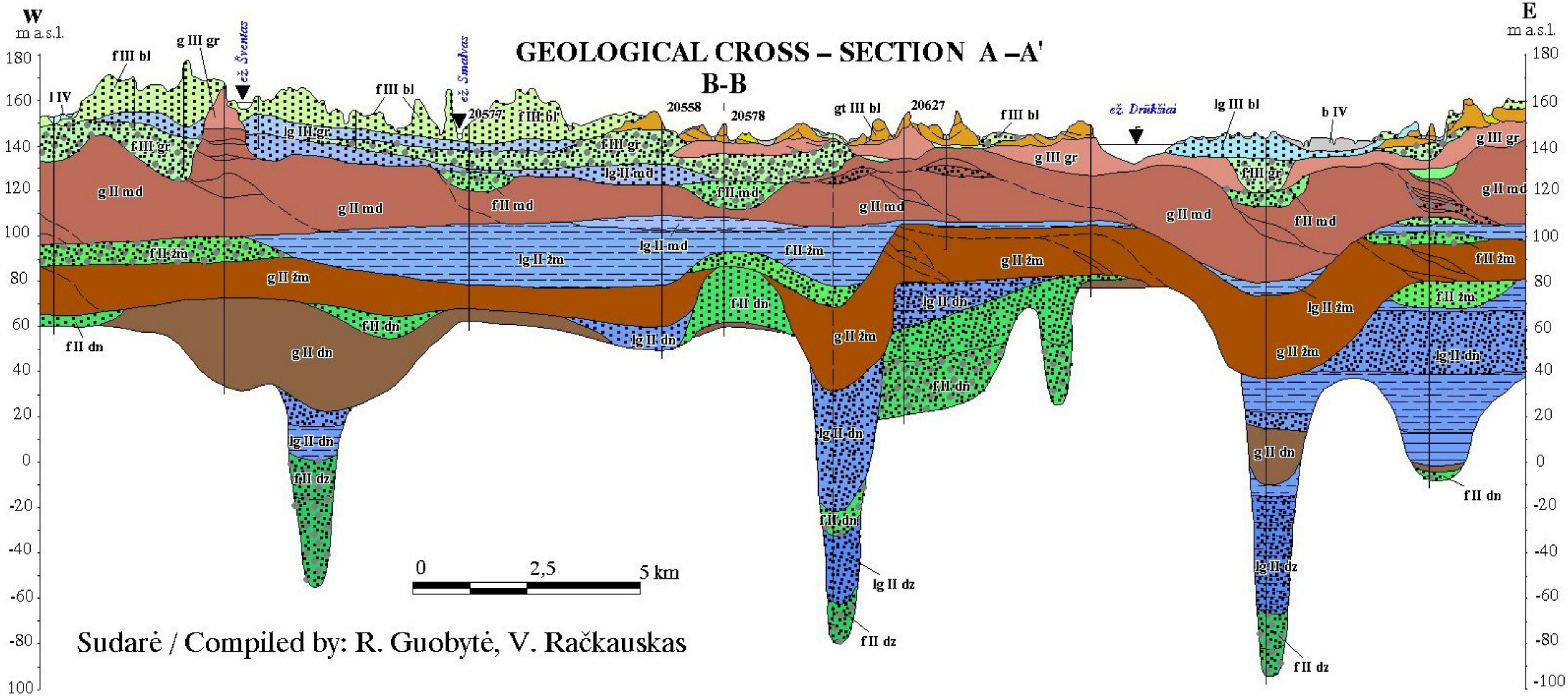


Figure 7.5-6. Quaternary geological cross-section A-A of the new NPP area (original scale 1:50 000, authors: R. Guobyte, V. Rackauskas (*Marcinkevicius V. et al., 1995*)); legend see Figure 7.5-5.

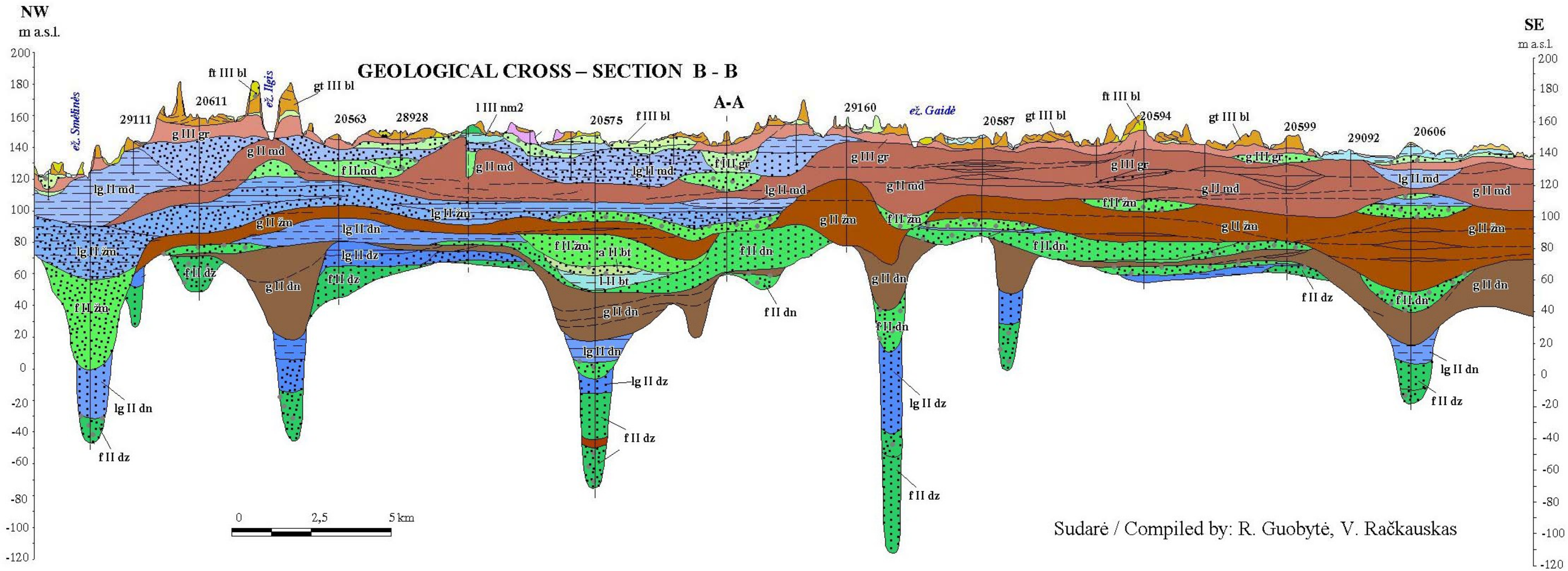


Figure 7.5-7. Quaternary geological cross-section B-B of the new NPP area (original scale 1:50 000, authors: R. Guobyte, V. Rackauskas (*Marcinkevicius V. et al., 1995*)); legend see Figure 7.5-5.

7.5.1.3 Geologic structure of the new NPP sites

Geological composition of the whole industrial site of the Ignalina NPP and the proposed sites for the NNPP has been sufficiently well investigated. In 1975–1976 the 25th Hydrogeologic Expedition of the Second Geological Board of the former USSR have drilled as many as 5 bore holes in the immediate vicinity of the surveyed site, with a bore depth from 720 to 745 m. Data obtained from later boring works and used in cartography reports of the sites allow for specification of deep layer stratification conditions in the area of the sites (*Vaitonis et al., 1975; Marcinkevicius et al., 1995*). Data obtained during these boring works provide for reliable distinction of three parts of the geological cross-section of the sites – crystalline basement, sedimentary rock layer, and Quaternary cover formed by shifts of continental glaciers.

Crystalline basement

Ignalina NPP industrial site, where the two sites for the new NPP are located, is in the area of junction of the large regional geological structures of the Eastern European platform. This is a junction between so-called Latvian Saddle and the Mazurian-Byelorussian Rise. The crystalline rock basement is stratified here at very uneven level of 550 to 750 m from the earth surface. This is because the crystalline basement (Figure 7.5-8) is divided into structural blocks of uneven size with different relative elevations. The difference in amplitude of elevation of these blocks in the environs of the Ignalina NPP is up to 55 m. Within the Ignalina NPP industrial site the surface altitude of the crystalline basement is from minus 561.2 m (bore P6) to minus 581.4 m while the absolute height isoline running across the INPP industrial site is minus 575 m.

In the surveyed sites there are no boreholes deeper than 130 m, the deeper layers may only be described on the basis of regularities of geological composition of adjacent territories and the Ignalina NPP industrial site.

Crystalline basement rocks are of Lower-Middle Proterozoic geological age. The deep bore bored near Lake Druksiai, slightly to the north of the first surveyed site (site 1), had reached rocks of the crystalline basement in the depth of 732 m (*Vaitonis et al., 1975; Juozapavicius, Juodkazis, 1987*). These rocks had been bored into up to a depth of 781 m. At this stretch between 781 and 732 m crystalline basement rocks consist of granite gneiss, amphibole, and shale.

Sedimentary rocks

On the surface of the dislocated crystalline basement there is a layer of sedimentary rocks with rocks from Vendian, Cambrian, Ordovician, Silurian, and Devonian geological systems.

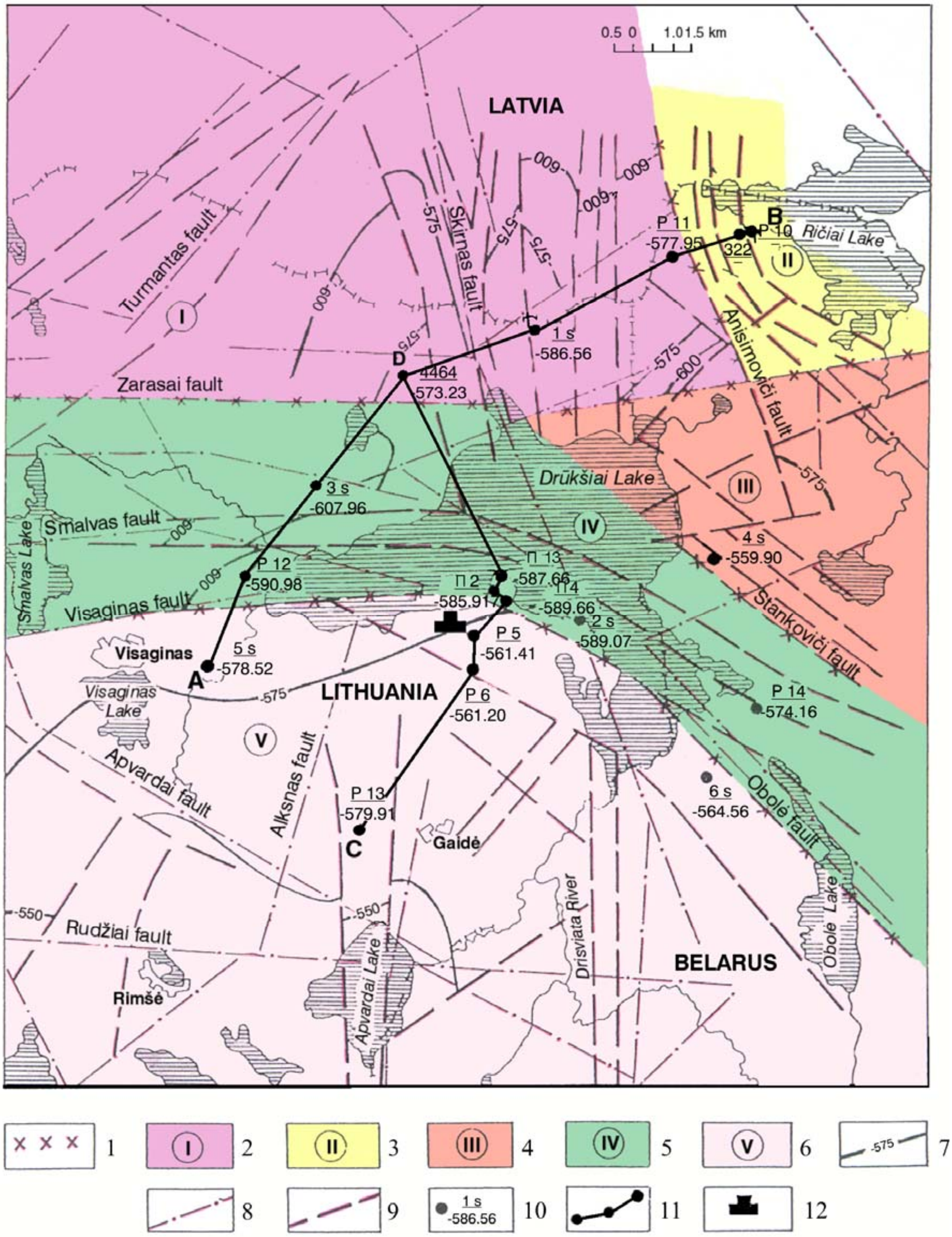


Figure 7.5-8. Structural scheme of the surface of crystalline basement of Ignalina NPP area: 1 – Border of the main structural elements (blocks) of the crystalline basement; Structural elements (blocks): 2 – North Zarasai bench; 3 – Anisimovici graben; 4 – East Druksiai uplift; 5 – Druksiai trough (graben); 6 – South Druksiai uplift; 7 – Isohypses (m) of the surface of the crystalline basement; 8 – Faults established by aeromagnetic and gravity data; 9 – Faults established by seismic data; 10 – Borehole: in numerator – number of borehole, in denominator– the absolute depth of the surface of the crystalline basement (m); 11 – Line of geological-tectonical section; 12 – Ignalina NPP (according to *Marcinkevicius et al., 1995*).

Data obtained from the deep bores made in the adjacent areas indicate that the crystalline basement of block composition is divided by tectonic deformations and covered by the rocks of the Vendian complex of Upper Proterozoic geological age, while the dislocated and degraded surface of the Vendian layer is covered with terigenous rocks of the Lower Cambrian complex. The Vendian complex is stratified 732 to 596 m deep. It consists of quartz sandstone and siltstone.

The argillite and sandstone layer with lytified clay layers occuring above the Vendian complex in the depth of 598 to 585 m is attributed to the Lower Cambrian complex. Fine-grained quartz sandstone is stratified at a depth from 585 to 570 m. This Middle Cambrian layer is in places covered by rocks of the Caledonian complex.

In the geological cross section of the first site, light-gray limestone and sandstone of the Lower Ordovician geological age is stratified above the Middle Cambrian rocks at a depth of 570–507.2 m, limestone and marl of the Middle Ordovician is stratified at a depth of 507.2–496.3, while light-gray limestone of the Upper Ordovician is stratified at a depth of 496.2 to 440.1 m.

Rocks of the Ordovician system are in places covered with light-gray dolomitic marl of the Lower Silurian geological age, the layer of which lies at a depth of 440.1–354.0 m. Dolomite, limestone, and marl of the Upper Silurian lay at a depth of 354.0–220 m.

On the degraded surface of the Silurian system rocks the Hercynian complex rocks are stratified. These include light-gray siltstone, sandstone, and dolomite of the Middle Devonian. In the surveyed site these rocks are stratified very unevenly and it may only be predicted that the bore should reach this layer at a depth of 220–119.5 m. In some boreholes (*Vaitonis et al., 1975; Marcinkevicius et al., 1995; Juozapavicius, Juodkazis, 1987*), which had been bored in the area of the first surveyed site a bit southwest from Lake Druksiai, the sandstone and siltstone layers of the Devonian system reach up to 76–77 m, while in other places this layer is either completely degraded in palaeoincisions or remains thin.

Rocks of Narva horizon of the Middle Devonian in the Ignalina NPP area comprise a regional aquitard. At the places where degraded rocks of the Devonian system have been eroded by palaeoincisions (Figure 7.5-1) the Narva aquitard horizon is much thinner; in some places its thickness is barely 5 m. Middle-Upper Devonian Sventoji–Upninkai sandstone layer is at places completely degraded in the area of the Ignalina NPP, while in other places only the lower part of the eroded layer remains. In the surveyed site, sandstone and siltstone of the Kukliai and Butkunai formations of the Upninkai series form erosion etched pre-Quaternary surface, which is covered by sediments formed during Quaternary glacial periods.

Quaternary cover

This layer of Quaternary geological age has a very complex composition and is very uneven. However this is the most important component of the engineering geological conditions of the sites. It consists of sediments and deposits formed during glacial periods. This layer also includes both current Holocene sediments (peat, sapropel, and peaty deposits) and technogenic grounds. A layer of Quaternary sediments and deposits at the sites reaches up to 120 m. Thickness of the sediments depends on the relief and absolute heights of the pre-Quaternary surface.

From a geomorphological point of view the new NPP sites are located in the Gaide glaciodepression of the Baltija Highland to the south of Lake Druksiai. The sites are surrounded by hummocky moraine landscape of the marginal zone of the last (Nemunas) glaciation. The hummocky landscape of this depression is interspersed with numerous individual glacial forms such as kames, eskers, glaciofluvial hills and other ice-crevice forms (*Marcinkevicius et al., 1995*).

Geological structure of site No. 1

NNPP Site No. 1 is located on the north-eastern side of the Ignalina NPP industrial site. The southern border is close to the west-east transport strip, the western border matches the strip of ruins of the Third Unit of the INPP, while in the north and north-west the investigated site is delimited by a stretch of channels constructed on the shore of Lake Druksiai.

From a geomorphological standpoint, the surveyed site No. 1 is a part of the Baltic Highland. Its surface relief has formed at the edge of the last Baltic glacier. It is a typical relief of moraine formations. On the southern side the relief belongs to the Cebarakai massive of the so-called Gaide glaciodepression (*Vaitonis et al., 1975*), the surface of which in many places is covered by a thin cover with a thin sand layer. The surface of the Cebarakai geomorphological massive is flat, hilly in some places, with many thermosinkholes.

The relief of the northern part is characterized by flat transition of the waterlogged undulate plain to a marshy shore of Lake Druksiai. Absolute altitudes of surfaces of the northern and eastern parts are several meters above the absolute altitude of the water level of Lake Druksiai.

The natural relief at the southern part of the site has been completely changed during the construction of the Third Unit of the Ignalina NPP. In former places of marshes peat has been completely or partially removed and covered with sand, gravel or other soil. Mounds have been formed for access roads. On the northern and northeastern part adjacent to the hydrotechnological channels, the original natural relief has been damaged by excavations. However, the declination of both southern and northern part of the current leveled surface has the northern and northeastern direction, towards the shore of Lake Druksiai.

Prequaternary rocks occur at a depth of 129.2 m (altitude +14.8 m) in the territory of site No. 1. These rocks belong to the Butkunai formation of Upninkai series of the Middle Devonian (D_2bt) that consists of siltstone, fine grained sand and clay. Above these sandy layers glaciolacustrine deposits of Middle Pleistocene Dzukija formation (lgIIdz) occur and consist of silty sand. The upper part of Dzukija formation consists of glaciofluvial deposits (fIIdz) that are also sandy and silty. The top of Dzukija formation occurs at the altitude of +46.0 m (Figure 7.5-9).

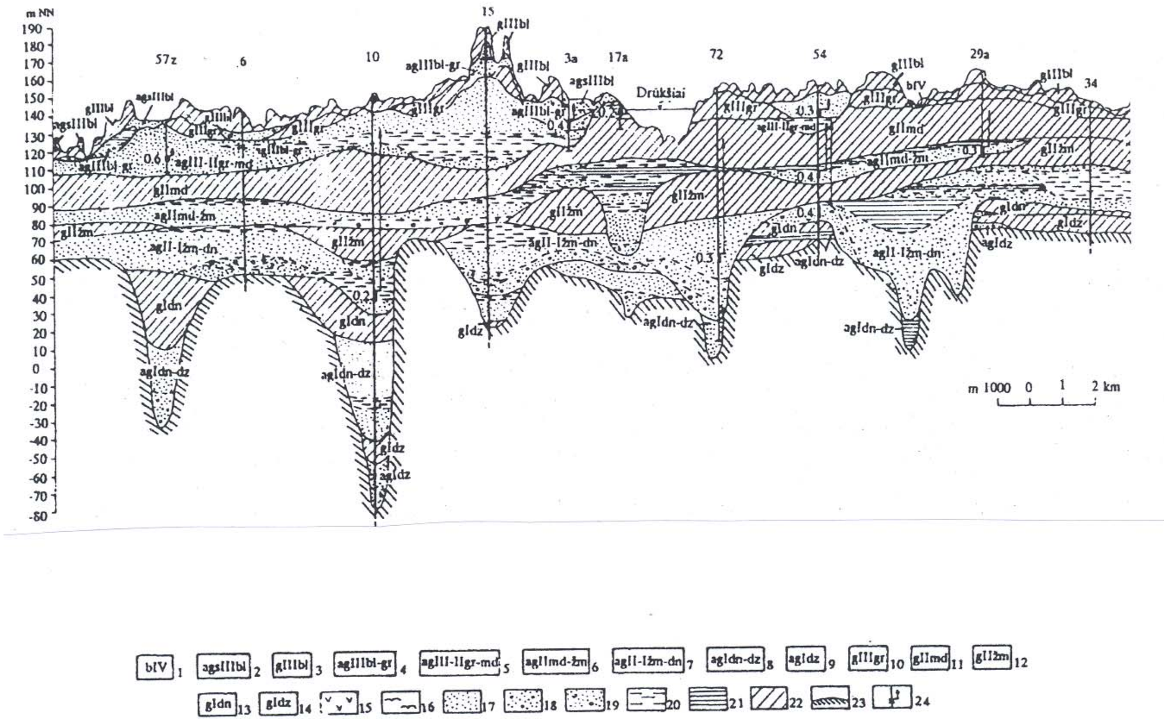


Figure 7.5-9. Schematic geological cross-section of the site No 1 with hydrogeological information. Genesis of layers: 1 – bog, 2 – glaciofluvial, 3 – glacial; intermorainic confined aquifers: 4 – Baltija - Grūda, 5 – Grūda – Medininkai, 6 – Medininkai–Žemaitija, 7 – Zemaitija–Dainava, 8 – Dainava–Dzūkija, 9 – Dzūkija fliuvioglacial deposits; low permeable beds – relative aquitards: 10 – Gruda, 11 – Medininkai, 12 – Zemaitija, 13 – Dainava, 14 – Dzukija glacial deposits; 15 – peat, 16 – sapropel; 17 – sand, very fine and fine; 18 – various – grained sand; 19 –gravel; 20 – silt; 21 – clay; 22 – loam; 23 – pre-Quaternary rocks; 24 – well tested and piesometric level of the aquifer tested (modified from *Kerasevicius and Kropas, 2006*).

Above the Dzukija formation the aquaglacial intertill deposits (agIIdn-dz) occur. This layer is distributed locally and consists of different sand, gravel and silt. The thickness of this intertill layer is about 8.2 m. In some places the basic till of the Dainava formation of Middle Pleistocene (gIIdn) was drilled. This layer consists of hard clayey till with gravel, sometimes with interbeds of silt or sand. The thickness of this till reaches 33.3 m (top altitudes +78.2–88.5 m). Above the basic till glaciofluvial sands of the Dainava formation (fIIdn) occur. The thickness of this layer varies from 1–5 to 8–18 m. Altitudes of the top layer are +83.6–100.6 m.

At the altitudes from +95.6 to +105.5 m the glacial deposits (basic till) of the Zemaitija formation (gIIžm) occur. These consist of clayey loam with gravel. Glaciolacustrine deposits of the Zemaitija formation (lgIIžm) occur above the basic till and consist of clay and silt. The thickness of glaciolacustrine deposits varies from 3 to 13 m. The upper part of Middle Pleistocene is formed by the Medininkai formation which consists of glacial basic till (gIImd) – clayey loam with gravel, and locally of glaciofluvial (fIImd) fine grained sand. The thickness of glacial deposits reaches 14–18 m at the altitudes from +132.2 to +143.2. Glaciofluvial deposits are only 0.5–13 m thick.

Glacial deposits of Gruda sub-formation of Upper Pleistocene (gIIgr) occur only in the southern part of site No. 1. The thickness of the layer is about 10 m, and altitudes of the top are from +144.5 to +148.4 m (*Jonusas et al., 2006*).

The most recent layers of Quaternary system belong to Holocene. These are lacustrine sediment (l IV) and biogenic sediments of bogs (b IV) and occur below the man made soils (tpl IV).

Geological structure of site No. 2

The site is located in the western part of Ignalina NPP industrial area. From a geomorphological standpoint, the surveyed site No. 2 is also a part of the Baltic Highland regionally called Aukštaičiai highland. The site belongs to the local geomorphologic unit of Gaidė morainic rise. Its surface relief was formed at the margin of the last Baltic glacier.

There are several knolls of 3–6 m. height at the site. The surface of the territory has a slight decline (altitudes 153.1–152.2) towards the north. Absolute altitudes of the surface are several meters above the absolute altitude of the water level of Lake Druksiai. The land surface has been changed during the construction works of Ignalina NPP. There are several structures which were built for the distribution of electricity remaining at the site.

Pre-Quaternary rocks of the site have only been mapped during the last geological mapping at a scale of 1:50 000 in 1995. More detailed geological investigations reached a maximum of 20 meters. According to the results of several investigations the Quaternary cover up to a depth of 20 m consists of glacial (g III) and glaciofluvial (f III) deposits of Upper Pleistocene and recent sediments (Holocene) of bogs (b IV), lacustrine deposits (l IV) and man made (t IV) soil (Figure 7.5-10). Man made soil that consists of natural soils from surrounding area forms several mounds.

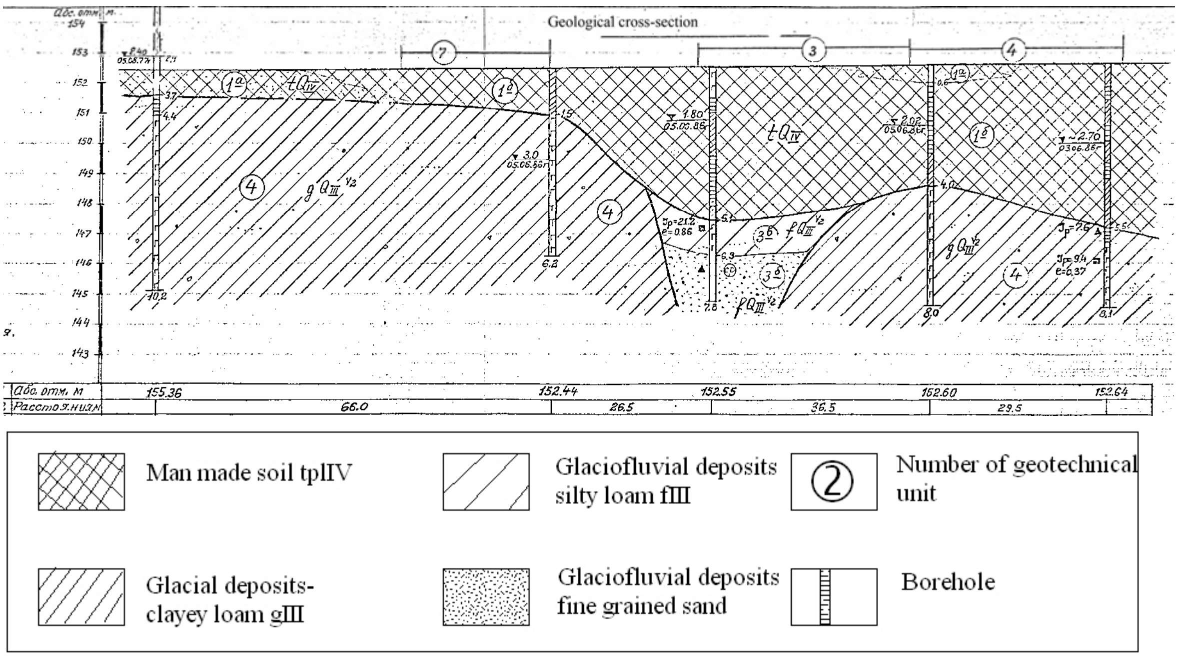


Figure 7.5-10. Geological cross-section of site No 2.

Glacial deposits are represented by clayey and silty loam that occurs at a depth of 0.5–1.0 m in the southern part of the site and at a depth of 5.5–11.0 m in the northern part. Average thickness of all glacial deposits is about 20–25 m. Glacial deposits belong to marginal till of the Baltija subformation (gtIII bl) of Upper Pleistocene and to basal till of the Medininkai formation (gII md) of Middle Pleistocene. Loamy deposits of the Medininkai formation occur at the altitudes 137.0–151.2. In some places glaciofluvial differently grained sands occur above the glacial loam. The layer of sand is quite thin. It belongs to marginal glaciofluvial deposits of the Baltija subformation (ftIIIbl). Its thickness varies from 0.5 m in the middle part to 5 m in the small incisions in the southern part of the site. The depth of the sandy layer varies from 1.0 to 9.2 m. The most part of the site is covered by man made soil that is represented by silty and clayey loam of low density and in some places peat. The thickness of the man made soil varies from 0.5 to 11.0 m. The largest layers of man made soil occur in the northern part of the site (*Krainiukov et al., 1986*).

7.5.1.4 Tectonic faults

Two types of faults can be distinguished in the new NPP area, i.e. the oldest pre-platform and younger platform features. The faults detected in the sedimentary cover are oriented N-S, W-E, NW-SE and NE-SW. The faults of the Druksiai Depression (Graben) and Anisimoviciu Graben are the most distinct tectonic features recognized in the study area. The Druksiai Depression (Graben) is as wide as 3–5 km; it consists of 0.5–1.5 km wide structural domains. The middle part of the graben is uplifted, representing the horst. The bounding faults exceed 20 km in length. The amplitude of the faults separating the horst is in the range of 25–55 m, the amplitude of the faults bounding the depression in the south and the north is about 10–20 m. The Anisimoviciu Graben is dissected by arcuate-shaped (in plan view) faults spaced at 0.5–0.7 km; the blocks stepping down to the northeast.

The length of the faults is of about 10 km; the amplitude reaches 15–60 m. Total amplitude of the faulting with respect to the top of the Silurian is about 180 m. The faults striking N-S are common in the North Zarasai Structural terrace and eastern part of the South Druksiai Uplift. The eastern part of the North Zarasai Structural terrace is fragmented by faults bounding the narrow (0.5–1.5 km) horsts and grabens of sub-longitudinal orientation. The faults are as long as 5–9 km, and the amplitude is in the range of 10–20 m. The Apvardai–Prutas and Macionys Grabens, bounded by 3–15 km long and 10–25 m amplitude faults, have been mapped in the South Druksiai Depression.

The faults striking northeast and northwest have been recorded in all tectonic structures (blocks) of the new NPP area. Their length varies from 3–5 km to 15–18 km; the offset is of 15–20 m (*Marcinkevicius et al., 1995*).

North Zarasai Terrace block, Anisimovitch Graben block to the east and East Druksiai Graben block belong to a large regional tectonic structure – the so-called Latvian Saddle, while the South Druksiai block belongs to another regional tectonic structure – the Mazury-Byelorussian Rise. The Druksiai Depression block (graben) is located within the junction zone of the two aforementioned regional tectonic structures (*Marcinkevicius et al., 1995*).

The North Zarasai Terrace block is located north to Lake Druksiai. It is separated from the Druksiai Depression block by a latitudinal Zarasai tectonic fault. The Skirnas tectonic fault crosses the middle of Lake Druksiai in the sub-longitudinal direction cutting the North Zarasai Terrace block into two.

The East Druksiai Uplift block is located in the southern and northeastern part of Lake Druksiai and its shore. In the southwest it is bordered by the Stankovičiai fault, while in the west it is bordered by the Zarasai fault.

The Druksiai Depression block forms an arch-shaped strip stretching from west to southwest across the whole area of the INPP. The block is broken by lower order faults and forms a neotectonically active graben-horst-graben structure. In the north the

Druksiai Depression block borders with Zarasai and Stankoviciai faults, while in the south and southwest it borders with the Druksiai (Visaginas) and Obole faults.

The South Druksiai block covers the southern part of the Ignalina NPP area. In the north and northeast it is separated from the Druksiai Depression by Druksiai (Visaginas) and Obole faults. In the south this block borders with the Rudziu fault, while in the west it borders with the longitudinal Smalva fault.

The South Druksiai block is crossed by several local faults of sub-longitudinal orientation, which break the block into several graben-type structures of small amplitude (Apvardai–Prutas, Macionys, etc.) (*Marcinkevicius et al., 1995*).

The territory of the first surveyed site is also affected by platform faults crossing the sedimentary rocks layer. The nearest such faults are the Druksiai (Visaginas) fault bounding the Druksiai Depression (Graben) from the south and Oboles fault bounding the same block from the southwest. The length of these faults is up to 20 km and the amplitude of the Druksiai (Visaginas) fault bounding the Druksiai block in the south is up to 10–20 m. In the eastern part of the South Druksiai Uplift block there are local faults of sub-longitudinal orientation with length of 5–9 km and amplitude of 10–29 m. The South Druksiai Uplift block has local faults, the amplitudes of which in the Apvardai–Prutas and Macionys grabens are up to 10–25 m. Intersection of the regional faults is in the Lake Druksiai, where deep faults of various orientations intersect (Figure 7.5-11).

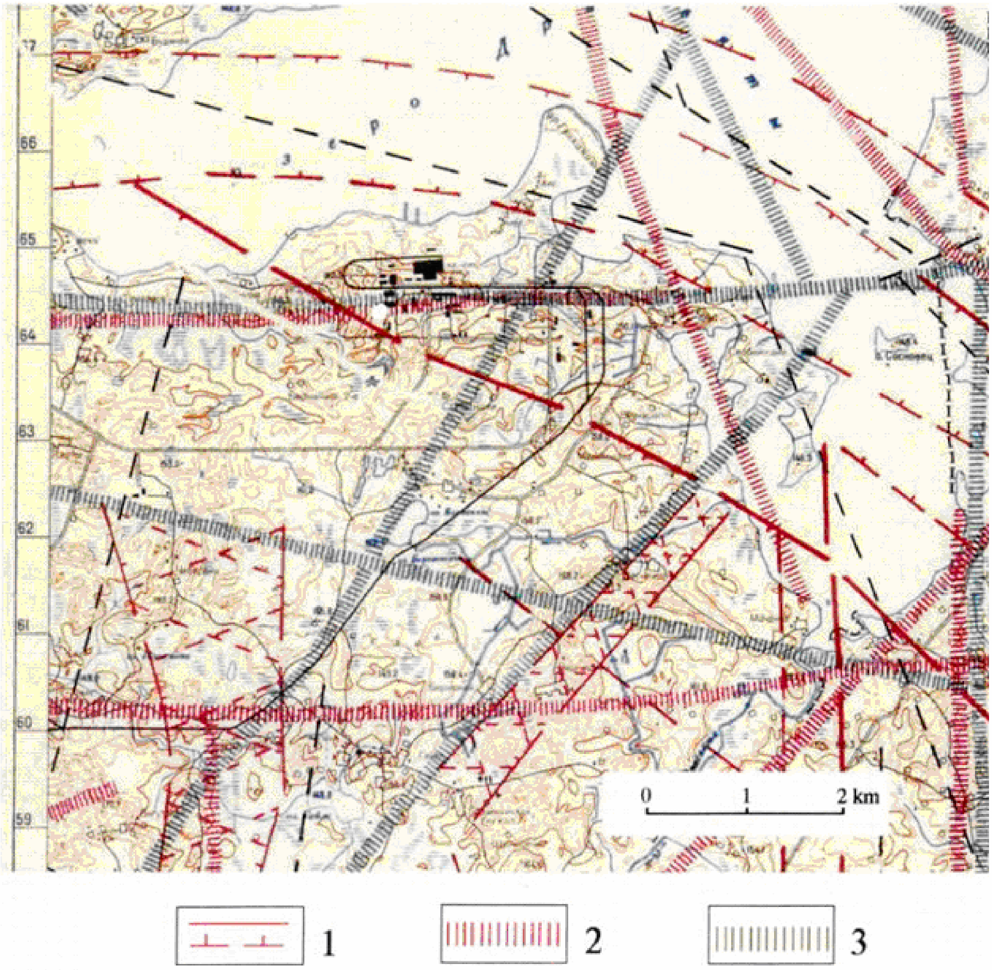


Figure 7.5-11. Tectonical scheme of the Ignalina NPP area: 1 – Tectonical faults; 2 – Neotectonical zones by morphometrical analysis; 3 – Neotectonical zones by morphostructural analysis (*Marcinkevicius et al., 1995*).

In the area of the Ignalina NPP there are neotectonically active zones, which may be locally related to the tectonic fault zones, but are somewhat displaced with regard to fault lines.

Skirnas and Druksiai (Visaginas) faults are neotectonically active. Neotectonic activity of these fault zones is confirmed by measurements of vertical and horizontal earth surface shifts in the Druksiai Geodynamic Ground (*Zakarevicius, 1999*).

The surveyed NNPP sites adjacent to the buildings of the Ignalina NPP are situated in the northeastern part of the South Druksiai structural block. This part of the block is 4–5 km away from the intersection of Skirnas and Druksiai (Visaginas) regional faults. The zone of Druksiai (Visaginas) regional fault is approximately 1.0 km away from the northern boundary of the surveyed site. The surveyed site is about 5–6 km away from the longitudinally oriented Skirnas fault (Figure 7.5-8). Local deep faults forming Apvardai–Prutas and Macionys grabens do not reach the surveyed site. The neotectonically active zone crossing the Ignalina NPP industrial site is to the south of the surveyed site No. 1.

Site No 2 is crossed by a tectonic fault from the north-west to the south-east. Neotectonically active zones cross site No 2 from west to east (Figure 7.5-8 and Figure 7.5-11).

Conclusions

- regional deep tectonic faults dissecting the crystalline basement and penetrating the sedimentary rock layers divide the Ignalina NPP area into four structural blocks;
- the surveyed NNPP sites are on the South Druksiai structural block, in a relatively stable solid monolithic part of this block;
- site No 1 is approximately 1.0 kilometer away from the zone of Druksiai (Visaginas) regional fault and about 5–6 kilometers away from the regional Skirnas fault;
- site No 2 is crossed by a tectonic fault, established according to seismic data during the mapping, from northwest to southeast;
- the detailed technical feasibility study of the new NPP should include investigation (at least one borehole) of the Ledai Subformation of the Upninkai Formation, because the absolute depth of the ridge of these rocks will provide the data for estimation of the probability of a local tectonic fault in a specific location of the projected buildings.

7.5.1.5 Neotectonics

It can be shown using morphometric, morphostructural and the interpretation of satellite image data that most of the faults, penetrating the crystalline basement and sedimentary cover, are active neotectonically. As a rule, neotectonically active zones coincide with fault lines or are displaced near it. The faults system of the Druksiai trough, Anisimoviciu graben, and Skirnas fault are the most active. The paleoincisions are connected with neotectonically active zones. Their depth sometimes reaches 200 m (from the pre-Quaternary surface) (*Marcinkevicius et al., 1995*).

On a regional scale, the Ignalina NPP area is in the region of a neotectonic vertical change of the earth surface. This region measures 120 × 230 km. In this region the rate of rising of the earth surface is about 2 mm per year (*Preliminary evaluation ..., 1981*). Compared to the fundamental Vilnius benchmark, the regional rate of rising of the earth surface at the Ignalina NPP territory is up to 2.5 mm per year.

In the general background of the neotectonic vertical rise of the Ignalina NPP area, differential shifts of structural blocks take place due to tectonic faults. These shifts – both vertical and horizontal – are measured in the Geodynamic Ground.

On the basis of the complex investigation data processed for reports in 1988 it was found (*Voskresenskaia et al., 1988*; *Conclusions of working group ..., 1988*), that the whole industrial site of the Ignalina NPP is located on a solid structural block; however, due to activity of deep faults, differential shifts of the earth surface take place at the junction of the Druksiai Graben and the South Druksiai block.

Assessing seismic conditions at the Ignalina NPP industrial site, the State Commission of the former USSR formed in 1988 stated that there was a lack of studies (including geodetic studies) conducted in the INPP area for analysis of the current activity of tectonic faults. Data of such geodetic studies were the qualitative indices for assessment of the geodynamic risk degree of the Ignalina NPP. Objectives for the studies were formulated as follows: to establish whether deep tectonic faults in the area of the Ignalina NPP were active, whether shifts of the earth surface caused by activity of tectonic faults posed any threat to active nuclear power objects and their operational safety.

A geodynamic ground has been equipped for measurement of current vertical shifts of the earth surface (*Juknelis et al., 1990*). The Geodynamic Ground of the Ignalina NPP consists of a precise leveling network (*Zakarevicius, 1999*), covering an area of 110 km^2 located at the depression of Lake Druksiai and including the Ignalina NPP industrial site. Precise geodetic measurements were conducted in 1989, 1990, 1991, 1992, and 1994. Graphic representation of the vertical earth surface shift measurement data is presented in Figure 7.5-12.

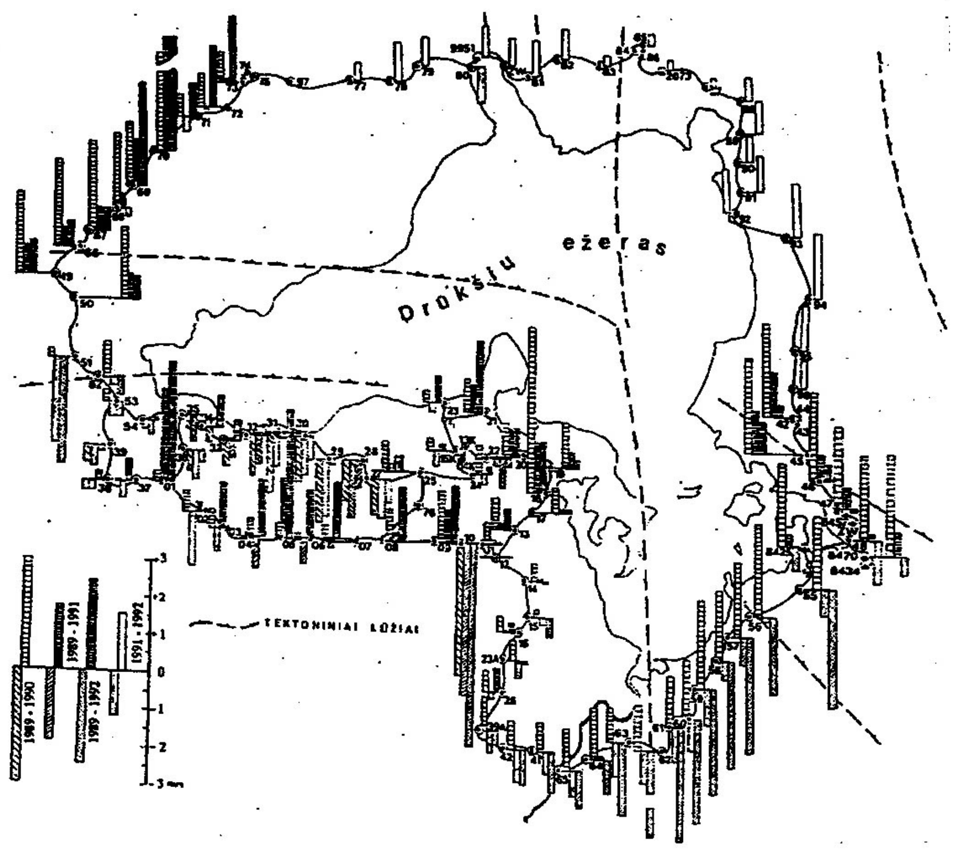


Figure 7.5-12. Measurement results from the Geodynamic Ground.

Vertical shifts of benchmarks of the Geodynamic Ground reveal that vertical shifts of the earth surface are differentiated according to blocks. Shifts of benchmarks are clearly differentiated according to tectonic blocks along the tectonic fault of Druksiai. During the investigation period between 1989 and 1994 the amplitude of relative vertical shift of the northern and the southern blocks has been about 5 mm (*Zakarevicius, 1999*). The northern block is rising relatively to the southern block. Inversion of direction of vertical shifts has been noted – one year measurement cycle data indicate a rise of a certain location, while the next year measurement cycle data indicate downward shift of the benchmark in that location (*Zakarevicius, 1999*). As different structural blocks of the area are bound by deep tectonic faults, it may be assumed that tilting of individual blocks is taking place. Measurement results indicate that differentiation of earth surface shifts in the Ignalina NPP district is related to structural blocks bound by tectonic faults. Shifts found by means of precise geodetic measurements are an expression of not only vertical shifts of the earth surface but also differential vertical shifts of the crystalline basement blocks.

This provides for a conclusion (*Voskresenskaia et al., 1988*; *Zakarevicius, 1999*), that active tectonic processes take place in the area of the Ignalina NPP at the present time. However, absolute values of shifts amounting to the amplitude of 5 mm in three years and changing direction of shift vector are infinitely small in practice. Maybe the more important conclusion of studies of these geodynamic shifts is that the industrial site of the Ignalina NPP area located at the junction of two regional tectonic structures in Lake Druksiai is located at an increased sensitivity zone from the seismic point of view.

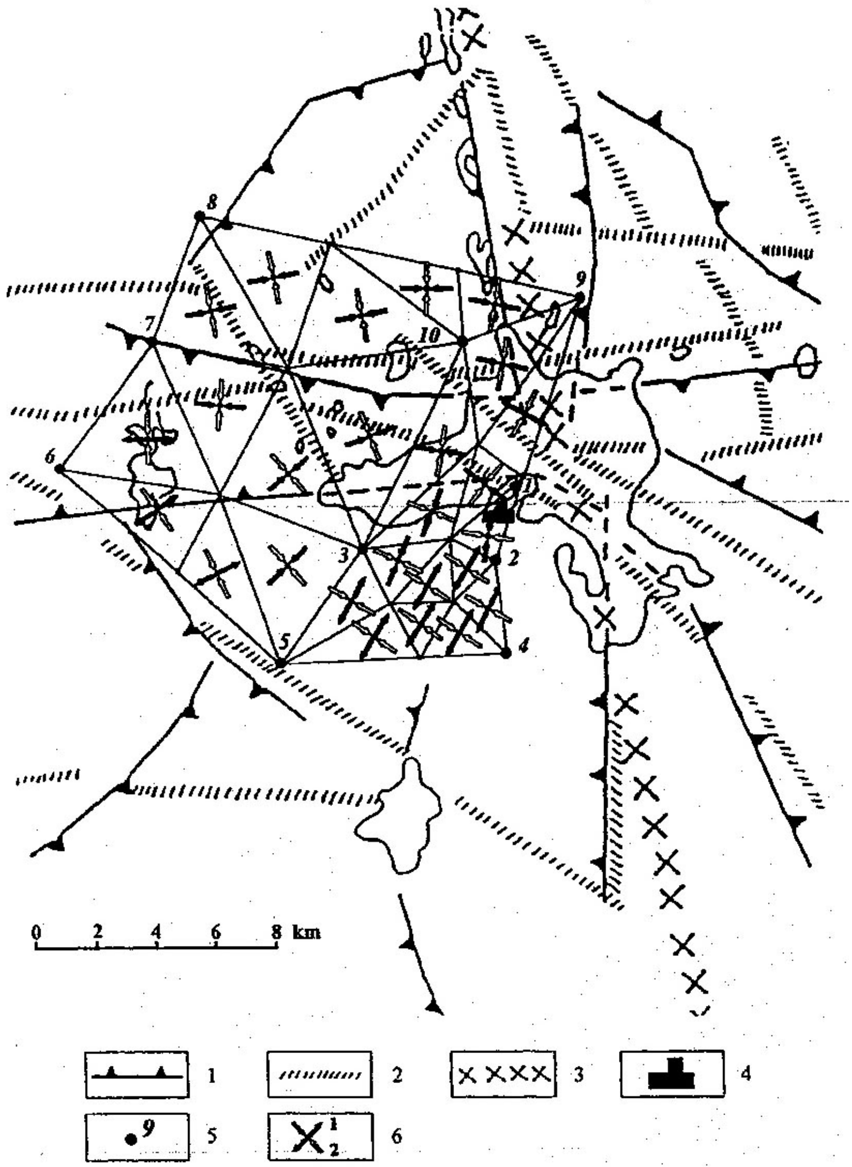
The presented data indicates that intensity of vertical neotectonic shifts of the earth surface at the first surveyed site is best represented by measurements conducted at some points. It may be seen that data of measurement cycles indicates a tendency for consistent rise of one point. The amplitude of the rise amounted to plus two mm for the period between 1989 and 1993. Inversions of vertical shift of another point were established for the period between 1989 and 1991 and amounted to an amplitude of almost half a millimeter, while in 1989–1992 the total amplitude of the vertical shift vector did not exceed one millimeter. Such absolute values of the measured shifts indicate that the area is not in a zone of active tectonic faults and the differentiated rise of infinitely small amplitude of the earth surface is caused by geodynamic processes taking place in the adjacent graben of the Druksiai Depression.

During recent years the measurement of horizontal differential shifts of the earth surface in the area of the Ignalina NPP was completed using precise geodetic methods. Studies of horizontal shifts indicated conformation of the block composition of the Ignalina NPP area with a very high probability.

Measurements indicate that in the Geodynamic Ground equipped in the area of the Ignalina NPP and around Lake Druksiai directions of the largest relative horizontal shifts coincide with directions of tectonic faults determined using geological methods (*Stanionis, 2005*).

Precise geological measurements conducted in 1992–1994 indicated that annual values of the largest elongation in the Ignalina NPP area amount to a tenth million part and going from southwest to northeast a compression zone turns into an extension zone. All territory of the industrial ground of the Ignalina NPP is within the general tectonic compression zone (*Stanionis, 2005*).

Therefore, precise measurements of horizontal shifts of the earth surface indicate that the first surveyed NNPP site (Site 1) (Figure 7.5-13) is affected by tectonic compression. The direction of the biggest and the most important stress almost coincides with the longitudinal direction; hence the compression stress is perpendicular to the Druksiai (Visaginas) regional fault crossing Lake Druksiai.



1 – seismic survey, 2 – aeromagnetic survey, 3 – morphostructural analysis. Others: 4 – Ignalina Nuclear Power Plant, 5 – GPS points, 6 – principal stresses (1 – maximal principal stress variation, 2 – minimal principal stress variation)

Figure 7.5-13. Pattern of Earth crust principal tectonic stress variations. Modified from (*Juknelis et al., 1990*).

Conclusions

- data of precise geodesic measurements of earth surface shifts confirm the conclusion of geological studies concerning block composition of tectonic structures in all Ignalina NPP area;
- these studies and measurements confirm the assumptions concerning activity of the Druksiai (Visaginas) and Skirnas tectonic faults; precise measurements revealed that in the proposed site No 1 earth surface shifts are infinitely small and that in certain periods the vertical shift vector changes its direction – the earth surface rises and then sinks;
- precise measurements have not been performed at site No 2;

- measurements of horizontal shifts indicate infinitely small relative deformations and infinitely small deformation gradients;
- the nature of the present earth surface movements indicates that the both NNPP sites are at sufficient distance from the junction between the Druksiai(Visaginas) tectonic fault and the Skirnas tectonic fault and belongs to the compressive stress area to the south of the Druksiai (Visaginas) tectonic fault zone.

7.5.1.6 Seismic activity

The Lithuanian territory is traditionally considered as a non-seismic or low-seismic zone. This is due to the geological structure of the territory and the long distance from tectonically active regions. Historical and recent instrumental data prove that seismic events of low or medium intensity have happened in territories of the Baltic States (Figure 7.5-14).

The most recent seismic events with magnitude of 4.4 and 5.0 on the Richter scale took place in the Kalingrad region of Russia in September 21, 2004. These were registered by seismological networks worldwide as well as by the seismological station of INPP.

Nineteen historical earthquakes took place within a radius of 250 km around the new NPP sites between 1616 and 1965 (*PNIIIS, Moscow, 1988*). In the new NPP region 4 seismological observation stations were installed in 1999 (Figure 7.5-14). Since then the Geological Survey of Lithuania according to agreement with INPP processes and analyses the data gathered at these stations.

Figure 7.5-14. Seismicity of Baltic States: circles – historical events from 1616 to 1965; hexagons – instrumental data from 1965 to 2004; triangles – operative seismic stations.

A new VATESI regulation P-2006-01 "Requirements for Analysis of Seismic Impact on Nuclear Installations" (*State Journal, 2006, No. 87-3447*) provides requirements and recommendations for the seismic design and impact analysis of the structures, systems and components of nuclear installations.

IAEA Safety Standards (*IAEA Safety Guide No. NS-G-3.3, 2002; IAEA Safety Requirements No. NS-R-3, 2003; IAEA Safety Guide No. NS-G-1.6, 2003*) set the requirements for evaluation of seismic properties of construction sites of nuclear power plants and other nuclear installations and for quantitative description of project parameters of earth tremors and seismic categories of soils.

IAEA Safety Standards (*IAEA Safety Requirements No. NS-R-3, 2003* and *IAEA Safety Guide No. NS-G-1.6, 2003*) assume that during an earthquake a nuclear power plant is shaking together with the geological basis, i.e. totality of the ground supporting the plant building. Therefore, assessment of seismic properties is conducted for the whole "building-basement" system. However, there are two aspects to discuss.

The first aspect is how the shaking basement affects seismic displacement of the building during an earthquake. Displacement of splits in the tectonic basement may cause destruction of NPP buildings. It is prohibited to construct nuclear power plants directly above splits in the tectonic basement (*IAEA Safety Series No. 110, 1993*). Other effects on NPP buildings also depend on construction, arrangement, and dynamic characteristics of the buildings. Composition, structure, water content, and physical properties of basement soils describing seismic categories of grounds are also very important.

The second aspect is evaluation of the basement soils capacity and settlement caused by permanent and seismic stresses. The essential principle for designing seismically durable NPP buildings and plant is strict observance of provisions of the IAEA Safety Standards to avoid radiation accidents, which may be caused by destruction of nuclear energy objects as a result of earthquakes.

As a NPP represents a potentially dangerous nuclear installation with regard to radiation safety, it is necessary to ensure its protection from seismic effects. However, there is no point in infinite improvement of seismic durability of the buildings and plant, the destruction of which would not cause radiation accident. Therefore the safety philosophy of the IAEA presumes different levels of safety requirements for each element of a NPP. Different durability categories are defined for buildings and plant in relation to radiation safety. Buildings of the nuclear reactor must be of the highest category.

Therefore, different levels of dangerous intensity of tremors and probability of shifts are set for each seismic durability category of buildings. These levels may become manifested during a possible earthquake at the specific NPP site.

IAEA Safety Standards provide that for each NPP site selected, two levels of seismic shifts, which may be caused with a certain probability at the NPP site by an earthquake, must be assessed:

- SL-1 (Seismic Level 1), corresponding to the seismic level PZ (Design Earthquake) of the Russian Federation standards, to the American OBE (Operating Basis Earthquake), and the British DBE (Design Basis Earthquake);
- SL-2 (Seismic Level 2), corresponding to the seismic level MRZ (Maximum Estimated Earthquake), of the Russian Federation standards, to the American SSE (Safe Shutdown Earthquake), and the British SSE or BDBE (Beyond Design Basis Earthquake).

Seismic Level 1 (SL-1) is such a probable highest level of ground seismic shift at the NPP site, which allows for termination of production of electric or heat power without shutting down a reactor, but rather only by changing its operation mode. The IAEA provides that probability for a repeat of an earthquake of this level is 10^{-2} 1/years. That is, ground seismic shifts of this level may be caused by an earthquake, which may take place at any time, but only once in 100 years. Therefore, possibly highest intensity of seismic shifts at the NPP site, which may be caused by the SL-1 earthquake, has a set probability that it may take place within the operating period of a specific NPP.

Seismic Level 2 (SL-2) is such a probable highest level of ground seismic shift at the NPP site, which still allows for a safe shut-down of the nuclear reactor. According to the VATESI document P-2006-01 (*State Journal, 2006, No. 87-3447*) SL-2 corresponds to a level with a probability of being exceeded in the range 1×10^{-3} to 1×10^{-4} (mean values) or 1×10^{-4} to 1×10^{-5} (median) per reactor per year. Therefore, the SL-2 sets the highest possible intensity of seismic shifts, which may be caused at the NPP site by an earthquake of such magnitude, the probability of which may not be rejected even if it is infinitely small.

Like intensity of earthquakes, seismic levels SL-1 and SL-2 are described by points according to the international 12-point scale MSK-64 (Medvedev–Schponhoyer–Karnik scale of 1964) or according to equivalent 12-point European Macro seismic Scale of 1998, EMS-98.

A risk of seismic deformations of NPP plant and buildings is increased by poor seismic characteristics of basement soils, which depend on composition, water content, and physical condition. The most dangerous from the seismic point of view are soils of the third seismic category (*STR 1.04.02: 2004; List of Regulations, SP 11-105-97, 1989; SNiP II-7-81, 1995*). If half or more of the 10-meter soil layer at the NPP site is of the third seismic category, seismic levels of the NPP site are increased by one point. This is a so-called assessment of the seismic level of the NPP site taking into account soil conditions.

Current assessment of seismic properties of the Ignalina NPP site is based on the official conclusion prepared by a task force for evaluation of the seismic conditions at the NPP site formed by resolution No. 1886 P adopted by the USSR Council of Ministers on September 22nd, 1989 (*Conclusions of working group ..., 1988*). Following requirements of the IAEA Safety Standards, a thorough analysis of data obtained during geological, tectonic, geophysical, geodetic, seismological, hydrogeological, engineering geological, and engineering seismic studies was conducted. On the basis of analysis of these data, seismic levels PZ (SL-1) and MRZ (SL-2) were determined for the Ignalina NPP site according to the MSK-64 scale taking into account the condition of soils (i.e. taking into account presence of grounds of the 3rd seismic category under buildings of the NPP).

Taking into account that the top 10-meter part of the basement layer under buildings of the Ignalina NPP site consists of grounds of the 3rd seismic category, the task force has determined the PZ seismic level of 6 points (in the MSK-64 scale), which corresponds to the 6-point level SL-1 in the MSK-64 or EMS-98 scale. The task force has determined the MRZ seismic level of 7 points (in the MSK-64 scale), which corresponds to the 7-point level SL-2 according to the MSK-64 or EMS-98 scale (*Conclusions of working group ..., 1988*).

In June–October of 1988 specialists of the Moscow Industrial and Scientific Research Institute conducted instrumental seismic studies and seismic micro-zoning of the Ignalina NPP site (*Voskresenskaia et al., 1988*). On the basis of the data obtained during instrumental studies, quantitative seismic parameters were evaluated and seismic micro-zoning, which also covered the area of the first surveyed NNPP site (Site 1), was performed.

On the basis of the seismic micro-zoning data it was established that the PZ (SL-1) level of the surveyed site is 6 points in the MSK-64 scale, taking into account that the top 10-meter part of the soil layer consists of grounds of the 3rd seismic category. The MRZ (SL-2) levels of the surveyed site is 7 points in the MSK-64 scale, taking into account, that there are grounds of the 3rd seismic category in the top 10-meter part of the soil layer (*Voskresenskaia et al., 1988; Mikhailitchenko et al., 1995*). Using abbreviations used in the IAEA Safety Standards, the seismic level SL-1 of the surveyed site is 6 points in the MSK-64 scale (or EMS-98 scale), while seismic level SL-2 is 7 points in the MSK-64 scale (or EMS-98 scale).

Assessment of seismic characteristics using instrumental measurements and modeling of seismic data of the Ignalina NPP site and its particular parts has been performed (*Voskresenskaia et al., 1988; Mikhailitchenko et al., 1995*). According to the data presented, parameters of seismic movements in the new NPP sites may be described by the following values (*Voskresenskaia et al., 1988*):

- Critical acceleration a_{max}=0.0375 g for seismic level PZ (SL-1);
- Critical acceleration a_{max}=0.075 g for seismic level MRZ (SL-2).

In the analytic report prepared by the National Projection and Scientific Research Complex Power Technology Institute in 1989 the 3rd seismic model was applied to the surveyed site. This model assumes an average ground density of ρ=2.2 $Mg \times m^{-3}$, transversal wave propagation speed of v_s= 400 $m \times s^{-1}$ and a longitudinal wave propagation speed v_p=1400 $m \times s^{-1}$ (*Mikhailitchenko et al., 1995*).

Dynamic characteristics of the ground layer stratified at a depth of up to 10 meters:

- Transversal wave propagation speed v_s= 250–270 $m \times s^{-1}$;
- Longitudinal wave propagation speed v_p= 1080–1125 $m \times s^{-1}$;
- Dynamic Puason's number v_d= 0.45–0.46;
- Dynamic Jung's modulus E_d= 365–450 MPa;
- Dynamic Kulon's modulus G_d= 125–160 MPa;
- Relative dissipation D_p= 0.5–0.85.

Averaged dynamic characteristics of the ground layer stratified deeper than 10 meters:

- Transversal wave propagation speed v_s= 380 $m \times s^{-1}$;
- Longitudinal wave propagation speed v_p= 1140 $m \times s^{-1}$;
- Dynamic Puason's number v_d= 0.43;
- Dynamic Jung's modulus E_d= 800 MPa;
- Dynamic Kulon's modulus G_d= 300 MPa;
- Relative dissipation D_p= 0.60.

Thus, when assessing deformation of basements under the NPP buildings as a result of seismic effects, a geological composition of ground layers is simplified: it is assumed that the base of the NPP buildings consists of an infinite continuum of horizontal layers, grounds are analyzed as viscous elastic medium with linear deformation, while deformation characteristics of grounds are taken to be the same within boundaries of the same layer.

Conclusions:

- seismic conditions at the Ignalina NPP industrial area have been thoroughly researched using complex methods such as seismic micro-zoning, the data of which may be used for determination of seismic levels of the proposed sites;
- the measured seismic parameters of ground layers correspond to the requirements of the IAEA Safety Standards for seismic research methods;
- it has been found that a part of the top 10-meters layer of the ground consists of low-strength grounds of the 3rd seismic category;
- taking into account domination of soils of the 3rd seismic category in the upper part of the geological cross-section at the sites, seismic micro-zoning works and research data provided the determination of the 6 point seismic level PZ (SL-1) and 7 points seismic level (SL-2) in the MSK –64 (or EMS-98) macro-seismic scale;
- results of the instrumental seismic studies conducted in the industrial area of Ignalina NPP provides the description of general seismic characteristics of soil layers at the proposed NNPP sites.

7.5.2 Assessment of impacts on the underground

Direct impacts on the underground include the possible changes in chemical composition of soil and shallow groundwater and changes of soil porosity under the planned buildings.

The geological conditions of the alternative sites are quite equal. The land surface of site No 1 has been flattened, peat has been removed from the lowerings which are filled with man made soil. The surface of site No 2 is quite flat except for a few knolls. At this site the soil has not been removed and man made soil occurs in former sags of the natural land surface. The volume of man made soil is larger at site No 2. Man made soil is too weak for the building foundation and has to be removed.

The contruction and operation is not expected to affect the deeper geological layers or the confined groundwater. The possible impacts on soil are discussed in more detail in the Section 7.4 and impacts on groundwater in Section 7.3.

Faulting and the vertical movements of the earth surface can potentially cause cracking of foundations and other constructions which in turn could increase the risks of accidents. Therefore the new NPP has to be built on a stable foundation which is not located on a tectonic fault.

The structural tectonic conditions at the new NPP sites are rather complicated. The area of the selected sites is located in the region of a neotectonic vertical change of the earth surface where both vertical and horizontal movements of the tectonic blocks occur. According to the studies the tectonic movements change direction and relative vertical shift of the blocks can reach amplitude of 2 mm per year. The largest relative horizontal shifts coincide with directions of tectonic faults determined using geological methods. The elongation of the area reaches only a tenth million part. The compression zone turns into an extension zone from the southwest to northeast. All the territory of the Ignalina NPP industrial area is located within a general tectonic compression zone.

Both sites are located on the same tectonic block which is quite stable. The absolute values of shifts at the sites are infinitely small in practice and negative impact due to the tectonic movements on the construction or operation of the new NPP is not expected. However the tectonic fault, established according to seismic data during the mapping, crosses site No 2 from northwest to southeast. If this fault really exists, it could be difficult to locate foundations of a particular area far enough from this fault at site No 2.

It is necessary to carry out more detailed investigations at site No 2 to further determine its suitability for construction of a new NPP. Site No 1 seems to be more suitable for construction of a new NPP.

7.5.3 Mitigation measures

The most important mitigation measure is the appropriate technical design. The technical design of the new NPP will meet all the safety standards required by IAEA recommendations and Lithuanian legislation and regulations.

The reactor as well as other buildings will be designed and constructed to remain stable in case of earthquakes of predicted intensity. The risk for negative impacts of the tectonic movements will be further diminished by layout design.

All possible changes of the environmental quality will be monitored. The NPP environmental monitoring program will include hydrogeological, geochemical and geodetic measurements of the new NPP site. If some changes of the environmental components exceed the permitted level, for example in an emergency case, the environmental component will be handled using technical measures.

7.6 Biodiversity

7.6.1 Present state of the environment

7.6.1.1 General description of the biodiversity and main values

When accessing impact of the new nuclear power plant (new NPP or NNPP) on biodiversity mainly the territory of the Lithuanian Republic with a radius of 30 km from village Tumelina (western edge of Lake Druksiai) has been analysed in this work. Further in this work the analysed territory will be named as the NNPP region. The region is located in Aukstaitija eminence, which is a part of the Baltic Eminencies physical geographical region. Higher and drier areas of the region are overgrown with forests. The relief is very undulating and rich in lakes.

The NNPP region belongs to the Boreal region of Mixed Forest Biome. In Lithuania it belongs mostly to Eastern Lithuania Laky Channels and Northern Nalsia Highlands units of the Eastern Baltic Province.

From the biodiversity point of view there are a few very important ecological complexes in the NNPP region: Lake Druksiai, the Smalvas and Smalvykstis lakes with adjoining wetlands, Antaliepte wetlands (Antaliepte Hydro-power water reservoir on Sventoji River), Pusnis mire and some others.

The climate of the region is continental. Yearly fluctuations are largest in the country. Transitions between seasons are fastest, winters are longest and coldest, and summers and the vegetation period are shortest.

The following biodiversity values have been discussed and taken into consideration in this EIA Report:

- NATURA 2000 areas and other areas of biodiversity protection
- Qualifying bird species (Annex I species of the Council Directive 79/409/EEC, which population protection the SPAs have been designated for);
- Other bird species covered by Annex I of the Council Directive 79/409/EEC);
- Qualifying plant and animal species (Annex II species of the Council Directive 92/43/EEC, which population protection the SCI have been proposed (designated) for);
- Other plant and animal species covered by Annex II of the Council Directive 92/43/EEC);
- Qualifying natural habitats (Annex I habitats of the Council Directive 92/43/EEC, which protection the SCI have been proposed (designated) for);
- Other natural habitats covered by Annex I of the Council Directive 92/43/EEC;
- Species covered by Annex IV of the Council Directive 92/43/EEC);
- Species included into the Lithuanian Red Data Book;
- Aggregated species (colonial, making aggregation on stop-over sites, etc.);
- Game species.

Thus in this work animal and plant species, habitat types of community interest, whose conservation requires the designation of special areas of conservation according to the Council Directives 79/409/EEC and 92/43/EEC; rare and threatened species included into the Lithuanian Red Data Book (LRDB) and other species of community interest in need of strict protection, were considered as biodiversity values.

7.6.1.2 Summary of NATURA 2000 conservation areas

NATURA 2000 implementation and designation values

The European ecological network "NATURA 2000" is a network of protected areas of the European Community, designated when implementing the Directives of the Council of the European Communities 79/409/EEC and 92/43/EEC. The main objective of the NATURA 2000 network is to ensure the survival of species and habitats that are threatened or rare throughout Europe.

Based on the Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds (further – Birds Directive), for conservation of Annex I species the most suitable areas have been designated as "Special Protection Areas" (SPAs). Annex I of the Directive lists bird species in danger of extinction, species, which are vulnerable to specific changes in their habitats, species, which are rare and other species, which deserve particular attention due to the specifics of their habitat.

With respect to the regularly occurring migratory bird species, which are not listed in Annex I, similar measures shall be taken, on the grounds of Article 4 (clause 2), whereby special attention shall be paid to the protection of wetlands. Regarding the SPAs, the member states are obliged to implement appropriate measures in order to prevent pollution and deterioration of the areas and to avoid disturbance of birds.

When implementing the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (further – Habitat Directive) Special Areas for Conservation (SACs) are to be established. Prior to establishment of SACs, based on scientific research, potential SACs (or Sites of Community Importance, SCIs) are to be selected and the list is to be presented to the European Commission (EC). After the potential SAC is approved by EC, the member state has to commence its establishment.

Potential SAC (SCI) territories are areas meeting the established criteria for selection of Special Areas for Conservation and indicated in the list, approved by the Order of the Minister of the Lithuanian Ministry of Environment No D1-302, dated June 15, 2005 (*State Journal, 2005, No. 105-3908*). According to the Directive the member states shall introduce measures in order to ensure that the quality of the natural habitats and the habitats of species in the NATURA 2000 network does not deteriorate and that no factors arise which might disturb the species for which the areas have been designated.

According to the requirements stated in Article 24 of Paragraph 2 of the Lithuanian Law on Protected Areas (*State Journal, 1993, No. 63-1188; 2001, No. 108-3902*), first a national protected area is to be established with the purpose to grant them the status of Special Protection Area or/and Special Areas for Conservation. The European Commission has already approved the list of potential SAC territories in Lithuania.

The basis for legal establishment of all mentioned SCIs is Order of the Minister of the Lithuanian Ministry of Environment No. D1-302, dated June 15, 2005 (*State Journal, 2005, No. 105-3908*).

NATURA 2000 areas within the NNPP region

There are 8 NATURA 2000 network Sites of Community Importance (SCIs), valuable for habitat, plant and animal species protection in the NNPP region (Figure 7.6-1 and Table 7.6-1).

Based on literature data most of the biodiversity values in the NNPP region are concentrated to the NATURA 2000 network sites. Thus special attention has been paid to the NATURA 2000 network areas in this assessment.

Most of the territories covered by SCIs are located in the western part of the region being situated on axis East–West. The NNPP region covers the areas of Grazute regional park and Dietkauscizna meadows SCIs only partly.

Table 7.6-1. NATURA 2000 network areas of importance for habitat and species protection (SCI) in the NNPP region and key information on their boundaries.

Site name: official / English	Area of the site, ha	Comments on site boundaries	Site code in NATURA 2000 network data base
Druksiu ezeras / Lake Druksiai	3611	The SCI has been established according to the special map. The border is nearly the same as for Druksiu ezeras SPA.	LTZAR0029
Smalveles upe ir slapzemes / River Smalvele and adjacent limy fens	547	The border is the same as for Smalva hydrographical reserve and nearly the same as for Smalvos slapzemiu kompleksas SPA.	LTZAR0026
Smalvos ir Smalvykscio ezerai ir pelkes / Lakes and wetlands Smalva and Smalvykstis	2225	The border is the same as for Smalvas landscape reserve.	LTZAR0025
Grazutes regioninis parkas / Grazute regional park	26125	The border is nearly the same as for Grazute regional park (with the exception of the zones for recreational, agriculture and other (residential) purposes). It comprise Siaures rytine Grazutes regioninio parko dalis SPA.	LTZAR0024
Pusnies pelke / Pusnis wetland	779	The border is the same as for Pusnis thelmological reserve.	LTIGN0001
Ruzo ezeras / Ruzas lake	205	Border has been established according to the special map.	LTIGN0026
Gerveles pelke / Gervele wetland	373	Border has been established according to the special map.	LTIGN0017
Dietkausciznos pievos / Dietkauscizna meadows	147	The SCI is a part of Dysna hydrographical reserve. Border has been established according to the special map.	LTIGN0004

* The official (Lithuanian) name, code of the protected area, area of the site are indicated as they are used in the NATURA 2000 Standard Data Form (”NATURA 2000” Network Database) for Special Protection areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC).

Sakeliskes meadows SCI is bordering the NNPP region. Aukstaitija National park is located to the south-east from the NNPP (in Figure 7.6-2 indicated in red), and is a few kilometres outside the border. These two protected areas, which are outside the NNPP region, have not been analysed in detail in this work.

Out of 8 NATURA 2000 network Sites of Community Importance (SCIs), 3 sites are of international importance for bird conservation (SPAs), 5 sites are fully or partly protected by national laws (are protected territories of national importance), two sites are water body protection zones (site protection reglement is based on surrounding terrestrial areas and targeted on achievement or maintenance of good water quality) and one site is still non-protected territory.

Presented qualifying (most important) values in SCIs (Table 7.6-3) show that SCIs of the NNPP region are of international importance for protection of biodiversity mostly related with wetland and woodland habitats: European otter (*Lutra lutra*), several species of plants, invertebrates and many types of habitats.

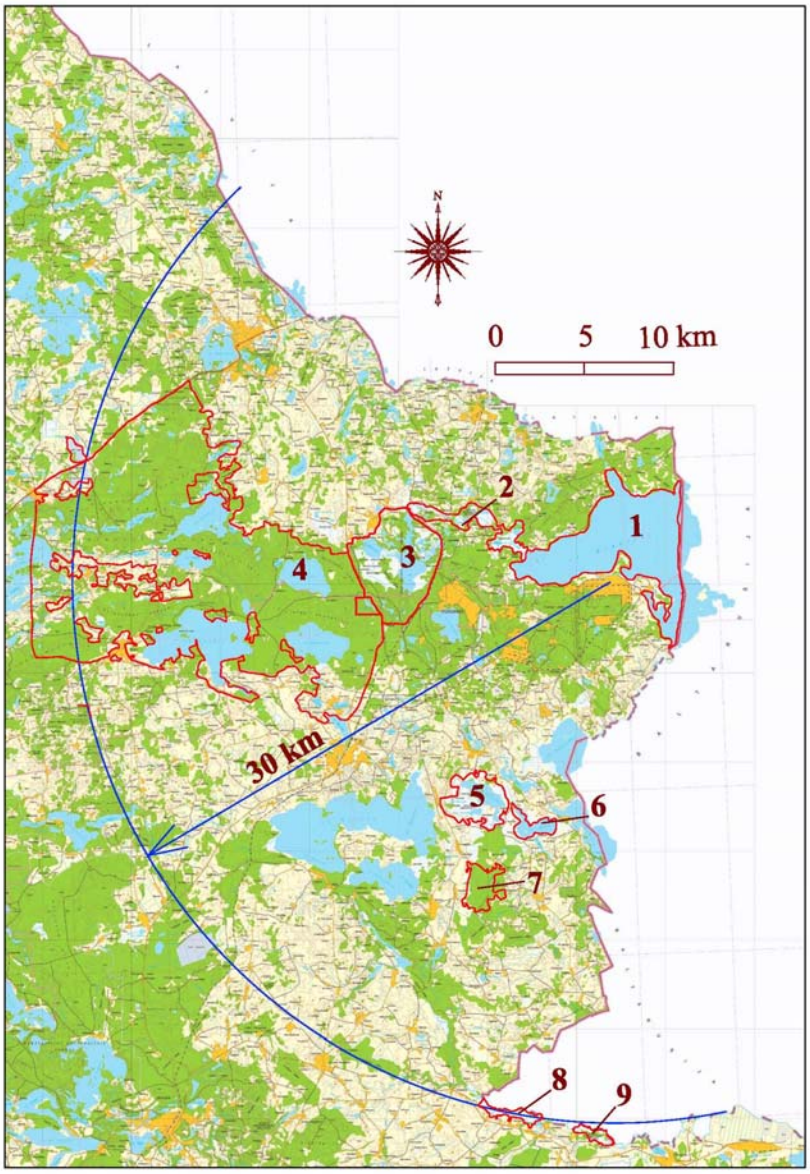


Figure 7.6-1. The NATURA 2000 network Sites of Community Importance (SCIs), valuable for habitat and animal species protection in the NNPP region. Perimeter of the region is indicated in blue). Sites of Community Importance: 1 – Lake Druksiai; 2 – River Smalvele and adjacent limy fens; 3 – Lakes and wetlands Smalva and Smalvykstis; 4 – Grazute regional park; 5 – Pusnis wetland; 6 – Ruzas Lake; 7 – Gervele wetland; 8 –- Dietkauscizna meadows; 9 – Sakeliskes meadows.

There are 4 NATURA 2000 network Special Protection Areas (SPAs), valuable for bird protection in the NNPP region (Figure 7.6-2 and Table 7.6-2).

A legal basis for establishment of the mentioned SPAS is Resolution of the Government of the LR No. 399, dated April 8, 2004 (amended resolution of the Lithuanian Government, dated September 25, 2006 No. 819) (*State Journal, 2006, No. 92-3635*).

Most of the territories covered by SPAs are located in the western part of the region being situated on axis East–West. The NNPP region covers part of the North-eastern part of Grazutes Regional Park SPA territory only. Aukstaitija National Park is located to the South-east from the NNPP, and is a few kilometres outside the border.

Table 7.6-2. Natura 2000 network areas of importance for protection of birds (SPAs) in the NNPP region and key information on their boundaries*.

Site name: official / English	Area of the site, ha.	Comments on site boundaries	Site code in NATURA 2000 network data base
Druksiu ezeras / Lake Druksiai	3612.33	The SPA covers part of national protected area. The border of the SPA has been defined according to the plan.	LTZARB003
Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas / The complex of Dysnai and Dysnykstis lakes surrounding wetland areas	4016.56	The SPA covers part of protected area. The border of the SPA has been defined according to the plan.	LTIGNB004
Smalvos slapzemiu kompleksas / The complex of Smalva wetlands	538	The border of the SPA is the same as for Smalva hydrographical reserve and nearly the some as for Smalveles upe ir slapzemes SCI	LTZARB002
Siaures rytine Grazutes regioninio parko dalis / North eastern part of Grazute regional park	5699.85	Siaures rytine Grazutes regioninio parko dalis SPA comprises a part of the Grazute Regional Park and part of the Grazutes regioninis parkas SCI territory. The border has been defined according to the plan.	LTZARB004

*The official (Lithuanian) name, code of the protected area, area of the site are indicated as they are used in the NATURA 2000 Standard Data Form (NATURA 2000 Network Database) for Special Protection Areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC).

Out of 4 NATURA 2000 network Special Protection Areas (SPAs), 3 sites are of international importance for habitat and species conservation (being as potential Sites of Community Importance (SCI), and 2 sites are fully protected by national laws (are protected territories of national importance). Two territories are water body protection zones (site protection reglement is based on surrounding terrestrial areas and targeted on achievement or maintenance of good water quality).

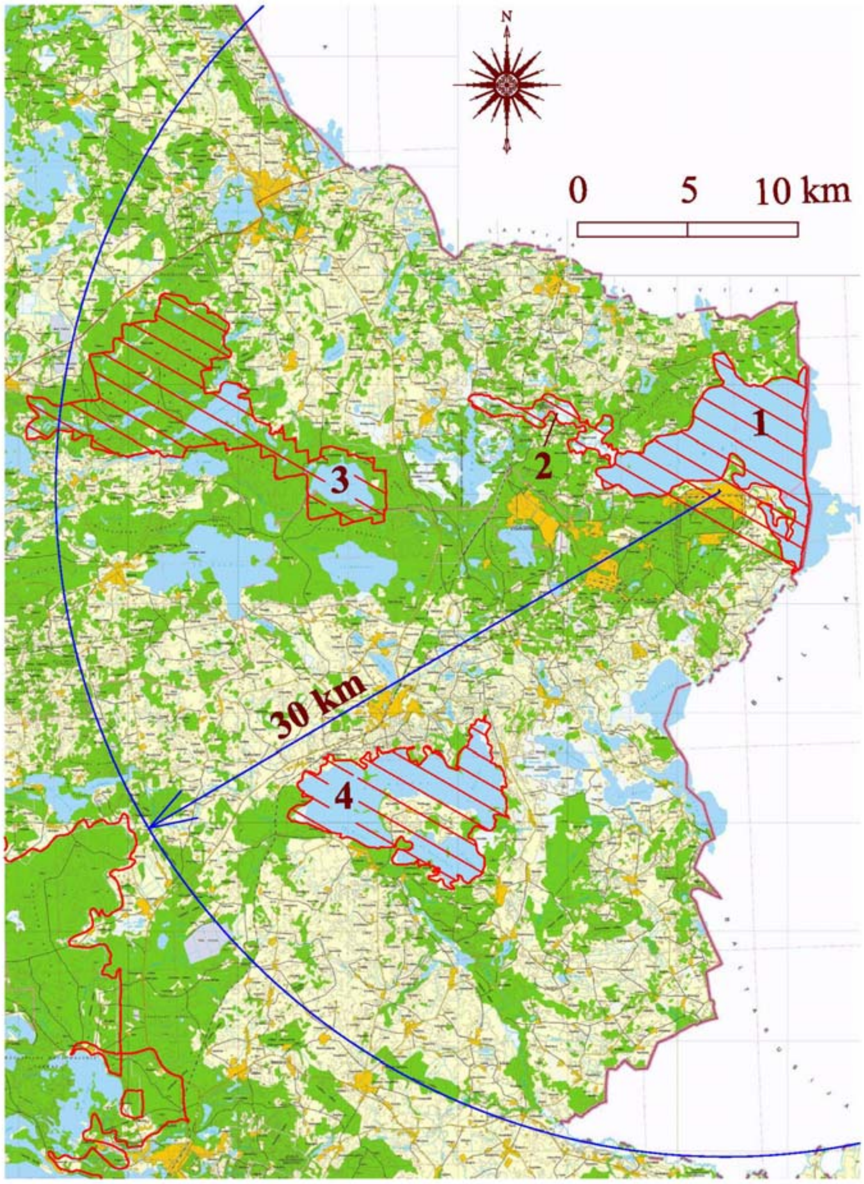


Figure 7.6-2. The NATURA 2000 network Special Protection Areas (SPAs), valuable for bird protection in the NNPP region. Perimeter of the region is indicated in blue. Special Protection Areas: 1 – Lake Druksiai; 2 – The complex of Smalva wetlands; 3 – North eastern part of Grazute Regional Park; 4 – The complex of wetland areas, surrounding Dysnai and Dysnykstis lakes.

Presented qualifying (most important) values in SPAs (Table 7.6-4) show that the SPAs of the NNPP region are of international importance for protection of populations of birds, representing various ecological groups, whose main breeding and feeding habitats are water bodies (e.g., Great Bittern (*Botaurus stellaris*) and Black-throated Diver (*Gavia arctica*)), forests (Pygmy owl (*Glaucidium passerinum*)), open agricultural landscape (Corncrake (*Crex crex*)) and a mixture of water body-wetland and meadow areas (Black Tern (*Chlidonias niger*)).

Table 7.6-3. Most important values in NATURA 2000 network areas designated for protection of habitats (SCI) in the NNPP region.

Site name: official / English[1]	Site code in NATURA 2000 data base	Most important values [2]	Amount of values[1] (local population; area)
Druksiu ezeras / Lake Druksiai	LTZAR0029	European otter (*Lutra lutra)*	6–10 ind.
Smalveles upe ir slapzemes / River Smalvele and adjacent limy fens	LTZAR0026	European otter (*Lutra lutra)*	1–5 ind.
Smalvos ir Smalvykscio ezerai ir pelkes / Lakes and wetlands Smalva and Smalvykstis	LTZAR0025	3140, Hard oligo-mesothrophic waters with benthic vegetation of *Chara* formations	354.59 ha
		9010* Western taiga	265.94 ha
		7140 Transition mires and quaking bogs	265.94 ha
		91D0 Bog woodland	88.7 ha
		9080 Fennoscandian deciduous swamp woods	88.7 ha
		7230 Alkaline fens	88.7 ha
		7210 Calcareous fens with *Cladium mariscus* and *Carex davaliana*	88.7 ha
		3160 Dystrophic lakes	53.2 ha
		Fen orchid *(Liparis loeselii), Drepanocladus vernicosus*	251–500 ind.
Grazutes regioninis parkas / Grazute Regional Park	LTZAR0024	3130 Oligothrophic waters in medio-European and perialpine area with amphibious vegetation: *Littorella* or *Isoetes* or annual vegetation on exposed banks (Nanocyperetalia)	105 ha
		7140 Transition mires and quaking bogs	69.6 ha
		7120 Degraded raised bogs, (still capable of natural regeneration)	27.2 ha
		3140 Hard oligo-mesothrophic waters with benthic vegetation of *Chara* formations	18.4 ha
		91D0 Bog woodland	10.9 ha
		6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco brometalia; important orchide sites*)	1.0 ha
		6120* Xeric sand calcareous grasslands (*Koelerion glaucae*)	6.4 ha
		Large copper (*Lycaena dispar)*	
		Eastern pasque-flower *(Pulsatilla patens)*	251–500 ind.
Gerveles pelke / Gervele wetland	LTIGN0017	7120 Degraded raised bogs, (still capable of natural regeneration)	50 ha
		91D0 Bog woodland	95 ha
Pusnies pelke / Pusnis wetland	LTIGN0001	6230* Species-rich *Nardus* grasslands, on silicious substrates in submountain areas in Continental Europe	7.9 ha
		6430 Hydrophilous tall herb fringe communities of plains and of the mountain to alpine levels	39.7 ha
		7140 Transition mires and quaking bogs	237.9 ha
Ruzo ezeras / Ruzas lake	LTIGN0026	*Dytiscus latissimus*	
		Vesicular aldrovanda *(Aldrovanda vesiculosa)*	>10 000 ind.
Dietkausciznos pievos / Dietkauscizna meadows	LTIGN0004	6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	4 ha
		6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	4 ha
		6450 Northern boreal alluvial meadows	14 ha
		6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	1 ha
		7230 Alkaline fens	21 ha
		9080* Fennoscandian deciduous swamp woods	4 ha
		Fen orchid (Liparis loeselii)	51–100 ind.

1 – The official (Lithuanian) name and amount of values are indicated as they are used in the NATURA 2000 Standard Data Form (”NATURA 2000” Network Data Base) for Special Protection areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC).

2 – Most important values are indicated according to the legal acts of designation of the SCIs. In some cases list of most important values in the NATURA 2000 Standard Data Form (”NATURA 2000” Network Data Base) for Special Protection areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC), in comparison with the legal act of their designation is longer (a new data/information available is included).

Table 7.6-4. Most important values in NATURA 2000 network areas designated for protection of birds (SPA) in the NNPP region*.

Site name: official / English	Site code in NATURA 2000 network data base	Most important values[1]	Amount of values (local population)
Druksiu ezeras / Lake Druksiai	LTZARB003	Great Bittern (*Botaurus stellaris*)	10 males
Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas / The complex of Dysnai and Dysnykstis lakes surrounding wetland areas	LTIGNB004	Corncrake (*Crex crex*)	30 males
Smalvos slapzemiu kompleksas / The complex of Smalva wetlands	LTZARB002	Black Tern (*Chlidonias niger*)	40 breeding pairs
Siaures rytine Grazutes regioninio parko dalis / North eastern part of Grazutes Regional Park	LTZARB004	Black-throated (Diver *Gavia arctica*), Pygmy owl (*Glaucidium passerinum*)	3 breeding pairs 4-5 breeding pairs

* – The official (Lithuanian) name and amount of values are indicated as they are used in the NATURA 2000 Standard Data Form (”NATURA 2000” Network Data Base) for Special Protection areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC).

[1] – Most important values are indicated according to the legal acts of designation of the SCIs. In some cases list of most important values in the NATURA 2000 Standard Data Form (”NATURA 2000” Network Data Base) for Special Protection areas (SPA) and for sites eligible for identification as Sites of Community Importance (SCI) and for Special Areas of Conservation (SAC) in comparison with the legal act of their designation is longer (a new data/information available is included).

Black-throated Diver (*Gavia arctica)* and Pygmy owl (*Glaucidium passerinum*) are very rare in Lithuania, therefore protection of their populations is of great importance on national scale as well. According to the data available (*Kurlavicius & Raudonikis 2001*) national minimum population of Black-throated Diver (*Gavia arctica)* consists of 3 pairs only. The NNPP region (particularly the North eastern part of Grazutes Regional Park SPA) is most important area from point of view the species conservation in Lithuania. Breeding population of the Pygmy Owl (*Glaucidium passerinum*) is also rather small (minimum 50 pairs; *Kurlavicius & Raudonikis, 2001*) in the country. Thus thebreeding local population of the species can in some years can make up to 10 % of the national population. Regional populations of other mentioned species do not formpresents so large a portion offrom the whole country’s population.

7.6.1.3 Individual descriptions of NATURA 2000 areas in the NNPP area

In the following the individual NATURA 2000 sites are described more in detail. First the SCI-areas are described and thereafter the SPA-areas. The focus is on Lake Druksiai NATURA 2000-areas (SCI and SPA) because most of the essential impacts are presumed to be limited to Lake Druksiai and its immediate vicinity.

SCI site: Lake Druksiai (LTZAR0029)

The lake is the biggest one in Lithuania. Area of the site is about 3611 ha. Part of the lake belongs to Belarus. The total area of the lake is 4480 ha. A centre of the territory is defined by E 26 34 57 longitude and 55 37 19 latitude (W/E Greenwich). Water bodies are predominating in the site (Table 7.6-5). The maximum depth of the lake is 31 m.

As the main possible impact is presumed to focus on Lake Druksiai area, this NATURA-site is described here more in detail compared with other NATURA –sites further away from the new nuclear power plant location.

Table 7.6-5. General habitat structure of the Druksiu ezeras SCI according to the NATURA 2000 DB* (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	58
Bogs, Marshes, Water fringed vegetation, Fens	3
Extensive cereal	4
Other arable land	6
Broad-leaved deciduous woodland	6
Mixed woodland	16
Other land (Including Towns, Villages, Roads, Waste places, Mines, Industrial sites)	7
Total habitat cover	100

* In this and other similar tables information is from the NATURA 2000 DB Chapter 4 (Site description). It is helpful to better understand habitat structure of the protected site.

Connections to other NATURA***–sites:*** The Druksiu ezeras SCI borders on other NATURA 2000 sites such us the Complex of Smalva wetlands SPA (LTZARB002) and the River Smalvele and adjacent limy fens SCI (LTZAR0026). At the same time the Druksiu ezeras SCI has nearly the same border as the Druksiu ezeras SPA (LTZARB003).

NATURA 2000 – designation values: The Druksiu ezeras SCI is designated with the main goal to protect the local population of qualifying species European otter (*Lutra lutra*), which is listed in Annex II of the Habitat Directive. Its population consists of 6–10 individuals. According to the recent data (*Svazas et al., 2008)* 8 sub-areas where European otter (*Lutra lutra*) has been registered most frequently (Figure 7.6-3). Based on common behaviour of the European otter (*Lutra lutra*) it can be concluded that when moving between habitats (sub-areas) and during dispersion the animal uses mostly the shore of a big water body and watercourses. The population dynamics of the European otter (*Lutra lutra*) in Lake Druksiai is not known in more detail.

According to the NATURA 2000 DB the fish species Spined Loach (*Cobitis taenia*) is the other important value of the site. It is considered as a common species here.

Other species / Mammals: Three other mammal species inhabiting Druksiu ezeras SCI are also listed in Annex II of the Habitat Directive. Wolf (*Canis lupus*) is an occasional visitor of the territory. In 2006-2008 single individuals of lynx (*Lynx lynx*) were counted in Zarasai district and one individual was registered in Ignalina district. It can be concluded that the NNPP is made a conclusion that INPP region is not very important for this animal (*Svazas et al., 2008*). Similarly to the whole Lithuania, in the NNPP region beaver (*Castor fiber*) is a very common mammal. The population of the region consists of 1100–2700 individuals (2006–2008).

The surroundings of the lake are the habitat of the rare mammal ermine (*Mustela erminea*), which is included in the LRDB. Three other mammal species, also included into the LRDB, have been registered in the territory. European otter (*Lutra lutra*), included into the Annex II of the Directive, is a focal, qualifying species. Mountain hare (*Lepus timidus*) is rare but is being observed regularly. Birch mouse (*Sicista betulina*) is a rare species in the meadows of surrounding forests (*Svazas et al. 1999*). A breeding colony of Noctule Bat (*Nyctalus noctula*) was found in Tilze village. The bat Nathusius' pipistrelle (*Pipistrellus nathusii*) has been observed in the region several times. Both these species are listed in the LRDB.

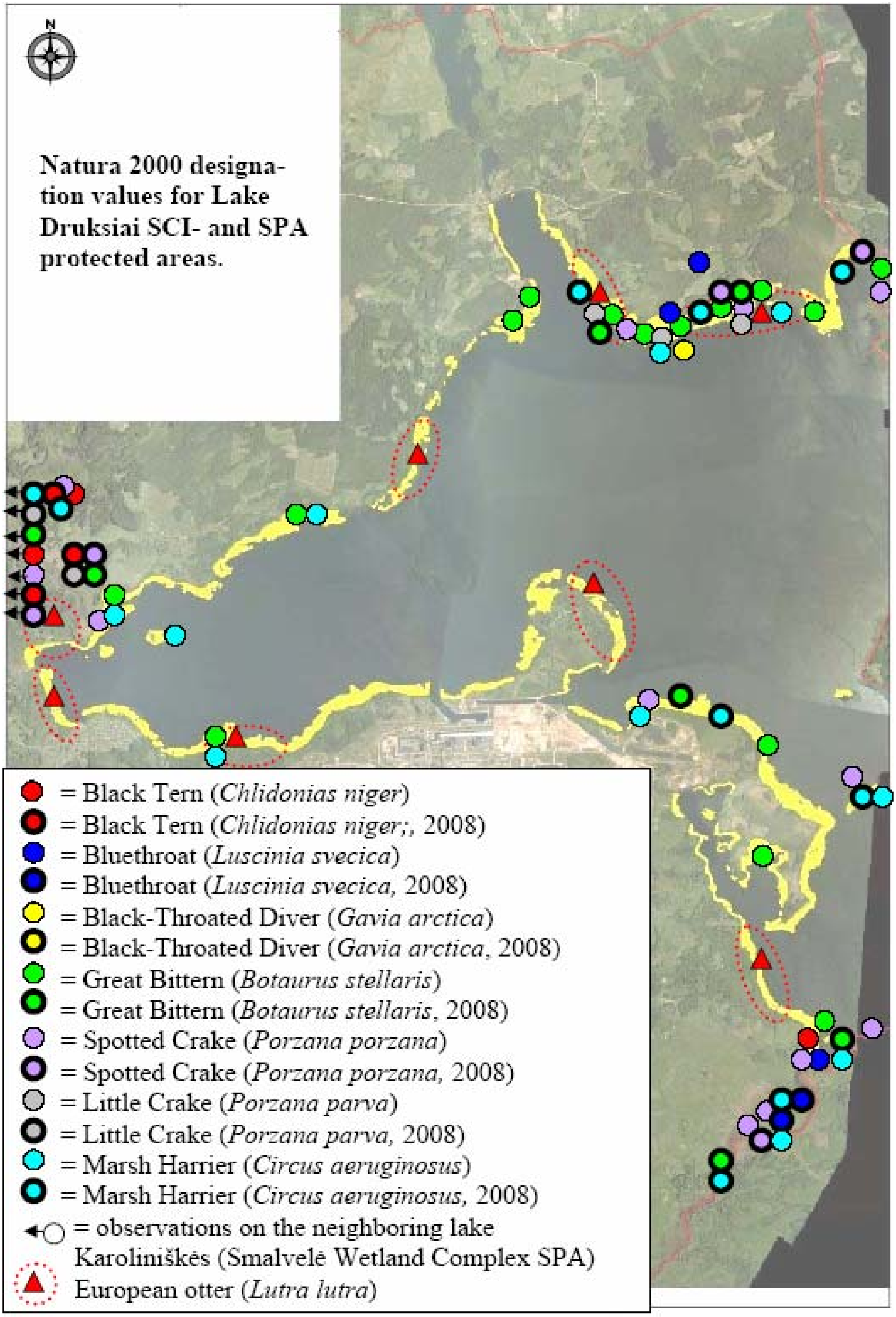


Figure 7.6-3. NATURA 2000 designation values for the Lake Druksiai SCI and Lake Druksiai SPA protected areas, Lithuania. The coloured dots and figures show approximate location of the Natura 2000 designation values (calling males (breeding sites), recorded individuals, and most frequently used habitats). The Spined Loach (Cobitis taenia) is not indicated in the figure. Yellow colour shows associations of Phragmitetea and Potamogenetea (Nymphaea) plants (*Institute of Ecology of the Vilnius University, 2006-2007 and data of L. Raudonikis, 2008*).

Other species / Amphibians and reptiles: A total of 10 species of amphibians and 5 species of reptiles have been registered in the NNPP region (*Rana temporaria*, *R. arvalis*, *R. lessonae*, *R. esculenta*, *Bufo bufo*, *B. calamita*, *Pelobates fuscus*, *Bombina bombina*, *Triturus vulgaris*, *T. cristatus; Lacerta vivipara*, *L. agilis*, *Anguis fragilis*, *Vipera berus* and *Natrix natrix; Svazas et al., 2008*).

In 2006 two rare amphibian species (*Triturus cristatus* and *Bombina bombina*) listed in Annex II of the Habitat Directive were found within a radius of 3 km from the INPP (*Svazas et al., 2008*). These two species as well as *Bufo calamita* are also included into the LRDB. 5 species (*Triturus cristatus, Bombina bombina, Rana arvalis, Rana lessonae, Pelobates fuscus* and *Lacerta agilis*) are listed in Annex IV of the EU Habitat Directive. *Bombina bombina* inhabits water bodies heavily disturbed by humans near the INPP. *Triturus cristatus* has been found in Tumelina forest in a very typical habitat very close to the INPP (*Svazas et al., 2008*).

Other species / Insects: More than 1500 species of insects have been found at Lake Druksiai and in its surroundings in total. During entomological studies some rare terrestrial insect species included in the LRDB have been registered here. *Leucorrhinia pectoralis* and *Lycaena dispar* are listed in Annex II of the EU Habitat Directive. *Lycaena dispar* and *Leucorrhinia albifron* (Odonata) are listed in Annex IV of the EU Habitat Directive. All three species are included in the LRDB. Odonata species are ecologically related to water bodies; in the surroundings of the NNPP mostly with Lake Druksiai. Single individuals have been registered in the south-western part of the lake near Yliske. Single individuals of *Lycaena dispar* (Lepidoptera, Lycaenidae) have been found in the entire region in meadows close to water bodies (*Svazas et al., 2008*).

Carabus coriaceus (Coleoptera, Carabidae) is also included in the LRDB. A small population has been discovered in the Tilze forest. Single individuals of *Papilio machaon* (Lepidoptera, Papilionidae) are registered annually in the surroundings of the villages Tilze and Visaginas. Occasionally *Aricia eumedon* (Lepidoptera, Lycaenidae) is found in wet meadows in the entire region. *Coenonympha tullia* (Lepidoptera, Nymphalidae) inhabits a meadow near Visaginas settlement. All these mentioned species have been listed in the LRDB (*Svazas et al., 2008*).

Rhyssella obliterata and *Phytodietus geniculatus* (Hymenoptera, Ichneumonidae) have been found in a meadow of the Smalvele river valley near Lake Druksiai. This is the only site in the country where these species have been recorded (*Svazas et al., 2008*).

Some other rare insect species have been recorded in the surroundings of Lake Druksiai as well. *Carabus convexus* (Coleoptera, Carabidae) is a rare species in Lithuania. It usually inhabits forest edges near water bodies. It has been found in woodland near the Smalvele River. *Sospita vigintiguttata* (Coleoptera, Coccinellidae) has been found in woodland near the Smalvele River. *Stenoptinea cyaneimarmorella* (Lepidoptera, Tineidae) and *Parornix traugotti* (Lepidoptera, Gracilariidae) have been found in Visaginas. This is the only known site in the country where these species have been recorded. *Caryocolum tischeriella* (Lepidoptera, Gelechiidae) has been found in Tilze village. This is the only site in Lithuania where this species has been recorded. It is now considered extinct. A large local population of *Buckleria paludum* (Lepidoptera, Pterophoridae) was discovered in Mistautai village near Bedugnis lake. *Melitaea phoebe* (Lepidoptera, Nymphalidae) has been found in a meadow of the Smalvele River valley near Lake Druksiai and very close to the main building of the INPP. *Temelucha arenosa* (Hymenoptera, Ichneumonidae) has also been found in a meadow of the Smalvele river valley near Lake Druksiai (*Svazas et al., 2008*).

Several rare species have been registered very close to the INPP. For example, *Aricia eumedon* has been found on the shore of Lake Druksiai about 2 km to the west from the INPP. *Lycaena dispar* has been observed in a meadow about 2.5 km to the south from the INPP.

Other species / Crustaceans**:** It has been pointed out (*Svazas et al. 1999; Raudonikis & Kurlavicius, 2000*), that Druksiu ezeras SCI inhabits several relict animal species. Some rare, relict crustaceans, such as *Mysis oculata relicta* and *Pallasiola quadrispinosa*, have been recorded here. They are included in the LRDB.

Other species / Flora: Some rare plant species, included in the LRDB, have been found in the area (*Baleviciene, Sinkeviciene et al., 1997*), such as *Scolochloa festucacea* (species included in the LRDB)*, Zanichelia palustris, Alisma gramineum* and *Nitella opaca* (rare species; to be protected). These species except *Alisma gramineum* are dominating in the communities of macrophytes of the lake. Some rare terrestrial plant species included in the LRDB have been registered in the surroundings of Lake Druksiai (*Svazas et al., 2008*): Fen orchid (*Liparis loeselii*), *Dactylohiza baltica*, *Dactylohiza incarnata*, *Eriophorum gracile*, *Gentiana cruciata*, *Juncus stygius*, *Cladium mariscus* and *Carex heleonastes. Hamatocaulis vernicosus* is not only listed in the LRDB but also in Annex II of the EU Habitat Directive. Most of the rare plants have been found on the shores of the lake and in shore wetlands as well as meadows (Figure 7.6-4).

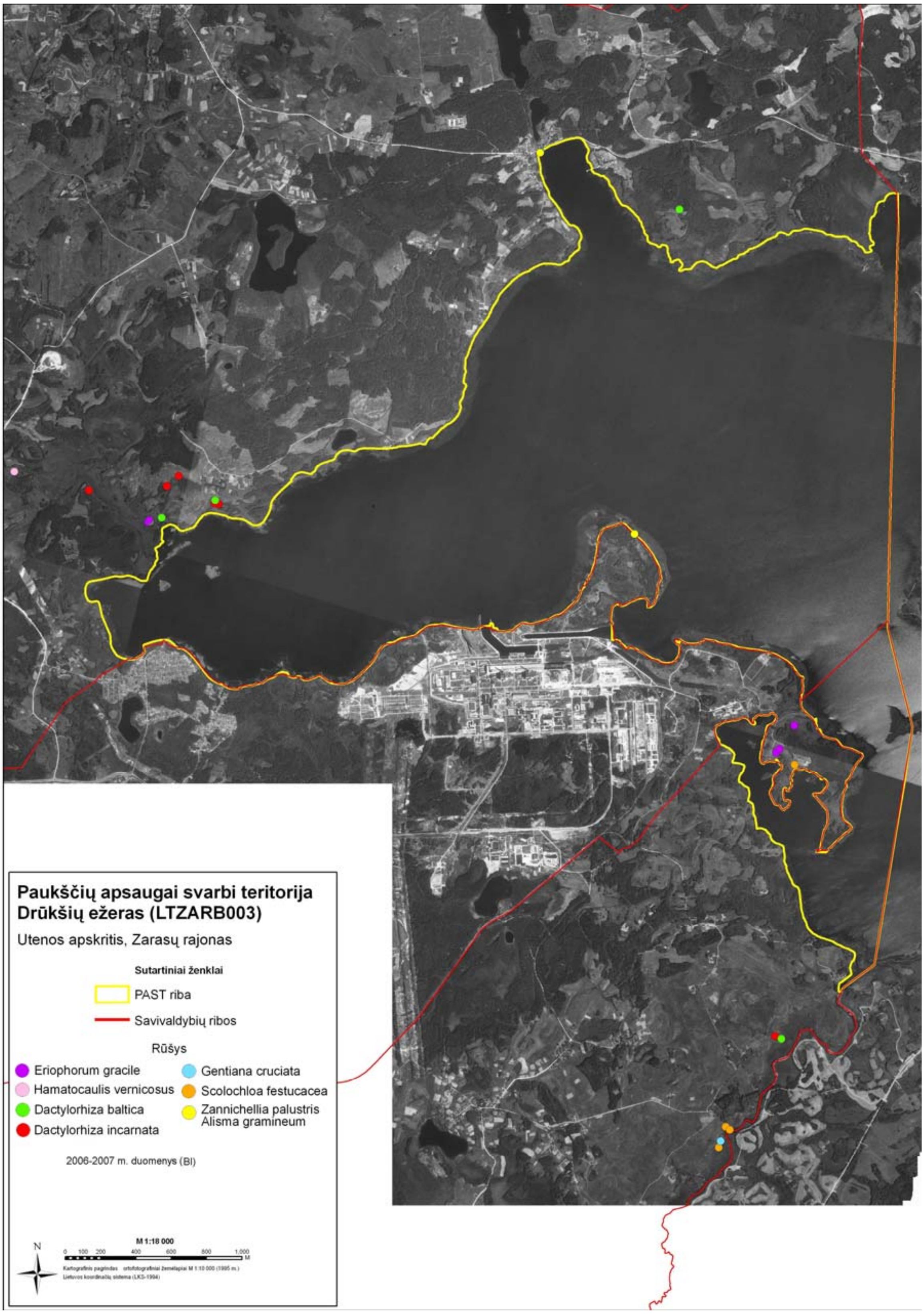


Figure 7.6-4. Distribution of some rare plants in the Druksiu ezeras SCI (*Svazas et al., 2008*). Dots show location of sites where listed plants have been mapped.

During long term detailed botanical studies some changes in plant life have been discovered. E.g., before the INPP started operating (studies of 1979–1983) the flora of the lake consisted of 95 water plant species. It was pointed out that *Nitella flexilis*, *Chara filiformis*, *Scolochloa festucaceae* were rare species (*Svazas et al., 2008*).

Other species / Fungi, lichens: Some rare macromycet species, included in the LRDB, have been found in the surroundings of Lake Druksiai (*Svazas et al., 2008*): *Russula aurata*, *Melanoleuca turrita* and *Tricholoma inocyboides*.

The NNPP region is rich in biodiversity which is known much better in comparison with other places of the country. During longterm complex studies (1979–1983) in the surroundings of Lake Druksiai (a zone of 0.5 km around the lake) in total 213 species of agaricoidic macromycets (*Agaricales*), 120 species of *Aphyllophorales,* 33 species of dyscomycets, 29 species of lichens and related fungus species, and 31 species of water fungus species were registered (*Svazas et al., 2008*).

Habitats: In the surroundings of Lake Druksiai some valuable habitats listed in Annex I of the EU Habitat Directive have been mapped: meadow habitats of 4 types (*6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco brometalia; important orchide sites*), *6410 Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)*, 6450* Northern boreal alluvial meadows*, 6510* Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*); forests of type *9080** Fennoscandian deciduous swamp woods; two types of bog (*7140* Transition mires and quaking bogs and *7230* Alkaline fens) and two types of water bodies habitat (*3140* Hard oligo-mesothrophic waters with benthic vegetation of *Chara* formations and *3150* Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation). Meadow habitats are concentrated to the valley of the Duksta and the Smalvele rivers. Boggy habitats are concentrated to the valley of the Smalvele River and near lakes Druksiai and Karoliniskes (Figure 7.6-5 and Figure 7.6-6). Results of mapping of valuable habitats listed in Annex I of the EU Habitat Directive in the surroundings of the Druksiu ezeras SCI (Svazas et al., 2008) were available for this assessment.

Recent changes: Botanical surveys of 1993–1997 (when two units of the INPP were operating), revealed some changes in plant communities of the lake. It was concluded that *Cladophora* species have prospered very much under influence of thermal pollution of the lake by the INPP. These species were covering all other submersed plants. At a depth of 6–7 m they were nearly fully growing over submersed plants. A belt of helophytes of 10–500 m width has developed on the lake shore. In most of the lake the belt is still fragmented (especially in northern, eastern, southern and north-western parts where waves are most heavy and active).

During special botanical investigations of the lake in 1996–1997 (*Baleviciene, Sinkeviciene et al., 1997*) 69 water plant species were registered. A total of 27 types of plant associations mostly belonging to predominating community classes *Potamogetonetea pectinati, Phragmitetea australis* and *Charetea fragilis* were found.

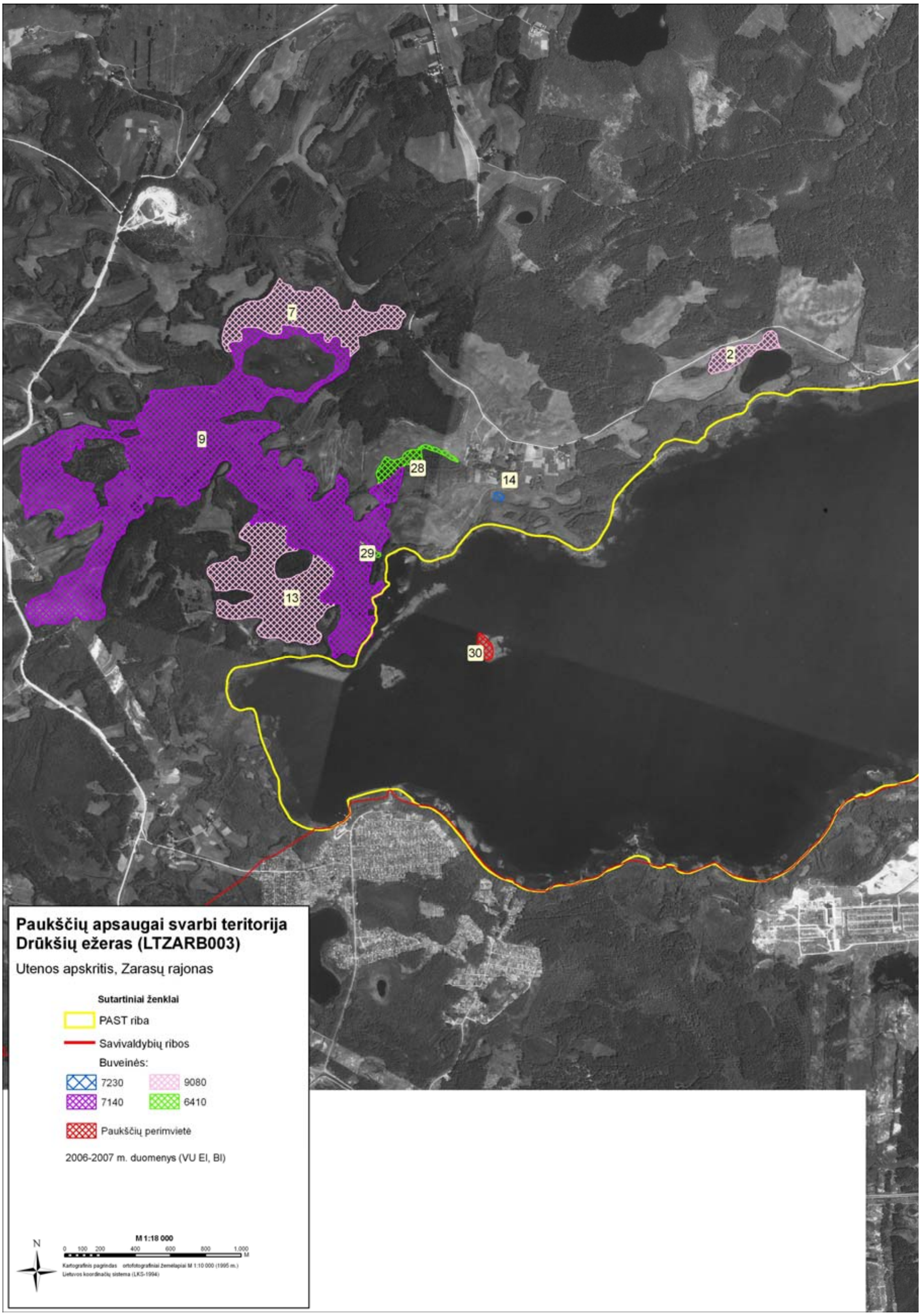


Figure 7.6-5. Some valuable habitats listed in the Annex I of the EU Habitat Directive (squared; codes are indicated in the legend). Areas squared in red are important breeding (aggregation) sites of birds in the Druksiu ezeras SCI (*Svazas et al., 2008*).

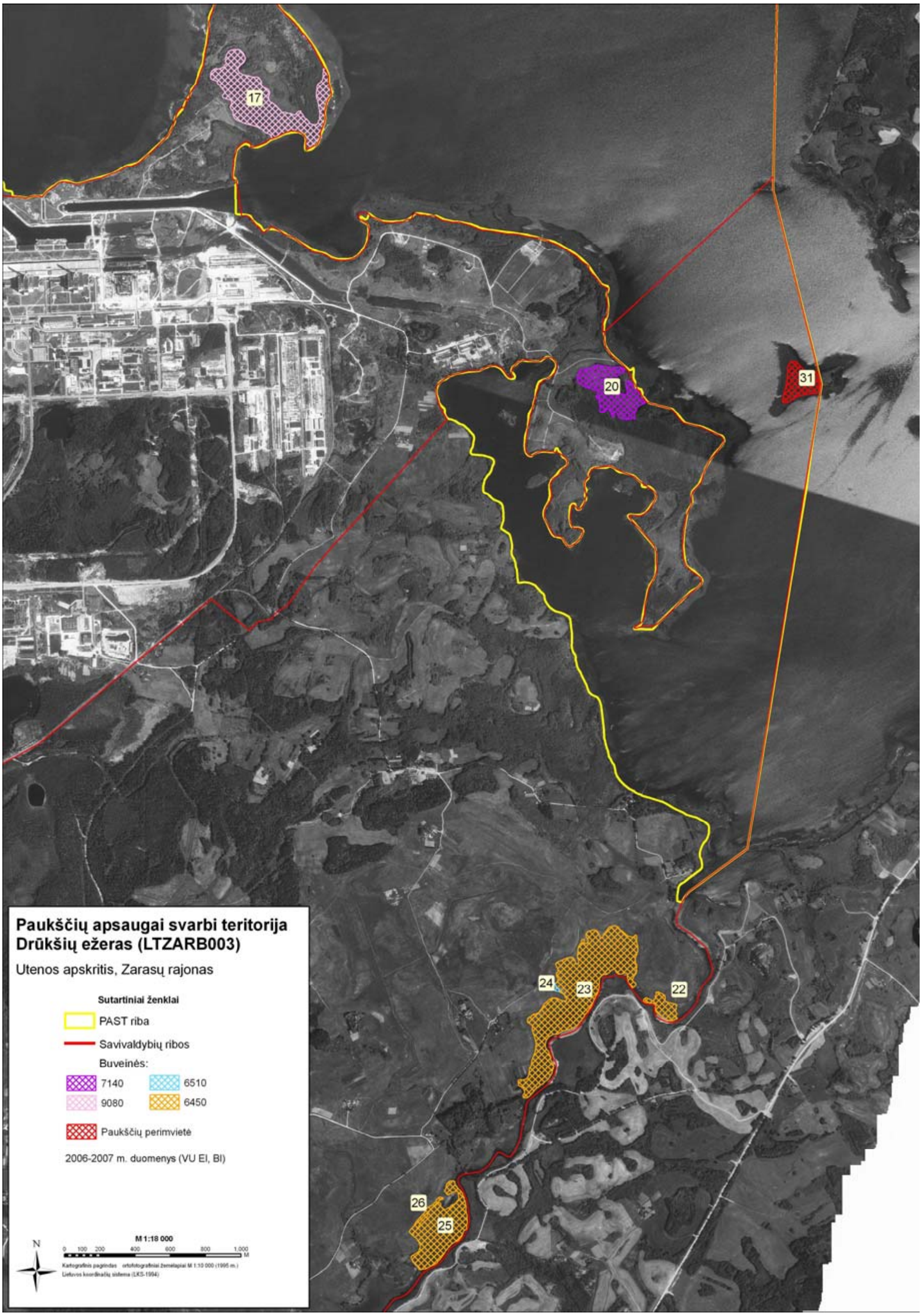


Figure 7.6-6. Some valuable habitats listed in Annex I of the EU Habitat Directive (squared; codes are indicated in the legend); Areas squared in red are important breeding (aggregation) sites of birds in the Druksiu ezeras SCI (*Svazas et al., 2008*).

The NNPP region is important for some game animals. The population of elk (*Alces alces*) of the Ignalina and Zarasai districts covers about one sixth of the country's population (and about 4.4 % of the area of the country). In comparison with all the country populations of other game mammal species, such as red deer (*Cervus elaphus*), rot deer (*Capreolus capreolus*), wild boar (*Suc crofa*), the populations of the NNPP region are not big.

SCI site: River Smalvele and adjacent limy fens (LTZAR0026)

The border is the same as for Smalvas hydrographical reserve and nearly the same as for Complex of Smalva wetlands SPA (LTZARB002). The area of the site is about 547 ha. A centre of the territory is defined by E 26 27 20 longitude and 55 38 09 latitude (W/E Greenwich). Wetlands and forests are predominating in the site (Table 7.6-6). The Smalveles upe ir slapzemes SCI is directly related to other NATURA 2000 sites, such as: the Druksiu ezeras SCI (LTZAR0029), Smalvos ir Smalvykscio ezerai ir pelkes SCI (LTZAR0025), Druksiu ezeras and Smalvos slapzemiu kompleksas SPAs (LTZARB003 and LTZARB002, respectively).

Table 7.6-6. Habitat structure of the Smalveles upe ir slapzemes SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Bogs, Marshes, Water fringed vegetation, Fens	43
Extensive cereal	5
Improved grassland	2
Other arable land	1
Broad-leaved deciduous woodland	12
Mixed woodland	37
Total habitat cover	100

The Smalveles upe ir slapzemes SCI has been designated with the main goal to protect the local population of qualifying species European otter (*Lutra lutra*). Based on the NATURA 2000 DB it can be pointed out that the European fire-bellied toad (*Bombina bombina*), which is listed in Annex II of the Directive, is the other important value of the site. It is considered as a common species here.

SCI site: Lakes and wetlands Smalva and Smalvykstis (LTZAR0025)

The border is the same as for Smalvas landscape reserve. The area of the site is about 2225 ha. A centre of the territory is defined by E 26 22 55 longitude and 55 37 07 latitude (W/E Greenwich). Water bodies and forests are predominating in the site (Table 7.6-7).

Table 7.6-7. Habitat structure of the Smalvos ir Smalvykscio ezerai ir pelkes SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	24
Bogs, Marshes, Water fringed vegetation, Fens	15
Other arable land	4
Broad-leaved deciduous woodland	2
Coniferous woodland	29
Mixed woodland	26
Total habitat cover	100

The Smalvos ir Smalvykscio ezerai ir pelkes SCI is directly related to other NATURA 2000 sites, such as: the Grazutes regioninis parkas (LTZAR0024) and Smalveles upe ir slapzemes SCIs (LTZAR0026).

The Smalvos ir Smalvykscio ezerai ir pelkes SCI has been designated with the main goal to protect qualifying habitats of EU importance, such as: Hard oligo-mesothrophic waters with benthic vegetation of *Chara* formations (3140), Western taiga (9010*), Transition mires and quaking bogs (7140), Bog woodland (91D0), Fennoscandian deciduous swamp woods (9080), Alkaline fens (7230), Calcareous fens with *Cladium mariscus* and *Carex davaliana* (7210) and Dystrophic lakes (3160), which are listed in Annex I of the Directive, and qualifying plant species Fen orchid (*Liparis loeselii*) and *Drepanocladus vernicosus*, which are listed in Annex II of the Directive.

According to Svazas et al. (*1999*), the territory hosts the rare mammal ermine (*Mustela erminea*), which is included in the LRDB. Mountain hare (*Lepus timidus*), listed in the LRDB as well, is not numerous here. European otter (*Lutra lutra*) and two families of beaver (*Castor fiber*), both species included in Annex II of the Directive, live in the lake complex. Wolf (*Canis lupus*), listed in Annex II of the Directive, has been observed only in some years. Two rare species of butterflies have been recorded here: Swallowtail (*Papilio machaon;* species included in the LRDB) and *Stigmella lediella* (the second record in the country).

Some rare plant species, included in the LRDB, have been found in the territory (*Svazas et al. 1999*): downy willow (*Salix lapponum*), European cutsedge (*Cladium mariscus*), slender cotton-grass (*Eriophorum gracile*), narrow-leaved marsh orchid (*Dactylorhiza russowii*), dwarf birch (*Betula nana*) and fen orchid (*Liparis loeselii*). Hollyleaved naiad (*Najas marina*) was recorded in Berzinis lake, while *Hydrilla verticillata* has been found in several lakes of the protected area.

SCI site: Grazute Regional Park (LTZAR0024)

The border is partly the same as for Grazute Regional Park. The area of the site is 26 125 ha. A centre of the territory is defined by E 26 08 23 longitude and 55 37 19 latitude (W/E Greenwich). Woodland and water bodies are predominating in the site (Table 7.6-8). The Grazutes regioninis parkas SCI is bordering another NATURA 2000 site Smalvos ir Smalvykscio ezerai ir pelkes SCI. It also covers the Siaures rytine Grazutes regioninio parko dalis SPA.

Table 7.6-8. Habitat structure of the Grazutes regioninis parkas SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	19
Extensive cereal	10
Improved grassland	2
Other arable land	7
Broad-leaved deciduous woodland	6
Coniferous woodland	31
Mixed woodland	25
Total habitat cover	100

The SCI has been designated with the main goal to protect qualifying habitats, plant and butterfly species, such as: Oligothrophic waters in medio-European and perialpine area with amphibious vegetation: *Littorella* or *Isoetes* or annual vegetation on exposed banks (Nanocyperetalia) (3130), Transition mires and quaking bogs (7140), Degraded raised bogs, (still capable of natural regeneration) (7120), Hard oligo-mesothrophic waters with benthic vegetation of *Chara* formations (3140), Bog woodland (91D0), Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco brometalia; important orchide sites 6210*), Xeric sand calcareous grasslands (*Koelerion glaucae*) (6120*); Large copper butterfly (*Lycaena dispar*) and Eastern pasque-flower (*Pulsatilla patens*).

NATURA 2000 DB shows that the Grazutes regioninis parkas SCI is also valuable for protection of other habitat types, such us: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation (3150), Active raised bogs (7110*), Fennoscandian mineral-rich springs and spring fens (7160), Petrifying springs with rufa formation (*Cratoneurion*) (7220), Western taiga (9010*), Fennoscandian hemiboreal natural old broad-leaved deciduous forests (*Quercus, Tilia, Acer, Fraxinus or Ulmus*) rich in epiphytes (9020*), *Tilio–Acerion* ravine forests (9180*) and Fennoscandian deciduous swamp woods (9080), which are listed in Annex I of the Directive. The site is also important for protection of local populations of European otter (*Lutra lutra*), great crested newt (*Triturus cristatus*), European fire-bellied toad (*Bombina bombina*) and *Thesium ebracteatum*, which are listed in Annex II of the Directive.

Other important species of flora of the site are *Betula humilis* and downy willow (*Salix lapponum*), which are included in the LRDB.

According to earlier references (*Svazas et al., 1999*), in Antaliepte hydrographical reserve, which is a part of the Grazutes regioninis parkas SCI, some other species listed in the Lithuanian RDB have been recorded. Heath spotted orchid (*Dactylorhiza maculata*) grows in wet meadows along the reservoir bank. *Hydrilla verticillata* grows in the Antalieptė reservoir near Azuolyne village. Yellow marsh saxifrage (*Saxifraga hirculus*) has been found in a marsh near Deguciai village. Fen orchid (*Liparis loeselii*) and single-leaved bog orchid (*Malaxis monophyllos*) grow nearby on a raised bog. Cross gentin (*Gentiana cruciata*) and green-winged orchid (*Orchis morio*) grow in meadows on bank slopes. Fir clubmoss (*Huperzia selago*) is found in a bogged forest (*Svazas et al., 1999*).

SCI site: Pusnis mire (LTIGN0001)

The border is the same as for Pusnis thelmological reserve. The area of the site is about 779 ha. A centre of the territory is defined by E 26 26 67 longitude and 55 29 52 latitude (W/E Greenwich). Water bodies, bogs, marshes, water fringed vegetation and fens are predominating in the site (Table 7.6-9).

According to Svazas et al. (*1999*) the Pusnis mire complex consists of transitional mires, fens and 5 lakes. Habitat diversity is very high. Former drainage ditches are dammed by beavers (*Castor fiber*).

Table 7.6-9. Habitat structure of the Pusnies pelke SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	27
Bogs, Marshes, Water fringed vegetation, Fens	36
Humid grassland, Mesophile grassland	7
Other arable land	8
Broad-leaved deciduous woodland	4
Mixed woodland	1
Other land (Including Towns, Villages, Roads, Waste places, Mines, Industrial sites)	17
Total habitat cover	100

The Pusnies pelke SCI is an isolated (directly not related with other analogous sites) NATURA 2000 site. It has been designated with the main goal to protect qualifying habitats of EU importance, such as: Transition mires and quaking bogs (7140), Eutrophic tall herbs (6430) and Species rich Nardus grasslands on siliceous substrates (6230), which are listed in Annex I of the Directive.

According to Svazas et al. (*1999*), the mire complex hosts the rare mammal ermine (*Mustela erminea*), which is included in the LRDB. European otter (*Lutra lutra*) and several families of beavers (*Castor fiber*), both species included in Annex II of the Directive, have been found in the area or live in the mire complex, respectively. Two species of butterflies have been recorded here: *Papilio machaon* (species included in the LRDB) and *Leucospilapteryx omisella* (the first record in the country).

In 1996-1999, during a special Lithuanian wetland survey (*Svazas et al., 1999*), it was concluded that Pusnies mire with some surrounding territories is valuable for many rare bird species, included in Annex I of the EU Bird Directive 79/409/EEC. Solitary females of Great Snipe (*Gallinago media*) breed in the mire. Black Grouse (*Lyrurus tetrix*) breeds here, leks have been found in the bog. One pair of Wood Sandpiper (*Tringa glareola*) breeds in the territory. Black Stork (*Ciconia nigra*) feeding individuals were recorded in the bog. Honey Buzzard (*Pernis apivorus*) is a possible breeder in the area. Annually 1–2 pairs of Montagu's Harrier (*Circus pygargus*) breed here as well. A minimum of 5 pairs of Crane (*Grus grus*) breed in the mire complex and 10-15 of immature individuals stay in the bog during the breeding season. Up to 100 staging individuals were found in the area during the autumn bird migration season. Courtship calls of 6–7 males of Spotted Crake (*Porzana porzana*) have been recorded in the territory. 11 territories of Corncrake (*Crex crex*) have been registered. At least 2 pairs of Short-eared Owl (*Asio flammeus*) breed in the bog. Bluethroat (*Luscinia svecica*) is considered as a possible breeder in the territory. Several other rare species have been registered in the mire, for instance Whiskered Tern (*Chlidonias hybridus*) breeds here.

During the Lithuanian wetland survey (*Svazas et al., 1999*), it was also stated that Pusnies mire and some surrounding territories form an important site for rare bird species included in the LRDB. About 5 pairs of Redshank (*Tringa tetanus*), 2–3 pairs of Curlew (*Numenius arquata*), more than 1 pair of Black-tailed Godwit (*Limosa limosa*) and one pair of Green Woodpecker (*Picus viridis*) breed in the mire complex in favourable years. Also breeding White-winged Black Tern (*Chlidonias leucopterus*) and Citrine Wagtail (*Motacilla citreola*) have been found here.

The Pusnis mire is one of a few sites in Lithuania, where Jack Snipe (*Lymnocryptes minimus*) possibly breeds. One pair was observed during the breeding season (*Svazas et al., 1999*).

The mire is a regionally important site for migrating goose. Up to 500 staging White-fronted Geese (*Anser albifrons*) and Bean Geese (*Anser fabalis*) have been recorded in the mire during spring migration (*Svazas et al., 1999*).

Some rare plant species, included in the LRDB, have been found in the mire (*Svazas et al., 1999*): downy willow (*Salix lapponum*), Single-leaved bog orchid (*Malaxis monophyllos*), green-winged orchid (*Orchis morio*) and *Dactylorhiza longifolia*.

SCI site: Ruzas Lake (LTIGN0026)

The area of the site is about 205 ha. A centre of the territory is defined by E 26 29 39 longitude and 55 29 03 latitude (W/E Greenwich). Water bodies are predominating in the site (Table 7.6-10). The Ruzo ezeras SCI is an isolated NATURA 2000 site. It has been designated with the main goal to protect the local population of qualifying species of invertebrates and plants: *Vertigo angustior*, *Dytiscus latissimus* and Vesicular Aldrovanda (*Aldrovanda vesiculosa*), which are listed in Annex II of the Directive.

Table 7.6-10. Habitat structure of the Ruzo ezeras SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Shingle, Sea cliffs, Islets	100
Total habitat cover	100

SCI site: Gervele wetland (LTIGN0017)

The area of the site is about 373 ha. A centre of the territory is defined by E 26 26 51 longitude and 55 27 13 latitude (W/E Greenwich). Woodland and water bodies, bogs, marshes, water fringed vegetation and fens are predominating in the site (Table 7.6-11). The Gerveles pelke SCI is not directly related with other NATURA 2000 sites (is an isolated protected area). It has been designated with the main goal to protect qualifying habitats of EU importance: Degraded raised bogs, (still capable of natural regeneration) (7120) and Bog woodland (91D0), which are listed in Annex I of the Directive.

Table 7.6-11. Habitat structure of the Gerveles pelke SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Bogs, Marshes, Water fringed vegetation, Fens	8
Other arable land	3
Broad-leaved deciduous woodland	24
Mixed woodland	65
Total habitat cover	100

SCI site: Dietkauscizna meadows (LTIGN0004)

The area of the site is about 147 ha. A centre of the territory is defined by E 26 27 56 longitude and 55 20 19 latitude (W/E Greenwich). Extensive cereal cultures and other arable land as well as woodland are predominating in the site (Table 7.6-12).

Table 7.6-12. Habitat structure of the Dietkausciznos pievos SCI according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Extensive cereal cultures	29
Mixed woodland	41
Other arable land	17
Broad-leaved deciduous woodland	13
Total habitat cover	100

The Dietkausciznos pievos SCI is an isolated NATURA 2000 site. The SCI is a part of the Dysna hydrographical reserve. It has been designated with the main goal to protect the qualifying habitat of EU importance *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*) (6410), which is listed in Annex I of the Directive.

Based on NATURA 2000 DB the Dietkausciznos pievos SCI is also valuable for protection of habitats Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) (91E0), and the plants fen orchid (*Liparis loeselii*) (51–100 individuals) and common butterwort (*Pinguicula vulgaris*).

SPA site: Lake Druksiai (LTZARB003)

Lake Druksiai is a cooler of the Ignalina NPP and is the nearest big water body as well as the nearest NATURA 2000 site to the NNPP sites. Other protected areas are located much further away from the NNPP sites (e.g. lakes and wetlands Smalva and Smalvykstis – about 5 km from the site, complex of Dysnai and Dysnykstis lake area – about 13 km, see Figure 7.6-1 and Figure 7.6-2). Human access is limited because of the border regime.

The area of the site is about 3612.33 ha. A centre of the territory is defined by E 26 33 43 longitude and 55 36 59 latitude (W/E Greenwich). Water bodies and arable land are predominating in the site (Table 7.6-13).

Table 7.6-13. Habitat structure of the Druksiu ezeras SPA according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	71
Bogs, Marshes, Water fringed vegetation, Fens	5
Extensive cereal	3
Improved grassland	3
Other arable land	10
Broad-leaved deciduous woodland	3
Mixed woodland	5
Total habitat cover	100

NATURA 2000 designation values: The SPA has been designated with the main goal to protect the local population of qualifying species of Great Bittern (*Botaurus stellaris*), which is listed in Annex I of the EU Bird Directive. According to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*) local breeding population of the species is one of the biggest in the country (10 calling males). A very high density of the species has been recorded in the SPA (Figure 7.6-3).

The lake is also an important site for other bird species listed in Annex I of the EU Bird Directive. One pair of Black-throated Diver (*Gavia arctica*), 5 pairs of Marsh Harrier (*Circus aeruginosus*), 6 males of Spotted Crake (*Porzana porzana*), one male of Little

Crake (*Porzana parva*), 10 pairs of Black Tern (*Chlidonias niger*) and one pair of Bluethroat (*Luscinia svecica*) have been observed breeding in the area (*NATURA 2000 DB; Ministry of Environment of the Republic of Lithuania*). According to Svazas et al. (*1999*), some years ago Black-throated Diver (*Gavia arctica*), an endangered species in Lithuania, was considered as a possible breeder in the lake. At the end of the previous century Black-throated Diver (*Gavia arctica;* especially immature individuals) were observed here annually.

Other bird species: There is some information available about other rare species, listed in Annex I of the EU Bird Directive and included in the Lithuanian RDB. White-tailed Eagle (*Haliaeetus albicilla*) also used to be considered as a possible breeder. According to later references (*Svazas et al., 2008*), this species breeds here. Up to 7 individuals have been recorded in winter. The site is especially valuable for the species during cold winters, when all other water bodies of the region suitable for feeding are covered by ice. Fragmentary visits show concentration of White-tailed Eagle (*Haliaeetus albicilla*) on Lake Druksiai in winter in cold periods. According to later studies (*Svazas et al., 2008*) Ferruginous Duck (*Aythya nyroca*) has been considered as a breeding species as well.

One pair of Montagu's Harrier (*Circus pygargus*) breeds in a bogged meadow in the valley of the Duksta rivulet. One – two pairs of Crane (*Grus grus*) breed on the northern bank of the lake. Single pairs of Dunlin (*Calidris alpine*) used to breed on Pilies Island, which belongs to Belarus. Islands of the lake are important staging areas for migratory birds.

According to latest references (*Svazas et al., 2008*) in Lake Druksiai and its surroundings in total 140 bird species have been found. A total of 33 species listed in the LRDB and 31 species included in Annex I of the EU Bird Directive have been registered.

Lake Druksiai and Druksa rivulet are valuable for some regionally rare species of birds (*Svazas et al., 1999*). Short-toed Eagle (*Circaetus gallicus*) is an extinct species in Lithuania, however occasionally it has been recorded in the territory. Two territories of Quail (*Coturnix coturnix*) have been registered in the valley of the Duksta rivulet. Red-breasted Merganser (*Mergus serrator*) breeds on the lake. A brood with fledglings was registered in 1999. Staging flocks of up to 350 individuals occur on the lake during bird migration periods. The species is also regularly recorded in the free from ice Lake Druksiai in January-February. Two pairs of Redshank (*Tringa totanus*) breed in the valley of the Duksta rivulet. Two–three pairs of Curlew (*Numenius arquata*) and several pairs of Black-tailed Godwit (*Limosa limosa*) breed on the Pilies Island (belongs to Belarus) and in the valley of the Duksta rivulet. One pair of Oystercatcher (*Haematopus ostralegus*) breeds along the eastern bank of the lake, belonging to Belarus. Single pairs of Gadwall (*Anas strepera*) have been annually recorded in recent years. Shoveler (*Anas clypeata*) breeds in some years in the surroundings of the lake. Goosander (*Mergus merganser*) is a rather common breeding species. More than 10 males were counted during one census. Lake Druksiai is an important staging and wintering site of this species in eastern Lithuania. Up to 900 staging birds have been recorded in autumn. The site regularly supports up to 500 wintering Goosanders. Kingfisher (*Alcedo atthis*) is considered as a possible breeder because it has been recorded regularly on the lake and along the Duksta rivulet. Citrine Wagtail (*Motacilla citreola*) has been registered breeding in the valley of the Duksta rivulet. The species is very rare in the country (*Svazas et al., 1999*).

In the period 1985–2000 in the surroundings of village Tilze (northern part of the lake) nearly annually the following territorial (very likely breeding) species were recorded:

Eurasian Hobby (*Falco subbuteo*), Black Grouse (*Tetrao tetrix*), Grey-headed Woodpecker (*Picus canus*), Green Woodpecker (*Picus viridis*), White-backed Woodpecker (*Dendrocopos leucotos*), Goosander (*Mergus merganser*), Ortolan Bunting (*Emberiza hortulana;* species included in the LRDB). White Stork (*Ciconia ciconia*), Red-backed shrike (*Lanius collurio*), Wood Lark (*Lullula arborea*) and European Nightjar (*Caprimulgus europaeus;* species listed in Annex I of the EU Bird Directive). At the time they were common here (*Kurlavicius, unpublished data*).

A mixed colony of Cormorant (*Phalacrocorax carbo*), with about 500 nests registered, Grey Heron (*Ardea cinerea*), with about 150 nests, and Great White Egret (*Egretta alba*), with a few nests, is located on the western bank of the lake close to the Ignalina NPP. Recently colonies of Cormorant (*Phalacrocorax carbo*) have been under influence of strong control throughout the country, especially in the Aukstaitija National Park (about 30 km from the NNPP). Most likely due to this activity the colony of Cormorant (*Phalacrocorax carbo*) of Lake Druksiai is rather stable. The Great White Egret (*Egretta alba*) is a new breeding bird species in Lithuania. It is listed in Annex I of the EU Bird Directive.

Lake Druksiai is important for the regional population of Great Crested Grebe (*Podiceps cristatus*). The breeding population of this species in the lake is the largest known in the region. Several colonies have been found on the lake. White-winged Black Tern (*Chlidonias leucopterus*) has been registered breeding in the valley of the Duksta rivulet (*Svazas et al. 1999*). The species is very rare in the country (*Raudonikis & Kurlavicius, 2000*).

In 1996-1999, during a special Lithuanian wetland survey (*Svazas et al., 1999*), it was concluded that large staging flocks of migratory waterfowl concentrate on the lake in spring and autumn, with up to 700 Mallards (*Anas pratyhynchos*), 550 Coots (*Fulica atra*), 480 Goldeneyes (*Bucephala clangula*), 120 Mute Swans (*Cygnus olor*) and numerous flocks of other species.

The western part of the lake and especially the site with a regular influx of warm water provides a suitable habitat for various species of waterfowl during cold winter periods. This area regularly supports numerous wintering mergansers (*Mergus merganser*), Goldeneyes (*Bucephala clangula*), Mallards (*Anas pratyhynchos*), Mute Swans (*Cygnus olor*) and Coots (*Fulica atra*)(*Svazas et al., 1999*).

Changes in bird communities and populations: In some recent references (*Svazas et al., 2008*) it has been pointed out that the bird fauna of Lake and its surroundings has undergone remarkable changes. The reasons for these changes have been reported as well. They are caused mainly by the lake eutrofication processes and field abandonment: overgrowing of open habitats with woody vegetation and expansion of reedbeds on the shore of the lake. Due to these reasons populations of some rare species have decreased in numbers or they have even turned locally extinct: Black-throated Diver (*Gavia arctica*), Oistercatcher (*Haematopus ostralegus*), Redshank (*Tringa totanus*), Black-tailed Goodwit (*Limosa limosa*), Eurasian Curlew (*Numenius arquata*), Dunlin (*Calidris alpine*), Ruff (*Philomachus pugnax*) and Common Tern (*Sterna hirundo*). Contrary, since the INPP was built, due to the mentioned habitat changes populations of birds of reedbeds, Great Bittern (*Botaurus stellaris*) and Little Crake (*Porzana parva*), have increased and a new species Bearded Tit (*Panurus biarmicus*) has occurred.

SPA site: Complex of wetlands on surroundings of Dysnu and Dysnykscio lakes (LTIGNB004)

The Area of the site is about 4016.56 ha. A centre of the territory is defined by E 26 19 56 longitude and 55 28 05 latitude (W/E Greenwich). Water bodies are predominating in the site (Table 7.6-14).

Table 7.6-14. Habitat structure of the Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas SPA according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	95
Extensive cereal	1
Other arable land	1
Mixed woodland	3
Total habitat cover	100

The Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas SPA is an isolated NATURA 2000 site. The SPA has been designated with the main goal to protect local populations of qualifying species Corncrake (*Crex crex*).

The SPA is also important for the protection of the national population of Great Bittern (*Botaurus stellaris*), Marsh Harrier (*Circus aeruginosus*), Montagu's Harrier (*Circus pygargus*) and Spotted Crake (*Porzana porzana*). These species are listed in Annex I of the EU Bird Directive. According to the NATURA 2000 DB (*Ministry of Environment of the Lithuanian Republic*) the local breeding population of Great Bittern (*Botaurus stellaris*) is 7 calling males, of Corncrake (*Crex crex*) – 30 calling males, of Marsh Harrier (*Circus aeruginosus*) – 11 pairs, of Montagu's Harrier (*Circus pygargus*) – 2 pairs and of Spotted Crake (*Porzana porzana*) – 8 calling males.

Lake Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas SPA is valuable for some regionally rare species of birds (*Raudonikis, 2004*). 11 breeding bird species are listed in the LRDB.

SPA site: Smalva wetland complex (LTZARB002)

The border is nearly the same as for Smalvas hydrographical reserve and River Smalvele and adjacent limy fens SCI. The area of the site is about 538 ha. A centre of the territory is defined by E 26 28 34 longitude and 55 37 34 latitude (W/E Greenwich). Wetlands and forests are predominating in the site (Table 7.6-15).

Table 7.6-15. Habitat structure of the Smalvos slapzemiu kompleksas SPA according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Bogs, Marshes, Water fringed vegetation, Fens	80
Extensive cereal	1
Other arable land	2
Mixed woodland	17
Total habitat cover	100

The Smalvos slapzemiu kompleksas SPA is directly related with another NATURA 2000 site the Smalveles upe ir slapzemes SCI (LTZAR0026). The SPA has been designated with the main goal to protect the local population of qualifying species Black Tern (*Chlidonias niger*). The species is included in Annex I of the EU Bird Directive.

According to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*) the local breeding population of the Black Tern is 40 pairs.

The site is also an important site for other bird species listed in Annex I of the EU Bird Directive. Their breeding populations are however not big. According to the NATURA 2000 DB two males of Great Bittern (*Botaurus stellaris*), two pairs of Marsh Harrier (*Circus aeruginosus*), one pair of Montagu's Harrier (*Circus pygargus*), three calling males of Spotted Crake (*Porzana porzana*), two pairs of Common Crane (*Grus grus*) and five pairs of the Red-backed Shrike (*Lanius collurio*) have been observed. Black Grouse (*Tetrao tetrix*) and White Stork (*Ciconia ciconia*) occur in the Smalvos slapzemiu kompleksas SPA, but data on their numbers is not available.

SPA site: North-eastern part of Grazute regional park (LTZARB004)

The area of the site is about 5699.85 ha. A centre of the territory is defined by E 26 09 32 longitude and 55 39 17 latitude (W/E Greenwich). Water bodies and coniferous woodland are predominating in the site (Table 7.6-16).

Table 7.6-16. Habitat structure of the Siaures rytine Grazutes regioninio parko dalis SPA according to the NATURA 2000 DB (*Ministry of Environment of the Republic of Lithuania*).

Habitat classes	Coverage, %
Inland water bodies (Standing water, Running water)	23
Extensive cereal	1
Broad-leaved deciduous woodland	1
Coniferous woodland	64
Mixed woodland	11
Total habitat cover	100

The Siaures rytine Grazutės regioninio parko dalis SPA is related with another NATURA 2000 site, the Grazutes regioninis parkas SCI, and with the national protected area Grazute Regional Park. The SPA has been designated with the main goal to protect local populations of qualifying species of Pygmy Owl (*Glaucidium passerinum*) and Black-throated Diver (*Gavia arctica*). These species are listed in Annex I of the EU Bird Directive. According to the NATURA 2000 DB the local breeding population of the Black-throated Diver (*Gavia arctica*) is 3 pairs and of Pygmy Owl (*Glaucidium passerinum*) 4–5 pairs.

The site is also important for other bird species listed in Annex I of the EU Bird Directive. Three pairs of Black Kite (*Milvus migrans*), 4–5 pairs of Tengmalm's Owl (*Aegolius funereus*), 7 pairs of White-backed Woodpecker (*Dendrocopos leucotos*), 3 pairs of Three-toed Woodpecker (*Picoides tridactylus*), 3 pairs of Lesser Spotted Eagle (*Aquila pomarina*), 7–8 pairs of Honey-buzzard (*Pernis apivorus*), 7–8 calling males of Great Bittern (*Botaurus stellaris*), 5 pairs of Black Woodpecker (*Dryocopus martius*) and 6 pairs of Wood Lark (*Lullula arborea*) as well as several pairs of Osprey (*Pandion haliaetus*), Hazel Grouse (*Bonasa bonasia*), Common Crane (*Grus grus*), European Nightjar (*Caprimulgus europaeus*) and Pied Flycatcher (*Ficedula parva*) have been monitored breeding in the area (*NATURA 2000 DB of the Ministry of Environment of the Republic of Lithuania*).

According to earlier references (*Svazas et al., 1999*), in Antaliepte hydrographical reserve, which is a part of the Siaures rytine Grazutes regioninio parko dalis SPA, some other species listed in Annex I of the EU Bird Directive and included in the Lithuanian RDB were recorded. 24 bird species, included in the Lithuanian RDB, have been registered in the reserve, for instance single individuals of White-tailed Eagle

(*Haliaeetus albicilla*) have been frequently recorded in the territory. One pair breeds in adjacent forests. Single individuals of Black Stork (*Ciconia nigra*) have been recorded in the reserve. The species probably breeds in the surrounding forests. One pair of Montagu's Harrier (*Circus pygargus*) breeds in the southern part of the reserve. Several calling males of Spotted Crake (*Porzana porzana)* and Corncrake (*Crex crex)* have been registered in the territory (*Svazas et al., 1999*).

Antaliepte hydrographical reserve is valuable for some other rare species of birds, included in the Lithuanian RDB (*Svazas et al., 1999*). Single calling males of Quail (*Coturnix coturnix*) have been recorded in the reserve. Redshank (*Tringa tetanus*) is a possible breeder. It has been recorded during the breeding season. 1–2 pairs of Curlew (*Numenius arquata*) possibly breed as well. Red-necked Grebe (*Podiceps grisegena*) is also a possible breeder. Flocks of Greylag Goose (*Anser anser*) of up to 40 individuals have been recorded in the fields of the reserve. 1–3 pairs of Shoveler (*Anas clypeata*) possibly breed in the reserve. Up to 15 pairs of Goosander (*Mergus merganser*) breed in the territory. Large staging flocks (up to 380 individuals) have been recorded here. 2-3 pairs of Kingfisher (*Alcedo atthis*) breed in the reservoir (*Svazas et al., 1999*).

The reserve is regionally important site for migrating birds. Up to 120 staging Red-breasted Merganser (*Mergus serrator*) were recorded in the reserve in autumn (*Svazas et al., 1999*).

7.6.1.4 Other protected and important biodiversity areas

There are 7 national protected areas valuable for nature protection in the NNPP region (Figure 7.6-7).

A legal basis for establishment of national protected areas, other key information about size of the areas, site code and main goals of their establishment are presented in Table 7.6-17.

Most of the territory covered by national protected areas is concentrated to the western part of the region. The national protected areas are mostly located on axis east–west. The NNPP region covers part of the territory of the Grazute Regional Park and Dysna hydrographical reserve. Pratkunai geomorphological reserve is just bordering the NNPP region. Aukstaitija National Park is located to the south-east from the NNPP, and is a few kilometres outside the border. Due to this reason the Aukstaitija National Park protected area has not been analysed more in detail here.

Out of 7 national protected areas, 5 sites are of international importance for habitat and/or species conservation (being as Sites of Community Importance (SCI) and/or Special Protection Areas (SPA)). Two Sites of Community Importance (SCI) are still non-protected by national laws.

Territories, which according to national legislation are considered as protection zones of water bodies, have not been analysed more in detail. They are both not indicated neither in the map of national protected areas (Figure 7.6-7), nor in the summary of key information (Table 7.6-17).

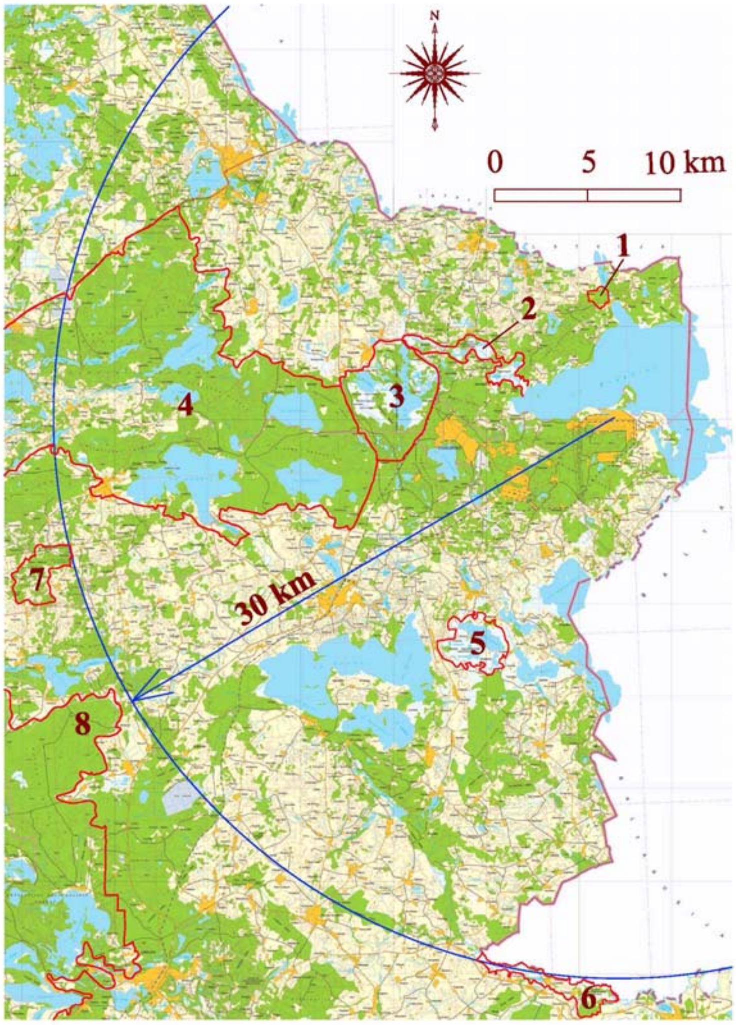


Figure 7.6-7. Protected areas, established according to the national legislation in the NNPP region (according to the Cadastre for the State protected areas; State Protected Area Service at the Environment Ministry of the Lithuanian Republic). Perimeter of the region is indicated in blue. The protected territories: 1 – Tilze geomorphological reserve; 2 – Smalva hydrographical reserve; 3 – Smalvas landscape reserve; 4 – Grazute Regional Park; 5 – Pusnis thelmological reserve; 6 – Dysna hydrographical reserve; 7 – Pratkunai geomorphological reserve; 8 – Aukstaitija National Park.

Information available (Table 7.6-17) shows that national protected areas in the NNPP region are multifunctional. They have been established mostly with the goal to protect landscape with valuable valleys of natural small rivers, picturesque relief. One protected area is designated with the goal to protect a complex of fen and one partly to protect not only nature but also cultural values.

Table 7.6-17. Key information about protected areas, established according to national legislation, in the NNPP region.*

Site name: official / English*	Area of the site, ha	Legal establishment basis	Main goal	Site code (ID)	International importance
Tilzes geomorfologinis draustinis / Tilze geomorphological reserve	43.68	Decision No. I-2913 of the Parliament of 24-09-1992 (*State Journal, 1992, No. 30-913*)	To protect unique complex of limnoglacial relief	0210200000010	Not known
Smalvos hidrografinis draustinis / Smalva hydrographical reserve	547.44	Decision No. 342 of the Ministerial Council of the Lithuanian SSR of 14-12- 1983 (*State Journal*, *1983, No. 36-383; 22-244*)	To protect natural valley of the Smalva rivulet	0210300000009	Important. Area is near the some as for Smalvos slapzemiu kompleksas SPA and the some as for Smalveles upe ir slapzemes SCI
Smalvo krastovaizdzio draustinis / Smalvas landscape reserve	2225.28	Decision No. 517 of the Ministerial Council of the Lithuanian SSR of 27-09- 1960 (*State Journal*, *1960, Nr. 27-244*)	To protect characteristic landscape with Smalvas and Smalvykstis lakes of the Aukstaitija highland	0230100000014	Important. Area is the some as for Smalvos ir Smalvykscio ezerai ir pelkes SCI
Grazutes regioninis parkas / Grazute Regional Park	29471	Decision No. I-2913 of the Parliament of 24-09-1992 (*State Journal*, *1992, Nr. 30-913*)	To protect characteristic landscape in the Sventoji river outflow and cultural values	0700000000012	Important. Part area is covered by Grazutes regioninis parkas SCI and by Siaures rytine Grazutes regioninio parko dalis SPA
Pusnies telmologinis draustinis / Pusnis thelmological reserve	779.4	Decision Nr. 1486 of the Government of 29-12-1997. (*State Journal*, *1998, Nr. 1-9*)	To protect complex of fen	0210900000027	Important. Area is the some as for Pusnies pelke SCI
Dysnos hidrografinis draustinis / Dysna hydrographical reserve	586.63	Decision Nr. 1486 of the Government of 29-12-1997 (*State Journal*, *1998, Nr. 1-9*)	To protect valley of the Dysna river on limnoglacial lowland	0210300000013	Important. Part of area is the some as for Dysnu ir Dysnykscio apyezeriu slapzemiu kompleksas SPA
Pratkunu geomorfologinis draustinis / Pratkunai geomorphological reserve	623.47	Decision No. I-2913 of the Parliament of 24-09-1992 (*State Journal*, *1992, Nr. 30-913*)	To protect highest morenic complex of Seliai highland with Pratkunai hill	0210200000011	Not known

* Source: the Cadastre for the State protected areas; State Protected Area Service at the Environment Ministry of the Republic of Lithuanian.

The official (Lithuanian) name, code of the protected area, area of the site are indicated as they are used in Cadastre for the State protected areas *http://stk.vstt.lt/stk/default2.jsp?bs=1&lang=lt&jsessionid=E00C236D64073306E6A695C978F8110E*.

7.6.1.5 Biodiversity values outside protected areas

There are only few literature sources dealing with the biodiversity values outside the protected area network of the NNPP region. Information available is not detailed enough. According to the LRDB *Hirudo medicinalis* has been recorded in Ignalina and Zarasai districts (*Rasomavicius, 2007*), *Papilio machaon*, *Bufo calamita* and *B. viridis*, Honey Buzzard (*Pernis apivorus*), White-tailed Eagle (*Haliaeetus albicilla*), Montagu's Harrier (*Circus pagargus*), Northern Goshawk (*Accipiter gentilis*), Lesser Spotted Eagle (*Aquila pomarina*), Osprey (*Pandion haliaetus*), Eurasian Hobby (*Falco subbuteo*), Black Grouse (*Lyrurus tetrik*), Quail (*Coturnix coturnix*), Spotted Crake (*Porzana porzana*), Corncrake (*Crex crex*), Crane (*Grus grus*), Stock Dove (*Columba oenas*) and Mountain hare (*Lepus timidus*) are rare species but distributed in all the districts of the country (*Rasomavicius, 2007*). Plants *Nitela syncarpa, Neckera pennata*, *Calliergon trifarium*, *Lycopodiela inundata*, *Huperza selago*, *Botrychium matricariifolium*, *Nymphaea alba*, *Myriophyllum alterniflorum*, *Thesium ebracteatum*, *Callitriche hermaphroditica*, *Alisma gramineum*, *Hydrilla verticillata*, *Najas minor*, *Gymnadenia conopsea*, *Dactylorhiza fuchsii*, *D. incarnate*, *D. longifolia*, *D. maculate*, *D. ochroleuca*, *D. traunsteineri*, *Hammarbya paludosa*, *Malaxis monophyllos*, *Corallorhiza trifida*, *Juncus stygius*, *Carex heleonastes* and *Scolochloa festucacea* have been recorded in the NNPP region (*Rasomavicius, 2007*). *Meesia triquetra* has been found in Zarasai district.

Based on available references it can be concluded that the most important biodiversity values are concentrated to the protected areas of the NNPP region. At the some time some biodiversity values do exist outside the protected areas. They are less known and most likely less important.

7.6.1.6 Biodiversity values outside Lithuania

Latvia

Protected areas of the NNPP region

In the 30 km zone and territory crossing the 30 km zone from the planned nuclear power plant in the territory of Latvia, the following particularly protected nature reserves are located: protected landscape area "Augsdaugava", which includes the nature park "Daugavas loki", protected landscape area "Augszeme", which includes the nature park "Meduma ezeraine" and the nature park "Svente", as well as nature reserves "Bardinska ezers" (lake), "Skujines ezers" (lake), and the nature park "Silene", which includes the nature reserves "Ilgas" and "Glusonkas purvs" (bog)(Table 7.6-18, Figure 7.6-8). Protection and use of the territories is established by the regulations No. 415 of July 22, 2003 of the Council of Ministers "Provisions of general protection and use of particularly protected nature territories". Within the 30 km zone in the territory of Latvia, there are also 9 micro-reserves with a total area of 126.8 ha, however in compliance with the legal enactments of the Republic of Latvia (Regulations No. 45 of the Council of Ministers "Regulations of establishment, protection, and management of micro-reserves"), more extensive information on micro-reserves must be requested at the State Agency "Latvijas Vides, geologijas un meteorologijas agentura" (Latvian Environmental, Geology, and Meteorology Agency). The territory also includes natural monuments: Medumu alley, Medumu park (dendrology plantations), as well as 74 protected trees (Law of April 7, 1998 of the Republic of Latvia "Law on Particularly Protected Natural Territories").

All of the aforementioned territories are particularly protected territories of European importance, i.e. NATURA 2000 areas.

List of particularly protected areas of the NNPP region in Latvia:

Augszeme
Protection category: protected landscape area (includes nature parks - Medumu ezeraine (Lakeland), Svente, nature reserves - Bardinska Lake, Skujines Lake), NATURA 2000 area.
Administrative division: Medumu, Sventes, Kalkunes, and Sederes rural municipalities.
Area: 20 828 ha.
Year of establishment: 1977.
Natural values: Valuable landscape territory includes Sventes and Medumu lakes with islands as well as several small lakes in the vicinity. The territory includes high-elevation territory of Augszeme, as well as several biologically valuable territories. 12 habitats of Annex 1 of the EU Habitat Directive and 8 species of Bird Directive can be found here.

Bardinska Lake
Protection category: nature reserve (included into the area of protected landscapes - Augszeme), NATURA 2000 area
Administrative division: Sederes rural municipality
Area: 5 ha
Year of establishment: 2004
Natural values: The territory was established for protection of EU Habitat Directive – transition bog and marshlands. There are 3 EU Habitat Directive species in the lake. One of the few Lapland hamatocaulis moss specimens that can be found in Latvia is located here.

Skujines Lake
Protection category: nature reserve (included in the protected landscape area - Augszeme), NATURA 2000 area
Administrative division: Sēderes rural municipality
Area: 10 ha
Year of establishment: 2004
Natural values: The territory was established for protection of EU Habitat Directive – transition bog and marshlands. There are 3 EU Habitat Directive species in the lake. One of the few Lapland hamatocaulis moss specimens that can be found in Latvia is located here.

Medumu ezeraine (Lakeland)
Protection category: nature park (included in the protected landscape area - Augszeme, the nature park includes the nature reserve - Medumu Lake islands), NATURA 2000 area
Administrative division: Medumu rural municipality
Area: 1484 ha
Year of establishment: 1977
Natural values: There are various types of forests in the territory, not forming extensive complexes, as well as transition bogs near the lakes, where EU directive species - Yellow Widelip Orchid has been found. The lakes are an excellent source of feeding for several rare bat species. Many rare and protected vascular plant, moss, and lichen species can be found here.

Medumu Lake Islands
Protection category: nature reserve (included in the nature park - Medumu ezeraine (Lakeland)), NATURA 2000 area
Administrative division: Medumu rural municipality
Area: 3 ha
Year of establishment: 1987
Natural values: The territory was established for protection of the islands in Medumu Lake. The main value of the territory is its forests on the islands, which are mainly broad-leaved tree forests, where linden, aspen, and wild birches, as well as oak trees and ash-trees dominate the habitat.

Medumu Park
Protection category: natural monument
Administrative division: Medumu rural municipality
Area: 12.5 ha
Year of establishment: 1977

Meduma Alley
Protection category: natural monument
Administrative division: Medumu rural municipality
Area: 0.4 ha
Year of establishment: 2005

Svente
Protection category: nature park (included in the protected landscape area - Augszeme, the nature park includes the nature reserve - Sventes Lake islands), NATURA 2000 area
Administrative division: Medumu, Sventes, Kalkunes, Sēderes rural municipality
Area: 2225 ha
Year of establishment: 1977
Natural values: Exquisitely scenic lake. Includes Sventes Lake, which is one of the clearest lakes in Latvia. There are 3 forest-covered islands in the lake. Excellent territory for protection of eutrophic lakes. Such biotopes as transition bogs and marshes, wet black alder woods have been found at the territory; particularly protected plant species: Enchanter's nightshade (*Circaea lutetiana*), Yellow widelip orchid (*Liparis loeselii*), Acute-leaved pondweed (*Potamogeton acutifolius*) etc.

Sventes Lake Islands
Protection category: nature reserve (included in the nature park - Svente), NATURA 2000 area
Administrative division: Sventes rural municipality
Area: 3 ha
Year of establishment: 1987
Natural values: Particularly scenic islands of Svente Lake, the largest island is the Visku island (1.7 ha). There are predominantly broad-leaved trees on the islands: black alder – birches – ash-trees.

Silene
Protection category: nature park (includes natural reserves - Ilgas, Glusonkas bog), NATURA 2000 area
Administrative division: Lidumnieku, Skrudalienas rural municipality
Area: 3825 ha
Year of establishment: 1977

Natural values: Excellent territory for protection of various forest types (especially bog-type forests) and eutrophic lakes. The lakes are a great source of grazing for bats. 2 large bat colonies have been observed. Particularly large number of rare and protected plant and animal species.

Ilgas
Protection category: nature reserve (included in the nature park - Silene), NATURA 2000 area
Administrative division: Skrudalienas rural municipality
Area: 157 ha
Year of establishment: 1999
Natural values: A large number of particularly protected species of Latvia have been established here: the plants Early marsh orchid (*Orchis palustris*), Northern running-pin, Stiff clubmoss (*Lycopodium annotinum*), Ground pine (*L. clavatum*), White adder's mouth, Green-winged orchid (*Orchis morio*), Shetland pondweed (*Potamogeton rutilus*), and bird species Lesser spotted eagle (*Aquilla pomarina*), White-backed woodpecker (*Dendrocopos leucotos*), Black woodpecker (*Dryocopus martius*), Grey-headed woodpecker (*Picus canus*), Honey buzzard (*Pernis apivorus*), Black stork (*Ciconia nigra*).

Glusonkas purvs
Protection category: nature reserve (included in the nature park - Silene), NATURA 2000 area
Administrative division: Skrudalienas rural municipality
Area: 155 ha
Year of establishment: 1977
Natural values: The territory has 2 diseutrophic lakes (Glusņas and Glusonkas), which are surrounded by poor grassy and transition bogs, marshes. In the periphery there are boggy pinewoods and fir-tree forests.

Augsdaugava
Protection category: protected landscape area (includes nature park - Daugavas loki (The River-bends of Daugava)), NATURA 2000 area
Administrative division: Naujenes, Salienas, Vecsalienas, Tabores, Skrudalienas rural municipality. The territory is included also in the district of Kraslava.
Area: 52 325 ha
Year of establishment: 1990

Natural values: The territory was established to maintain exquisite values of cultural sceneries and natural sciences in the Daugava river valley and vicinity. A large number of protected plant and animal species can be found at the territory. In the territory, there are such EU Habitat Directive biotopes as river overfalls, open inland dunes with Grey club grass (*Corynephorus canescens*) meadows, springs and spring bogs rich in mineral substances, hillside and ravine forests, dry fields in calcareous soils, etc.

Daugavas loki (The River-bends of Daugava)
Protection category: nature park (included in the protected landscape area - Augsdaugava), NATURA 2000 area
Administrative division: Naujenes, Salienas, Vecsalienas, Tabores, and Skrudalienas rural municipality. The territory is included also in the district of Kraslava.
Area: 12372 ha
Year of establishment: 1990

Natural values: The territory was established to maintain the unique landscape of the medium courses of the Daugava River valley, the valuable natural areas, versatility of nature therein, as well as the monuments of local history. The nature park includes 8 large bends of the River Daugava from Kraslava to the Naujene ravine.

Table 7.6-18. Protected areas of the NNPP region in Latvia and their area.

No	Name of Protected Nature Territory	Area (ha)
1.	Protected landscape area “Augsdaugava”	52 325
1.1.	Nature park “Daugavas loki”	12 372
2.	Protected landscape area “Augszeme”	20 828
2.1	Nature Park “Medumu ezeraine”	1484
2.1.1.	Nature reserve “Meduma ezera salas”	3
2.2.	Natural monument “Medumu parks”	12.5
2.3.	Natural monument “Medumu aleja”	0.4
2.4	Nature Park “Svente”	2225
2.4.1.	Nature reserve “Sventes ezera salas”	3
2.5.	Nature reserve “Skujines ezers”	10
2.6.	Nature reserve “Bardinska ezers	5
3.	Nature Park “Silene”	3825
3.1.	Nature reserve “Glusonkas purvs”	155
3.2.	Nature reserve “Ilgas”	157

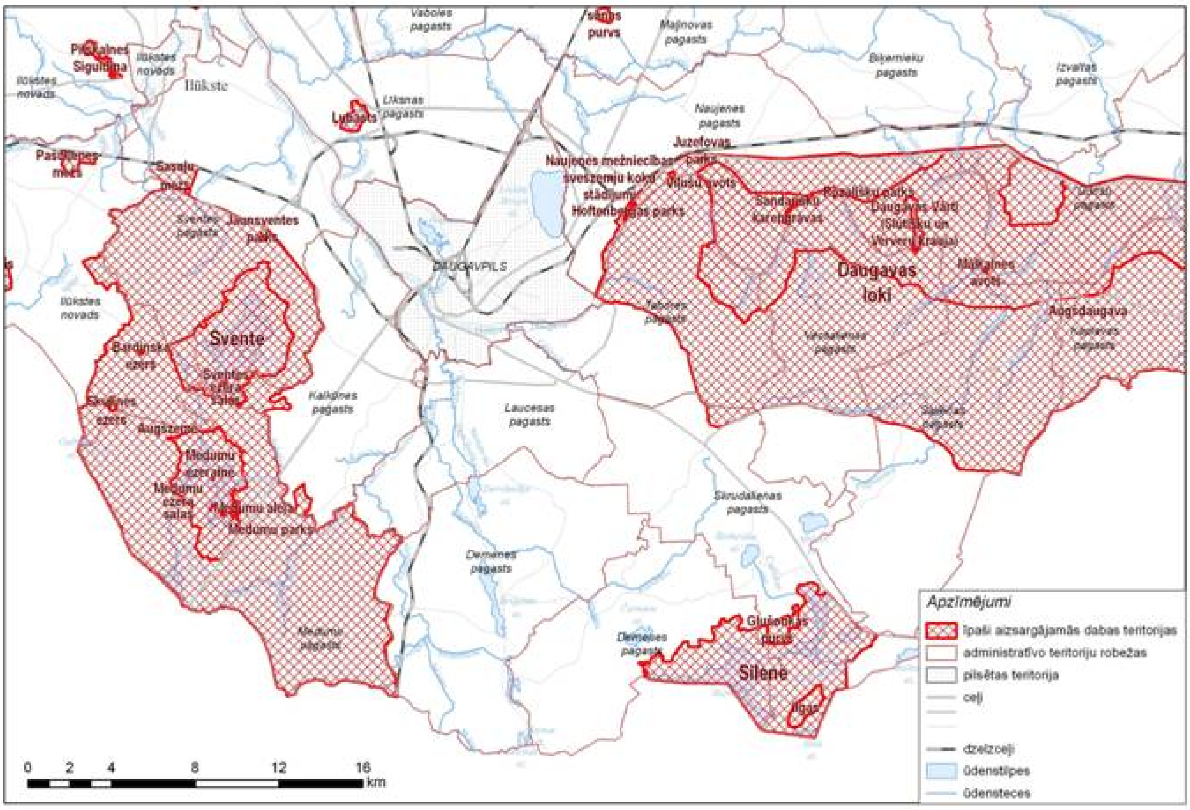


Figure 7.6-8. Protected areas of the NNPP region in Latvia.

Belarus

Protected areas of the NNPP region

All territory in the 30 km zone from the planned nuclear power plant in the territory of Belarus belongs to Braslav administrative district. In the territory some protected areas are located. The nearest and probably best known one is the Braslav Lakes National Park.

Braslav Lakes National Park

The objectives of the Braslav Lakes National Park are: conservation of the natural complex of Braslav lakes group, its unique ice age landscape, biodiversity (especially plant and animal) typical for Belorussian Poozerye; organization of environmental education of the population; conservation of cultural heritage; organization of recreation and tourist activities.The Braslav Lakes National Park was established in 1995.

The park occupies a territory of 71.5 thousand hectares or more than a third of the Braslav administrative district. From north to south the park stretches for 56 km. Width of the park fluctuates from 7 to 29 km. Depending on predominating values functional zones of the park have been identified. 27 746 ha (39 %) belongs to regulated usage zone. Territory of the zone is a subject for study, restoration, development and sustainability of the ecosystems undisturbed by human economic activities. Economic zone covers 25 815 ha (36.3 %). It is established for the location of the facilities for servicing park's visitors and administration, recreation and living buildings. Recreation zone occupies 12 103 ha (17.0%). It is meant for the location of recreation and tourist facilities necessary for the population recreation, organization of cultural activities. Nature reserve zone covers 3 452 ha (4.9 %). It is identified in the most valuable and the least loaded part of Boguinsky forest land in order to conserve untouched typical and unique ecosystems.

The park is rich in forest and lake. The forests occupy 46 % of the park. There are 60 lakes occupying 17 % of the territory in the park. The biggest lakes are, Drisvyaty (Lake Druksiai), Snudy, Strusovo, Boguinskoye. Volos Yuzhny is a deepest lake (40.4 m) of the park.

The relief here was shaped in the result of the last ice shelf . The Braslav upland is one of the most unique natural complexes in Belarus. The combination of chains, hills, lakes, wetlands and rivers makes this territory very mosaic. In the park there are a lot of huge stones (up to 10 m long), which are remarkable in geological and historical respects. The Braslav upland is characterized by sod-podzol more rarely sandy loam soils.

The modern fauna is represented by species typical to mixed forests of Middle Europe. The lakes are inhabited by 29 species of fish. There are 189 bird species including 45 rare and threatened ones. Breding Black Stork (*Ciconia nigra*), Willow Grouse (*Lagopus lagopus*), Dunlin (*Calidris alpina*) here are of geratest value. Big animal species inhabiting the park are elk (*Alces alces*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), lynx (*Lynx lynx*). About 500 species of flora (20 of them are rare for Belarus) have been registered here. Volos Yuzhny Lake is the only one in Belarus where relict Crustacea of the ice age can still be found.

Other protected areas

There are some other protected territories of international value in the Vitebsk region located a little bit outside the 30 km zone from the NNPP in Lithuania. They are as follows (*Kozulin et al., 2002*): Bolota Elnia (E 27 55 and N 55 34; 23200 ha), Azerna-bolotny Kompleks "Asveiski" (E 28 01 and N 56 06; 22600 ha); Lesa-bolotny Kompleks "Cervony bor' (E 28 30 and N 56 00; 34234 ha); Servatc (E 27 30 and N 55 00; 9268 ha).

Bolota Elnia is a national hydrographical nature reserve (zakaznik), established in 1968. In 1998 it was designated as an Important Bird Area (IBA) of international value. Azerna-bolotny Kompleks "Asveiski" is a national landscape nature reserve (zakaznik), established in 2000. In 1998 it was designated as an Important Bird Area (IBA) of international value. Lesa-bolotny Kompleks "Cervony bor' is a national landscape nature reserve (zakaznik), established in 1995. It is considered as a potential Important Bird Area (IBA) of international value. Servatc is a national hydrographical nature reserve (zakaznik). It is considered as a potential Important Bird Area (IBA) of international value.

7.6.1.7 Summary of biodiversity values (in Lithuania only)

There are 8 NATURA 2000 network Sites of Community Importance (SCI), valuable for habitat, plant and animal species protection according to the EU Habitat Directive in the NNPP region in Lithuania. There are 23 habitat types of international importance protected in the NATURA 2000 network Sites of Community Importance (SCI). Those habitats and 12 species of animals as well as plants of international importance are considered as designation values according to the EU Habitat Directive in the NNPP region in Lithuania.

There are 4 Special Protection Areas (SPAs) valuable for bird protection in the NNPP region in Lithuania. In those areas there are 26 breeding bird species of international importance, which are considered as NATURA 2000 network designation values.

From the point of view of biodiversity impact assessment most important values in this work were considered to be those, which are designation values of the Lake Druksiai SCI and the Lake Druksiai SPA. They are as follows: European otter (*Lutra lutra;* 6–10 individuals), Spined Loach (*Cobitis taenia;* a common species here), Great Bittern (*Botaurus stellaris;* local breeding population of 10 calling males), Black-throated Diver (*Gavia arctica;* 1 pair), Marsh Harrier (*Circus aeruginosus;* 5 pairs), Spotted Crake (*Porzana porzana;* 6 males), Little Crake (*Porzana parva;* 1 male), Black Tern (*Chlidonias niger;* 10 pairs) and Bluethroat (*Luscinia svecica;* 1 pair).

Biodiversity values within the immediate vicinity of the two proposed sites

Several biodiversity values of international importance are located in the immediate vicinity of the INPP and the two proposed sites of the NNPP. Two important habitats of European otter (*Lutra lutra*), one of Great Bittern (*Botaurus stellaris*), one of Spotted Crake (*Porzana porzana*) and one of Marsh Harrier (*Circus aeruginosus*) are on the shore of Lake Druksiai close to the proposed sites of the NNPP. All these species are designation values of the Druksiai SPA and the Druksiai SCI (Figure 7.6-9).

Some other species, listed in Annex II of the EU Habitat Directive and Annex I of the EU Bird Directive have been registered in the immediate vicinity of the INPP and the two proposed sites of the NNPP. During bird breeding period Tawny Pipit (*Anthus campestris*) inhabits a disturbed territory used as a site for excavating of gravel. The species is listed in Annex I of the EU Bird Directive. Spotted Crake (*Porzana porzana*) and Tawny Pipit (*Anthus campestris*) are included in the LRDB.

Two rare amphibian species, listed in Annexes II and IV of the EU Habitat Directive and included in the LRDB (*Triturus cristatus* and *Bombina bombina*), occur very close to the INPP (Figure 7.6-9). *Bombina bombina* inhabits water bodies heavily disturbed by humans. *Triturus cristatus* inhabits small water bodies in Tumelina forest.

A mixed colony of Cormorant (*Phalacrocorax carbo*), with about 500 nests registered, Grey Heron (*Ardea cinerea*), with about 150 nests, and of Great White Egret (*Egretta alba*), with a few nests, is located on the Lake Druksiai shore close to the Ignalina NPP. The Great White Egret (*Egretta alba*) is a new breeding bird species in Lithuania. It is listed in Annex I of the EU Bird Directive.

In close vicinity of the INPP the rare habitat "Fennoscandian deciduous swamp woods" (9080) is located. This valuable habitat is listed in Annex I of the EU Habitat Directive.

Large copper butterfly (*Lycaena dispar*) has been observed in a meadow about 2.5 km to the south from the INPP. This species is listed in the Annex II of the EU Habitat Directive.

Some rare plant species, included in the LRDB have been found close to the INPP (e.g., *Scolochloa festucacea, Eriophorum gracile).*

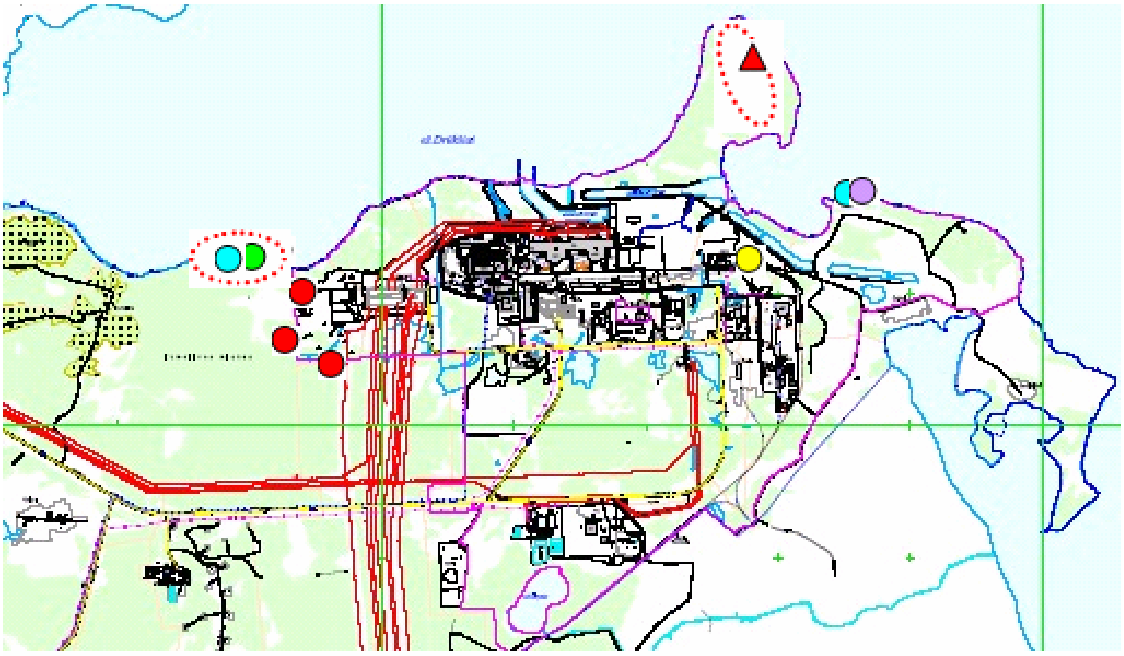


Figure 7.6-9. Location of most important biodiversity values in the immediate vicinity of the INPP and the two proposed sites. Legend: red pointed line – most frequently used habitat of European otter (*Lutra lutra*); sky blue spot – breeding habitat of Marsh Harrier (*Circus aeruginosus);* green spot – habitat of Great Bittern (*Botaurus stellaris);* yellow spot – breeding habitat of Tawny Pipit *(Antus campestris*); violet spot – breeding habitat of Spotted Crake (*Porzana porzana);* red spot – habitat of great crested newt *(Triturus cristatus);* red triangle – breeding colony of Great White Egret (*Egretta alba*).

Some rare invertebrate species have been registered close to the INPP. E.g., *Melitaea phoebe* (Lepidoptera, Nymphalidae) inhabits a meadow of the Smalvele river valley near Lake Druksiai close to the main building of the INPP. *Temelucha arenosa* (Hymenoptera, Ichneumonidae) has also been found in a meadow of the Smalvele river valley near the Lake Druksiai. *Aricia eumedon* has been found on the shore of Lake Druksiai about 2 km to the west from the INPP.

7.6.1.8 Terrestrial radioecological status of biodiversity

General issues about radioecology

Radioecology is a scientific discipline which studies how radioactive substances interact with nature, how different mechanisms affect the substances migration and uptake in food chain and ecosystems and what are aspects of the environmental impact of radioactive substances. Radioactivity originates from natural and anthropogenic sources, including radioactive materials used in industry and power generation.

It is known that modern nuclear power plants pollute the environment very little. Nevertheless, it is important to monitor radioactive pollution in relation to operating of NPPs and to study dispersion and transfer of radioactive materials in nature. An in international interest in the topic of protection of the environment from radiation is increasing.

Results of monitoring

It has been established that in 1996–2001, maximal values of ^{137}Cs activity in plants of forest ecotope ranged from 71 to 174, and in their soil it was up to 109 Bq/kg (Table 7.6-19). In forest ecotope the highest activity of this radionuclide was detected in *Hiloconium splendens* and *Pteridium aquilenium* (respectively 164 and 174 Bq/kg). In analyzed indicator sorts of plants highest values of ^{137}Cs activity ranged respectively from 102 up to 130 Bq/kg, and in their soil it was up to 108 Bq/kg (Table 7.6-19). In plants of meadow ecotope and in their soil the highest values of ^{137}Cs activity were the lowest and were respectively 26 and 30 Bq/kg (Table 7.6-19). In plants and soil the highest ^{137}Cs activity is detected in the forest and swamp ecotopes at the closets to Ignalina NPP Grikiniskiu reference site and in Tilze, located on the opposite side of INPP, on the other shore of the Lake Druksiai. In 2003–2005 and 2007 in INPP region values of ^{137}Cs specific activity in forest, swamps and meadow plants in most cases were similar or less than in 1996–2001 (Table 7.6-19).

Table 7.6-19. Values of specific activity of radionuclides (Bq/kg, d.w.) in tested species of plants in various ecotopes of the Ignalina NPP region.

Ecotope	Plant species	Range of radionuclides activity: minimal – maximal values							
		^{137}Cs			^{60}Co			^{90}Sr	
		1996–2001	2003–2005	2007	1996–2001	2003–2005	2007	1996–2005	2007
Forest	Lichenies	50–71	–	–	15	3	–	8–15	–
	Hilocomium splendens	30–164	29–80	31±4	3–28	<mdl–3	<mdl	6–26	6
	Vaccinium myrtillus	17–75	32–64	26±3	2–3	<mdl	<mdl	3–16	11
	Pteridium aquilinum	82–174	158–174	50±4	<mdl	<mdl	<mdl	31	–
	Dryopteris filix-mas	26–37	–	–	<mdl	–		–	–
	Calamagrostis arundinacea	7–43	34	14±1	–	<mdl	<mdl	6–8	6
	soil	22–109	29–46	–	<mdl–7	–		16–28	–
Swamp	*Sphagnum* sp.	28–104	27–76	70±5	2–4	<mdl	<mdl	6–12	7
	Calluna vulgaris	25–130	20–78	100±6	1	<mdl	<mdl	15	–
	Calla palustris	15–102	35–110	83±7	<mdl–10	<mdl	<mdl	10–30	20
	soil	20–108	25–47	–	<mdl–2	–		10–32	–
Meadow	meadow plants	4–26	–	–	3–9	–		6–83	–
	meadow moss	–	1	4±1	–	<mdl	1±0.3	–	1
	soil	11–30	–	–	<mdl	–		–	–

<mdl: under minimal detectable level

In 1996–2007, activities ^{134}Cs and ^{54}Mn of all examined plants at reference sites in forest, swamp and meadow, and the soil of their ecotopes were less than the minimal detectable level.

In 1996–2001, the greatest activity of ^{60}Co was detected in plants, at the closest to INPP Grikiniskiu reference site. From tested species of plants the greatest activity of this radionuclide was detected in *Hiloconium splendens* (up to 28 Bq/kg) (Table 7.6-19). In other tested species of plants, activity values of this radionuclide ranged from 1 to 10 Bq/kg or were less than minimal detectable level (Table 7.6-19). In the soil, ^{60}Co is detected only at the closest to INPP Grikiniskiu reference site. Activity of this radionuclide in the soil ranged from 2 to 7 Bq/kg or was less than minimal detectable level. In 1996–2007, activity values of ^{60}Co in the analyzed plants were less than minimal detectable level (Table 7.6-19).

In 1996–2005, highest values of ^{90}Sr activity in the forest and swamp plants were 12–30 Bq/kg, and in their soil 28–32 Bq/kg, and were less than ^{137}Cs (Table 7.6-19). The highest ^{90}Sr activity values are detected in meadow plants (up to 83 Bq/kg), in which values of this radionuclide were far higher than ^{137}Cs. At Tilze and Grikiniskiu reference sites ^{90}Sr activity in the tested plants was higher than in other reference site plants, located further from INPP. In 2007 ^{90}Sr activity values in plants were similar to those in 1996–2005 (Table 7.6-19).

The comparison of activity of radionuclides in the same species of tested plants in the region of Ignalina NPP and other regions of Lithuania demonstrates that after accidents at the Chernobyl NPP average values of activity ^{137}Cs in plants most contaminated with radionuclides were far higher in Varena region than in Ignalina NPP region (Figure 7.6-10). Values of ^{90}Sr activity in plants in Plunge and Varena regions differ very little or were higher than in Ignalina NPP region. During the analysis period (from 1994 till 2002), in plants of Plunge and Varena regions, the tendency of ^{137}Cs and ^{90}Sr activity decrease is observed (Figure 7.6-10). However, in the tested species of plants in Ignalina NPP region values of ^{137}Cs and ^{90}Sr specific activity during the entire analysis period (1996–2007) ranged in similar limits, i.e. the tendency of activity decrease in these radionuclides has not been observed (Figure 7.6-10).

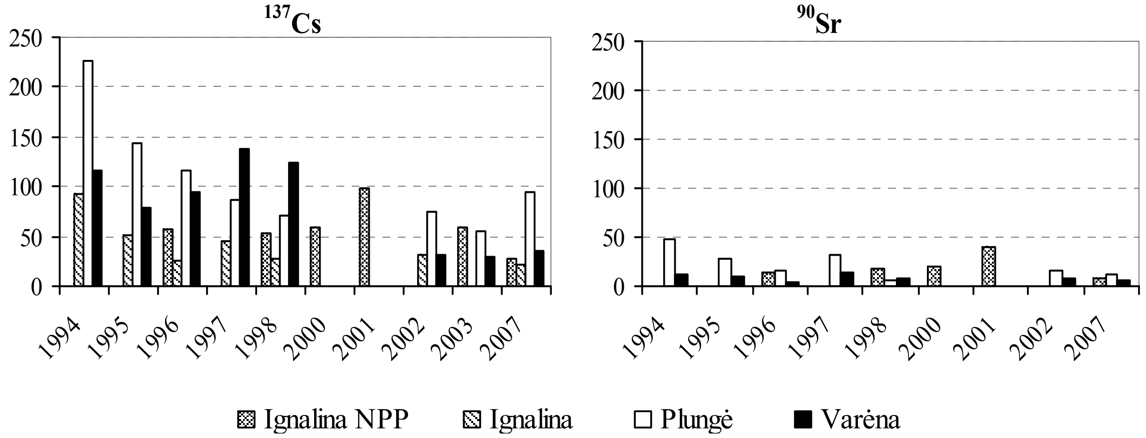


Figure 7.6-10. Average values of specific activity of ^{137}Cs and ^{90}Sr (Bq/kg d.w.) in plants at background monitoring stations in the INPP region, Ignalina, Varena, and Plunge regions.

7.6.2 Assessment of impacts on vegetation, fauna and protected areas

It is evident that there will be several factors which can have diverse impacts on biodiversity by various means. Furthermore, there may be impacts which will emerge in very long-term perspective and these impacts will depend on many factors which most probably cannot be foreseen today. Therefore it is worth mentioning that this assessment of impacts is based on factors that can be predicted at the time of this assessment – such phenomena as global warming or climate change cannot be taken into consideration with much emphasis. It is more reasonable to concentrate on the most evident and probable, foreseeable impacts in order to produce as clear and accurate assessment as possible and not include all possible long-term future situations which will not depend on this project.

As there are NATURA 2000 protected areas near by the project area, the impacts towards the NATURA 2000 designation values are assessed separately. Thereafter the impacts on terrestrial fauna, flora and habitats are assessed. The impacts on aquatic nature values (apart from NATURA 2000 values) are assessed in Section 7.1 and are therefore not repeated here.

Relevant impact factors

The construction, and further, the operation of a new nuclear power plant is presumed to influence the natural environment mainly through i) traffic, ii) noise and vibration, iii) direct construction impacts, and iv) aquatic environmental characteristic change in Lake Druksiai (water temperature, eutrophication, water flow, ice coverage). Later in the assessment these factors will be referred as i, ii, iii and iv and they include the following features:

i) The traffic during construction and operation is presumed to happen mainly through now existing routes and this traffic is not expected to create major impacts if compared to existing situation. During construction it can be expected that the traffic amounts will increase compared with power plant operation time (now or future), but this effect must be considered, however, relatively temporary (even though the construction will take for example 5 years).

ii) The noise and vibration levels will mostly affect the Lake Druksiai environment – this is supposed to be valid both for the construction period and operation period. In total the noise level is not assumed to rise significantly from the present situation.

iii) Direct construction impact is hereby defined to be immediate destruction of habitats, vegetation and possible populations of sessile fauna within the new power plant exact area and other operational areas which will be built. Both options for new locations are taken into consideration as well as areas intended for other use relating to the NNPP.

iv) Changes in aquatic environment are here assumed to be the most essential impact factors. The main impact issue is considered to be the thermal effect of the NNPP. Naturally also other aquatic characteristics may change directly or indirectly (such as eutrophication depending from e.g. waste water treatment systems), but the thermal effect is here considered to be the main impact (upon which the other changes to some proportion depend on). Changing the present situation (warmer or cooler) will most probably have the clearest effects on the surrounding natural environment of the NNPP. There will be three (3) impact options considered here (they are described more in detail in the aquatic environment impact assessment chapter and therefore not repeated here in details).

In order to illustrate the impacts of different thermal loads and cooling technology combinations in a concise and still comprehensive way, three scenarios were created based on the modelling results and hydrological, limnological and biological expert assessment of the probable effects. In all the scenarios the electricity production is assumed to be 3 400 MW_e but the cooling system and consequently the thermal load to the lake varies. The following scenarios were chosen to the assessment:

- Scenario T1 – Thermal load to the lake will be at maximum 3 160 $MW_{released}$. This corresponds approximately 1 700 MW electric energy produced by using direct cooling for heat dissipation. The remaining 1 700 MW_e will be produced using cooling towers. This scenario resembles roughly the conditions when both units of INNP were in operation.
- Scenario T2 – Thermal load to the lake will be at maximum 6 310 $MW_{released}$. This corresponds approximately 3 400 MW electric energy all produced by using direct cooling for heat dissipation. In this scenario the heat load and the temperatures in lake will rise compared to the period of INPP operation and to the scenario T1.
- Scenario T3 – Only cooling towers will be used for cooling and the thermal load to the lake will be negligible. In this scenario the lake water temperatures will decrease compared to the period of INPP operation and to scenarios T1 and T2.

Consequently, this assessment can, from the lake point of view, be considered roughly corresponding to production of 1 700 MWe (T1), 3 400 MWe (T2) and 0 MWe (T3) with direct cooling.

Due to the above explained issues the main focus of biodiversity impact assessment will be on Lake Druksiai water temperature change – other areas around Lake Druksiai (whether NATURA 2000 areas or other important areas) are not given much attention since it is rather evident that clearly the main effects of the NNPP will fall on Lake Druksiai (the most important effect, water temperature, cannot affect other water bodies further away and up-stream of Lake Druksiai). The above mentioned water temperature option will be later referred as T1, T2 and T3.

7.6.2.1 NATURA 2000 impact assessment

Assessment justification and values to be assessed

The NATURA 2000 network has been established to protect and maintain various, important biodiversity values. These so called *designation values* are nature values, which are the reason why the certain area has been selected to be part of the NATURA-protection network. There are two different types of NATURA 2000 areas and they have different designation values. Special Areas for Conservation (SACs, or Sites of Community Importance SCIs) are selected to protect habitats and animal species which are listed in official NATURA 2000 standard data form in chapters 3.1. (habitat types) and 3.2.c-3.2.g. (mammals, amphibians, fishes, invertebrates and plants of Annex II of the EU Habitat Directive). Special Protection Areas (SPAs) are selected to protect bird species which are listed in official NATURA 2000 standard data form in chapters 3.2.a (EU Bird Directive, Annex I species) and 3.2.b (regularly occurring migratory birds not listed on Annex I of the EU Bird Directive).

It should be noted that the NATURA 2000 impact assessment will concentrate strictly on these values, which are the designation values for each NATURA 2000 area. Other possible biodiversity values are discussed separately.

As it has been shown previously, there are many NATURA 2000 areas in the nearby NNPP region. However, as the main impacts of the NNPP are determined to link strongly to the possible alterations in water temperature (see above, Section 7.6.2), the emphasis should be focused on Lake Druksiai NATURA 2000-area since no reasonable, significant direct or relevant indirect effect will concern the areas nearby under normal power plant operation or construction (some indirect effects may arise such as increasing volume of people moving around the protected areas, but these factors are here considered to be marginal and also uncertain to predict). Also it is to be noted that there were no other projects indicated or identified which would be now ongoing or planned and would have relevant meaning as cumulative or summarizing factor to interact with the NNPP project in relation towards the NATURA 2000 designation values.

The assessment is concentrated on the favourable conservation status (hereafter FCS) of the designation values. FCS can be simply described to be a situation where a habitat type or species is doing sufficiently well in terms of quality and quantity and has good prospects of continuing to do so in the (predictable) future. Species must remain as viable component of their natural habitats on long-term basis, the natural range of the species (or habitats) is not reduced or is not likely to be reduced in the foreseeable future and there will be sufficient conditions to maintain habitats or populations on long-term basis. Any significant negative impact (changing the above mentioned factors) by the NNPP project (project alone or the sum of influences with any other project in progress now or now in planning) must not be caused to any designation value. It is not clearly or simply clarified what can be interpreted as significant negative impact and therefore FCS is used to measure this.

Within this NATURA 2000 assessment it is also taken into consideration what is valid for the precautionary principle in NATURA 2000 assessments. This means that if a certain risk cannot be excluded, according to the so called precautionary principle, such risk that the plan or project will have a significant effect, is considered to exist.

Impact assessment in detail

Traffic: The NATURA 2000 assessment has revealed (Table 7.6-20) that if the traffic during construction and operation would be organised through now existing routes, and if during construction it can be expected that the traffic amounts will increase compared with power plant operation time (now or future), this would not have a relevant negative impact on designation values. This conclusion will be valid, if no new roads would be built out of nowadays devastated (urban) territory (especially closer to Lake Druksiai, because the designation values are more or less ecologically related with the water ecosystems).

Noise, vibration and construction: Noise and vibration as well as construction of the NNPP could have a moderate negative impact on three species. No negative impact from those factors is expected on the remaining 5 species (designation values)(see Table 7.6-20).

Change in aquatic environment: Depending on water maximum temperature in Lake Druksiai, very different NNPP impacts on the NATURA 2000 area of Lake Druksiai are expected. The maximum temperature of the water will depend on NNPP thermal load. Three scenarios were analysed in this work: T1, T2 and T3. The highest negative impact on NATURA 2000 network values would occur if T2 scenario would be selected (thermal load to lake would be at maximum 6 310 $MW_{released}$ and the temperature would rise significantly). Option T2 has the greatest potential to have negative impact of almost all the species in question. The main impact factor would be the decrease of food resources (fish, insects and other aquatic animals). This would be the case in the very extreme conditions – most probably it is evident that even with rather high temperatures it is probable that there would be enough fish, insects, other aquatic animals and plants to maintain the favourable conservation status (FCS) of all the species. However, when taking precautionary principle into account, T2 must be considered to be an option, which can pose a threat of significant negative effect towards one or more Natura 2000 designation values (see Table 7.6-20). The species in question are ecologically fully dependent on the ecosystem of the lake. On the other hand, operation of the NNPP according to T1 or T3 scenarios would not have any significant negative impact on NATURA 2000 network values.

Table 7.6-20. Presumed essential impacts on NATURA 2000 protected areas (Lake Druksiai) relevant designation values, depending on construction site and cooling water scenario.*

DESIGNATION VALUE / NATURA-AREA	Traffic	Noise and vibration	Direct construction	T1	T2	T3
European otter (*Lutra lutra*) / Lake Druksiai LTZAR0029	No relevant impact, since traffic is directed mainly through present roads.	The present situation of noise intensity will not essentially change in long-term. If Site No. 2 would be selected for construction of the NNPP, a risk of disturbance could occur because the source of noise, in comparison with present situation, would be ten times closer to one of priority sites (most frequently used habitat which very likely is the breeding habitat) of the European otter *(Lutra lutra)*. Possible relevant negative impact in case of the second proposed site.	No known breeding or resting places of the species will be destroyed directly through construction. If Site No. 2 would be selected for construction of the NNPP, a risk of human disturbance could occur (noise, presence of people, blocking of dispersal/migration roads, etc). Especially big threat for the local population would occur because it is expected that construction work and new NPP could block dispersal and migration route of the local population. The otter is a shore species with large territories whose individuals are controlling when moving along the shore. Built and in other way disturbed territory is almost unsuitable habitat for the species, even for migration. Thus direct construction in case of Site 2 would decrease FCS of the species, if no mitigation measure would be implemented.	The present situation does not change significantly, there will be conditions equivalent to present conditions for the species to breed and use the area.	The significant warming of the lake does pose a potential risk of changes in composition of the fish community (fish is main food of the species). According to the predictions, even though the species composition of fish will most probably change, the biomass or amount of fish would not decrease and thus there would be enough food for the species to keep the FCS.	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.
Spined Loach (*Cobitis taenia)*/ Lake Druksiai LTZAR0029	No impact, not relevant (the Spined Loach is a fish).	No impact, not relevant.	Construction of the cooling water intake and outlet structures and the possible dredging may negatively affect the Spined loach population in the immediate vicinity of the site. The impacts are, however,	Because the present situation does not change considerably, any significant effects on the population are not expected.	Spined loach is tolerant for high water temperature and relative low oxygen concentrations. It is dwelling in the littoral zone were permanent anoxic conditions are unlikely. It also spawns in densely vegetated areas. Based on the	The littoral zone habitats will not be significantly altered from the present. Therefore no significant

DESIGNATION VALUE / NATURA-AREA	Traffic	Noise and vibration	Direct construction	T1	T2	T3
			considered local and temporal and will not affect survival of the spined loach population and FCS of the species.		habitat preferences it is considered quite tolerant to the eutrophication and warming affects and no significant adverse effects are expected.	impacts on spined loach population are expected.
Black-throated Diver (*Gavia arctica)/* Lake Druksiai LTZARB003	No impact, not relevant (the Black-throated Diver is a waterfowl).	Because the present situation of noise intensity will not essentially change in long-term, no relevant impact on the species is foreseen.	No nesting or resting places of the species will be destroyed through construction. No relevant impact on the species is foreseen.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the species to breed and use the area.	The significant warming of the lake does pose a potential risk of decrease of fish diversity. Possible negative impact on habitat quality (mainly feeding conditions and development of helophytes) of the species. Thus relevant negative impact. Even though the species composition of fish will most probably change, the biomass or amount of fish would not decrease and thus there would be enough food for the species. Development of helophytes in the lake could decrease the FCS of the species in the nearest future.	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.
Marsh Harrier (*Circus aeruginosus)/* Lake Druksiai LTZARB003	No relevant impact, since traffic is directed mainly through present roads.	The present situation of noise intensity will not essentially change in long-term. Independently which of the two proposed sites would be selected for construction of the NNPP, a risk of disturbance of the species could occur because the source of noise, in comparison with present situation, would be critically close to the breeding site of at least	No nesting or resting places of the species will be destroyed through construction. A risk of human disturbance could occur (noise, presence of people, etc) for one pair. FCS of the species would not change, if special mitigation measures would be implemented.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the species to breed and use the area.	Possible negative and positive impact on population of the species. Amount of a breeding habitat (helophytes – mostly *Phragmitetum australies* associations) would increase. Feeding conditions of the species could become worse. Because surroundings of the lake are mostly non-agricultural areas (very small part of agricultural areas are meadows or grazing areas), the main feeding areas of the species are located in the lake and adjoining wetlands. In spite of this	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.

DESIGNATION VALUE / NATURA-AREA	Traffic	Noise and vibration	Direct construction	T1	T2	T3
		one pair. Possible relevant very local (one pair) negative impact. However, equivalent amount of pairs compared to the present situation can breed in the future (FCS would not change) in case special mitigation measures would be implemented.			most likely there will be enough food resources for the species to maintain FCS.	
Spotted Crake, (*Porzana porzana)/* Lake Druksiai LTZARB003	No relevant impact, since traffic is directed mainly through present roads.	In case Site No. 1 would be selected for construction of the NNPP, a risk of disturbance could occur because the source of noise, in comparison with present situation, would be much closer to one of the breeding sites. Possible relevant impact in case of Site No. 1. In spite of this the FCS of the species would not change, if special mitigation measures would be implemented.	No nesting places of the species will be destroyed through construction. If Site No. 1 would be selected for construction of the NNPP, a risk of human disturbance could occur (noise, presence of people, etc) for one breeding site. If special mitigation measures would be implemented, the FCS of the species would not change.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the species to breed and use the area.	The significant warming of the lake does pose some risk of habitat change where species composition of plant community and water level could change causing a decrease of the shore terrestrial habitat suitability and quality for the species. However, the food resources for the species can be assumed to be adequate (insects and aquatic animals) to maintain the FCS.	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.
Little Crake (*Porzana parva)/* Lake Druksiai LTZARB003	No impact, not relevant, because breeding habitat of the species is mainly a shore	Because the present situation of noise intensity will not essentially change in long-term, no relevant impact on the species could be foreseen.	No nesting or resting places of the species will be destroyed through construction. No relevant impact on the species is foreseen.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the	Possible negative and positive impact on population of the species. Amount of a breeding habitat (helophytes – mostly *Phragmitetea australlis* assotiations) would increase. Feeding conditions of the species would become worse. However, it	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.

DESIGNATION VALUE / NATURA-AREA	Traffic	Noise and vibration	Direct construction	T1	T2	T3
	reedbed.			species to breed and use the area.	can be assumed that still it would be enough food (insects and other small animals) to maintain the FCS for the species.	
Black Tern (*Chlidonias niger)/* Lake Druksiai LTZARB003	No relevant impact, since traffic is directed mainly through present roads.	Because the present situation of noise intensity will not essentially change in long-term, no relevant impact on the species is foreseen.	No nesting, resting places and feedind sites of the species will be destroyed through construction. No relevant impact on the species is foreseen.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the species to breed and use the area.	Possible potential risk of oxygen lost, changes in habitat structure and damage of biodiversity. This might have both negative and positive impact on population. Amount of a breeding habitat would increase due to faster eutrofication of the lake. Feeding conditions of the species in the lake could become worse in very extreme case. However, it can be assumed that the will be enough food (mostly insects) to maintain the FCS.	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.
Bluethroat (*Luscinia svecica)/* Lake Druksiai LTZARB003	No relevant impact, since traffic is directed mainly through present roads.	Because the present situation of noise intensity will not essentially change in long-term, no relevant impact on the species is foreseen.	No nesting, resting places and feeding sites of the species will be destroyed through construction. No relevant impact on the species is foreseen.	Because the present situation does not change significantly, no relevant changes in temperature, there will be conditions equivalent to present situation for the species to breed and use the area.	Possible risk of habitat change (in case, if species would breed in lake shore wetland) where species composition of plant community and water level could change causing a decrease of the shore terrestrial habitat suitability, quality for the species. However, it can be assumed that the FCS will still be maintained here.	Since the temperatures will resemble the natural temperatures no significant negative impacts are expected.

* "Traffic", "Noise and vibration" include the disturbance during construction and future operation. "Direct construction" means direct impacts of construction. "T1", "T2" and "T3" mean different water temperature options explained in Section 7.6.2.

7.6.2.2 Assessment of impacts on terrestrial fauna

An initial conclusion is that impact of the NNPP on biodiversity would be focused on the cooling area (Lake Druksiai) and on the construction site. Thermal releases to Lake Druksiai and direct as well as direct damage of the NNPP construction site as a habitat would be the biggest threats for biodiversity. The noise levels and vibration levels are not expected to increase in comparison with the present situation and thus any other relevant impact of the NNPP on other territories and on other NATURA 2000 sites is not expected.

Impact of the thermal releases of the NNPP on the NATURA 2000 network sites Lake Druksiai SPA and Lake Druksiai SCI have been analysed above (see Section 7.6.2.1 for details). It was concluded that the thermal releases to Lake Druksiai will not have any significant direct negative impact on local terrestrial or semi-aquatic animals on territory covered by construction of the NNPP and on the lake, if special mitigation measures are be implemented. The animal species depending on the fish as food resource would have enough food also in the future with all the scenarios (T1, T2, T3) mentioned above since the amount of fish is not predicted to decrease – only the species composition can be expected to change in scenario T2.

Direct NNPP construction impact on terrestrial or semi-aquatic fauna could be relevant in the territory covered by construction and in its immediate vicinity. The impact will depend on the proposed sites for construction. Biodiversity values inhabiting or using the territory of the INPP and its surroundings were listed above in Section 7.6.1.7. Analyses of possible impact of the direct construction on these values allowed making a conclusion that noise and vibration, in relation with construction of the NNPP, will not have any negative impact on local terrestrial animal populations, provided certain mitigation measures are implemented (Table 7.6-21).

Increase of traffic intensity within the construction period could have a negative impact on local rare amphibians Great crested newt (*Triturus cristatus*) and European fire-bellied toad (*Bombina bombina*) mainly during their migrations and dispersal.

If the proposed Site 1 would be selected for construction of the NNPP, this could fully destroy the breeding habitat of the Tawny Pipit (*Anthus campestris*) and the species would become locally extinct.

In case Site 2 would be selected for construction of the NNPP, this could destroy part of the habitat of great crested newt (*Triturus cristatus)* and there is a risk that the isolated local population could decrease.

In both cases site 1 or 2, there will be a negative impact on local population of European fire-bellied toad (*Bombina bombina*). Part of the species habitat and part of the population would disappear.

Table 7.6-21. Presumed essential impacts of the NNPP on terrestrial fauna depending on proposed construction site.*

FAUNA SPECIES INHABITING IMMEDIATE VICINITY OF THE NNPP	Traffic	Noise and vibration	Direct construction
Tawny Pipit (*Anthus campestris*). 1-2 pairs.	No relevant impact in case of proposed Site No. 2, since traffic is directed mainly through present roads.	The present situation of noise intensity will not essentially change in the long-term. No relevant impact in case of proposed Site No. 2.	No nesting or resting places of the species will be destroyed through construction in case of proposed Site No. 2. If Site No. 1 would be selected for construction of the NNPP, than the breeding habitat of the species would be destroyed.
Great crested newt (*Triturus cristatus*). Numbers of population is not known.	A negative impact in case of proposed Site No. 1. Though traffic is directed mainly through present roads, an increase of intensity could damage population of the species.	The present situation of noise intensity will not essentially change in the long-term. No relevant impact.	No nesting or living places of the species will be destroyed through construction in case of proposed Site No. 1. If Site No. 2 would be selected for construction of the NNPP, then part of living and breeding habitat of the species would be destroyed.
European fire-bellied toad (*Bombina bombina*). Numbers of population is not known.	Though traffic is directed mainly through present roads, an increase of intensity would damage the population of the species.	The present situation of noise intensity will not essentially change in the long-term. No relevant impact.	In both cases of Site No. 1 or No. 2 part of living and breeding habitat of the species would be destroyed.
A mixed colony of Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta alba*). About 500, 150 and few nests respectively.	No relevant impact, since traffic is directed mainly through present roads.	The present situation of noise intensity will not essentially change in the long-term. No relevant impact.	No nesting or resting places of the species will be destroyed through construction. A risk of human disturbance could occur (presence, visits of people, etc).
Lycaena dispar. Numbers of population is not known.	No relevant impact, since traffic is directed mainly through present roads.	The present situation of noise intensity will not essentially change in the long-term. No relevant impact.	No living places of the species will be destroyed through construction.

* Main definitions ("Traffic", "Noise and vibration" and "Direct construction") are as in Table 7.6-20.

There is a risk that when constructing the NNPP a mixed colony of Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta *alba*) would be damaged due to human disturbance (very likely visits of people, recreation, etc).

No negative impact of the NNPP on the Large copper butterfly (*Lycaena dispar*), inhabiting a meadow about 2.5 km to the south from the INPP, is expected.

7.6.2.3 Impact assessment on terrestrial flora and habitats

Direct NNPP construction impact on terrestrial flora and rare habitats in the territory covered by construction and in its immediate vicinity was analysed. Biodiversity values inhabiting or using the territory of the INPP and its surroundings were listed above in Section 7.6.1.7 Analyses of possible impact of the direct construction on these values allowed to make a conclusion that the traffic, noise and vibration as well as direct construction of the NNPP, will not have any negative impact on local terrestrial plants and protected habitats (Table 7.6-22).

Table 7.6-22. Presumed essential impacts of the NNPP on terrestrial flora and rare habitats, depending on proposed construction site.*

PROTECTED FLORA SPECIES AND HABITATS IN IMMEDIATE VICINITY OF THE NNPP	Traffic	Noise and vibration	Direct construction
Scolochloa festucacea	No relevant impact, since traffic is directed mainly through present roads.	No relevant impact.	Independently on which proposed site would be selected, no habitat of the species will be destroyed through construction of the NNPP.
Eriophorum gracile	No relevant impact, since traffic is directed mainly through present roads.	No relevant impact.	Independently on which proposed site would be selected, no habitat of the species will be destroyed through construction of the NNPP.
Habitat 9080, Fennoscandian deciduous swamp woods	No relevant impact, since traffic is directed mainly through present roads.	No relevant impact.	Independently on which proposed site would be selected, the area covered by the habitat 9080 would not be destroyed through construction of the NNPP.

* Main definitions (“Traffic”, “Noise and vibration” and “Direct construction”) are as in Table 7.6-20.

7.6.2.4 Summary of biodiversity impacts

It can be concluded that impacts of the NNPP project on biodiversity focuses quite strictly on Lake Druksiai and its immediate vicinity. The aquatic biodiversity impacts are described and assessed in Section 7.1. This assessment concentrates on terrestrial biota and Natura 2000-values. The most important impacts can be summarized as follows:

Impacts on NATURA 2000 values

There will be no significant negative impact of the traffic on NATURA 2000 designation values (Table 7.6-23).

The negative impact of the noise would be caused by increase of a risk of disturbance. The risk would increase because the source of noise, in comparison with present situation, would be critically close to breeding sites of some pairs (individuals) of the Natura designation species and could disturb them. The negative impact of the "direct construction" would be caused by increase of a risk of human disturbance (during the construction) of designation species by expected increase of visits, presence of people, whichcould disturb them (especially within their breeding period).

Table 7.6-23. Severity of presumed essential impacts of the NNPP on NATURA 2000 designation values, depending on proposed construction site and water cooling scenario.*

DESIGNATION VALUE / NATURA-AREA	Traffic	Noise and vibration	Direct construction	T1	T2	T3
European otter (*Lutra lutra*) / Lake Druksiai LTZAR0029	-	2x	2x	-	x (<70%)	-
Spined Loach (*Cobitis taenia)*/ Lake Druksiai LTZAR0029	-	-	-	-	x (<30%)	-
Black-throated Diver (*Gavia arctica)/* Lake Druksiai LTZARB003	-	-	-	-	x	-
Marsh Harrier (*Circus aeruginosus)/* Lake Druksiai LTZARB003	-	1, 2x(20%)	1, 2x(20%)	-	x (<30%)	-
Spotted Crake (*Porzana porzana)/* Lake Druksiai LTZARB003	-	1x(20%)	1x(20%)	-	x (<30%)	-
Little Crake (*Porzana parva)/* Lake Druksiai LTZARB003	-	-	-	-	x	-
Black Tern (*Chlidonias niger)/* Lake Druksiai LTZARB003	-	-	-	-	x	-
Bluethroat (*Luscinia svecica)/* Lake Druksiai LTZARB003	-	-	-	-	x	-

* Main definitions are as in the Table 7.6-20. Symbols used: "-" – no negative impact; "x" – negative impact; "xx" – very big negative impact; "1" and "2" – proposed construction site. Percents mean part of the local (of Lake Druksiai) population under negative impact.

Impact of water temperature changes in Lake Druksiai, depending on the thermal load to the lake from the NNPP (scenarios T1, T2, and T3; see Section 7.6.2 for details), would have different impact predictions on NATURA 2000 values. Scenarios T1 and T3 are not likely to cause negative impacts on NATURA 2000 designation values. However, the effects on the ecology should be constantly monitored and mitigation measures implemented if applicable.

Scenario T2 has the largest potential to cause significant negative impacts. All species (perhaps with the exception of the Bluethroat) are dependent on the lake ecosystem. Possible impacts could be significant decrease in populations if the temperatures would rise so high that the relevant food resources would become scarce. It is however likely that even if the changes in species composition would be significant the amount of fish and other relevant food resources (insects) would not decrease in biomass meaning that the lake would have sufficient amount of suitable food for the above mentioned species.

Taking the precautionary principle into consideration, it cannot be ruled out that scenario T2 can cause significant negative impacts. This could be caused by decrease of quality of their feeding conditions (amount or quality of food) on habitats of the lake ecosystem or in sites ecologically dependant on the lake ecosystem; and by decrease of quality of their habitat (mostly breeding: vegetation amount, species composition, horizontal and vertical structure, etc.).

Depending on the species, up to 70 % members of population (four biggest populations were analysed only) would be influenced by this negative impact. If no mitigation measures would be implemented, in the long-term the negative impact of the T2 scenario could lead to decrease of the FCS of local populations of the European otter (*Lutra lutra*) and Black-throated Diver (*Gavia arctica*).

Impacts on terrestrial fauna

Noise and vibration, in relation with construction of the NNPP, will not have any negative impact on local terrestrial animal populations (Table 7.6-24).

Increase of traffic intensity within the construction period would have a negative impact on great crested newt (*Triturus cristatus*) and European fire-bellied toad (*Bombina bombina*). It is expected that this would cause a higher (in comparison with present situation) mortality rate of the populations of these two species (more of these amphibians would be run over by cars).

Table 7.6-24. Severity of presumed essential impacts of the NNPP on terrestrial fauna depending on proposed construction site.*

TERRESTRIAL FAUNA SPECIES IN IMMEDIATE VICINITY OF THE NNPP	Traffic	Noise and vibration	Direct construction
Tawny Pipit (*Anthus campestris*).	-	-	1xx
Great crested newt (*Triturus cristatus*).	2x	-	2x
European Fire-bellied Toad (*Bombina bombina*)	1,2x	-	1,2x
A mixed colony of Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta alba*)	-	-	1,2x

* Definitions and symbols are as in Table 7.6-23.

If the proposed Site No. 1 would be selected for construction of the NNPP, this would fully destroy the breeding habitat of the Tawny Pipit (*Anthus campestris*) and the species would locally extinct. If the proposed Site No. 2 would be selected for construction of the NNPP, this could destroy part of habitat of great crested newt (*Triturus cristatus)* and there is a risk that the population could decrease or even disappear in the long-term.

Both sites 1 and 2 will have a negative impact on the local population of European fire-bellied toad (*Bombina bombina*). Part of the species habitat will be destroyed and part of the population would disappear. A mixed colony of Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta alba*) could be damaged due to visits of people, recreation, etc.

Any negative impact of the NNPP on other conservation values (species included in the Annex I of the EU Bird Directive, Annex II of the EU Habitat Directive and listed in the LRDB), is not expected.

Impacts on terrestrial flora and habitats

Traffic, noise and vibration as well as direct construction of the NNPP will not have any significant negative impact on local terrestrial plants and protected habitats.

7.6.2.5 Summary of radioecological impacts

Many years' tests (1994–2007) of radionuclide activity in terrestrial flora and its soil in the Ignalina NPP region have shown that the greatest impact on the radioecological state of flora of this region and its soil is due to ^{137}Cs, the activity of which in these components during the entire period of testing has not decreased, but ranged in similar limits. However, in terrestrial flora of Ignalina NPP region activity of ^{137}Cs and also ^{90}Sr, was similar or lower than in flora of other regions of Lithuania (Plunge, Varena and Ignalina). Main amount of ^{137}Cs, penetrated into terrestrial ecosystem, accumulates in soil (thickness 10-15 cm), where characteristically for this radionuclide, as opposite to ^{90}Sr, a so-called aging process occurs, i.e. the longer ^{137}Cs stays in solid, the stronger it is tight into it. In soil, due to increased ^{137}Cs fixation, flow of this radionuclide from the soil may decrease up to ten times. Therefore, processes of natural cleaning of this soil contaminated by this radionuclide are processed much slower than of other radionuclides. Plants play a great part in the process of cleaning of soil, contaminated by radionuclides, especially ^{137}Cs.

Based on data of the performed analysis, it may be stated that the radioecological state of flora and its soil at Ignalina NPP region is quite good; however, assessing natural possibilities of soil cleaning of ^{137}Cs, impact of new NPP to the radioecological state of the region should be lower than of existing Ignalina NPP.

7.6.3 Mitigation measures

7.6.3.1 NATURA 2000 issues

In case the project or plan will cause significant negative impact on NATURA 2000 designation values, it is still possible to proceed with the project or plan. However, certain requirements must be met, and they are explained in Habitat Directive 92/43/EEC Article 6(4).

It must be shown that the alternative which is selected to put forward for approval, damages least the designation values and no other feasible alternative with less impacts exists. There must also be imperative reasons of overriding public interest. This imperative reason of overriding public interest is, however, not defined within the Directive even though such things as human health, safety and beneficial consequences for the environment are mentioned as examples. Services of general interest have been described by the European Commission as "*activities of commercial service fulfilling missions of general interest, and subject consequently by the member states to specific obligations of public service. It is the case in particular of services in transport, energy, communication networks".* Also the reason must be genuinely overriding and therefore must be also a long-term interest. The NNPP would, based on what is said above, seem to fulfill the qualifications for this imperative overriding reason as the effects on global warming can be interpreted to be beneficial and energy production is essential for Lithuanias economy as well as local economy and society. The outlet and inlet solutions as well as cooling systems can be selected so that a least damaging situation is reached meaning that for NATURA values (as well as many other biodiversity values) it is important that the lake water temperature would remain at the present level. Unless the mitigation measures and application of other safeguards is not sufficient, compensatory measures must be considered. The compensatory measures adopted must always be communicated to the European Commission (*European Commission, 2007*).

An impact assessment (see Section 7.6.2) analysis shows that negative impact of the NNPP should be minimised for three designation values. If Site 2 will be selected for construction of the NNPP, mitigation measures should be implemented for European otter (*Lutra lutra*) and for Marsh Harrier (*Circus aeruginosus*; see Table 7.6-25). In order to assure (enforcing the precautionary principle) the FSC of these two species, it is recommended to establish a buffer zone on the lake shore to be managed out of development. The zone would decrease a negative effect of disturbance of the species and would be used as a migration and dispersal corridor for European otter (*Lutra lutra*) and many other species ecologically related to the lake ecosystem.

Noisy construction work impact can be minimised if it is not performed in the main breeding period of the designation species. The main breeding period of the Marsh Harrier (*Circus aeruginosus*) in Lithuania lasts from April to the end of June.

Table 7.6-25. NNPP negative impact mitigation mesures for the designation values in the proposed construction Site 2.*

DESIGNATION VALUES	Noise and vibration	Direct cons-truction	Mitigation measures
European otter (*Lutra lutra*)	x	x	Moving proposed Site 2 a minimum of 200 m from the Lake Druksiai shore (to the south) would form a buffer zone between the NNPP (as disturbance source for animals) and the lake shore, as an ecologically very important area - a migration corridor for various animals, especially for the European otter (*Lutra lutra*). The buffer zone should be out of urbanization and development. It should remain as natural as possible. Forming the buffer zone of Site 2 would decrease the effect of noise and vibration on important nearest habitat of the European otter (*Lutra lutra*) in the lake. The measure would allow maintaining FCS of the species because the main migration and dispersal corridor of the species (as well as of many other animal species, ecologically related to the lake ecosystem), would be secured in long-term.
Marsh Harrier (*Circus aeruginosus*)	x(20%)	x(20%)	Moving proposed Site 2 a minimum of 200 m from the Lake Druksiai shore (to the south) would form a buffer zone between the NNPP (as disturbance source for animals) and the lake shore. Performing loud construction works outside the main breeding period of the species (April – June) would diminish noise and vibration disturbance towards the species thus saving favourable conservation status of one pair (roughly about 20 % of the total population) breeding close to the proposed second construction site.

* Definitions and symbols are as in Table 7.6-23.

If Site No. 1 will be selected for construction of the NNPP, mitigation measures should be focused on Marsh Harrier (*Circus aeruginosus*) and Spotted Crake (*Porzana porzana*) which have been registered here. They are considered as nearest designation values breeding on the lake shore wetland and in the reedbed. In order to maintain FSC of these two species it is recommended to establish a buffer zone on the lake shore to be managed out of development (Table 7.6-26). The zone would decrease a negative impact of disturbance of the species and would be used as a migration and dispersal corridor for European otter (*Lutra lutra*) and many other species ecologically related to the lake ecosystem. Most of the area to the east from Site No. 1 and potentially suitable as a buffer zone is already narrower than 200 m. Nevertheless, this migration corridor is recommended and beneficial for various animal species considered.

Loud construction works are recommended to be carried out outside the main breeding period. Main breeding period of the Marsh Harrier (*Circus aeruginosus*) in Lithuania lasts from April until late June, and Spotted Crake (*Porzana porzana*) breeds from early May to late June.

Table 7.6-26. NNPP negative impact mitigation measures for the designation values in the proposed construction Site No. 1.*

DESIGNATION VALUES	Noise and vibration	Direct cons-truction	Mitigation measures
Marsh Harrier (*Circus aeruginosus)* Spotted Crake (*Porzana porzana)*	x(20%) x(20%)	x(20%) x(20%)	If the proposed Site No. 1 would be selected for construction of the NNPP, it is recommended to save the existing buffer zone between the channel and the lake. The buffer zone is recommended to remain as natural (present state) as possible. Loud construction works are recommended to be carried out outside the main breeding period of these species (breeding period of the Marsh Harrier (*Circus aeruginosus*) in Lithuania: April – June; of the Spotted Crake (*Porzana porzana*): May – June). This mitigation measure would separate the NNPP (source of the disturbance), and the nearest habitats of the Marsh Harrier (*Circus aeruginosus*) as well as the Spotted Crake (*Porzana porzana*), and decrease a negative impact of noise and vibration. It would most probably ensure the successful breeding of the pairs located not far from the proposed Site No. 1.

* Definitions and symbols are as in Table 7.6-23.

Independently of which site will be selected for construction of the NNPP, it is recommended to minimise potential negative impacts of the NNPP for European otter (*Lutra lutra*). In order to assure (enforcing the precautionary principle) the FCS of the species, it is suggested to take special measures in the buffer zone of the NNPP. As it was described above, it is recommended to manage the zone out of development. It is assumed that the zone would decrease a negative effect of disturbance of the species and would be used by European otter (*Lutra lutra*) and also by other species ecologically related with the lake ecosystem as a migration and dispersal corridor.

It could be that due to unnaturally high water temperature the cooling water discharge channel of the NNPP is an obstacle for the otter (*Lutra lutra*) and other terrestrial animals when using their migration corridor (the buffer zone). This means that the FCS of the European otter (*Lutra lutra*) in the area close to the INPP may even now not be assured, and it would not be assured in the future, after the NNPP would have been constructed. The status of the FCS of the otter is today not known as there is no data about population trend of the species at all. In order to re-establish the blocked migration corridor for the otter (*Lutra lutra*) it is recommended that a closed "bridge" (like a water-pipe of a rather great diameter) is constructed to be placed on the very shore of the lake across the channel. The western border of the buffer zone/otter migration corridor next to the NNPP and to the cooling water discharge channel should be fenced. Fences will direct the migrating mammals to the shore and to the “bridge”.

It is well known that otters are using underground openings when crossing highways or roads. In many European countries there is a good practice when protecting otters where their migration roots and human roads cross. Similar experience could be applied when constructing the NNPP in Lithuania.

It is recommended that negative impact of the NNPP would be minimised for also other biodiversity values next to Natura 2000 designation values. If Site No. 2 will be selected for construction of the NNPP, mitigation measures are recommended to be focused on European fire-bellied toad (*Bombina bombina*) and on great crested newt (*Triturus cristatus*)(Table 7.6-27*)*. In case Site No. 1 would be selected for the construction of the NNPP, it would necessary to implement mitigation measures for European fire-bellied toad (*Bombina bombina*)(see Table 7.6-27).

In case Site No. 1 would be selected for the NNPP construction, it is recommended to take mitigation measures towards Great White Egret (*Egretta alba*) breeding near the project area*.* This is a bird species which according to the EU Bird Directive ought to be announced as a designation value of the Lake Druksiai SPA. The breeding site of the Great White Egret is a mixed colony of Cormorant (*Phalacrocorax carbo*)*,* Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta alba*). It is located on the Lake Druksiai shore close to the INPP. The total colony is recommended to be protected since all the birds in the colony are ecologically related. If necessary, some populations (e.g. Cormorant (*Phalacrocorax carbo*)) could be controlled.

Table 7.6-27. NNPP negative impact mitigation mesures for the biodiversity Habitat Directive annex IV species.*

DESIGNATI ON VALUES/ PROPOSED SITES FOR CON-STRUCTION	Traffic	Direct const-ruction	Mitigation measures
European fire-bellied toad (*Bombina bombina*) Proposed construction Sites No. 1 or No. 2 great crested newt (*Triturus cristatus*). Proposed construction Site No. 2.	x	x	In relation with new construction activities traffic in the NNPP area and its surroundings would increase. Therefore it is recommended to minimize significantly the risk of the European fire-bellied toad (*Bombina bombina*) and great crested newt (*Triturus cristatus*) to be run over by road traffic on existing and new roads. A species management plan is recommeded to be prepared, and it is recommended to be confirmed and implemented by the project developer of the NNPP. Detailed studies of ecology of the species in selected construction site and its immediate vicinity are recommended. This should include mapping breeding habitats, wintering sites, main migration and dispersal routes. Based on this data it is possible to get adequate data on the species. In the management plan should be indicated: - ranges where roadsides are to be blocked (fence) in order to prevent crossing of the road by those amphibians; - sites where special animal migration underground openings (if necessary; co-ordinating with water management measures; to be used not only by European fire-bellied toad (*Bombina bombina*) but also by other amphibians, small mammals (including even single individuals of the European otter (*Lutra lutra*), etc.); - wintering sites to be saved or/and created; - small breeding waterbodies to be saved and/or created., etc. The management plan should be integrated into right development and construction plans and implemented together with the NNPP construction works.
A mixed colony of Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and of Great White Egret (*Egretta alba*). Proposed construction Sites No. 1 or No. 2	-	x	A possible risk that when constructing the NNPP the colony would be damaged due to very likely visits of people and local recreation. Territory of the colony and rest part of the peninsula is recommended to be included into above mentioned buffer zone between the NNPP and Lake Druksiai. The main goal of the buffer zone should be securing the long-term functioning of migration and dispersion of the terrestrial and semi-terrestrial animals (including European otter (*Lutra lutra*)) on the lake shore and protection of breeding habitats of other valuable species. The buffer zone should be closed for visitors but open for terrestrial species moving along the lake shore.

* Definitions and symbols are as in Table 7.6-23.

7.7 Landscape and land use

7.7.1 Present state of the environment

The proposed new NPP will be constructed and operated within the INPP industrial area. The landscape of the sites is industrial and is characterized by power production units and buildings connected to power production operation (ancillary facilities, operative spent fuel storage facility, household wastewater treatment plant, ducts for the district heating system of Visaginas and the electricity transmission lines), see Figure 7.7-1. The most visible part of the existing power plant is the ventilation stacks.

Figure 7.7-1. Present landscape of the INPP industrial area and NNPP sites.

The landscape around the nuclear power plant is mainly composed of forests and wetlands. Residential areas consist of small villages with traditional houses. Lake Druksiai is a major natural landscape element with associated activities (fishing, recreational use).

The landscape of the Lake Druksiai watershed is characterised by a relief formed during glacial periods, consisting of picturesque mountain ridges, ravines, lakes, and plains as well as by pine forests and vast water meadows (Figure 7.7-2) (*Pauliukevicius G. et al., 1997*).

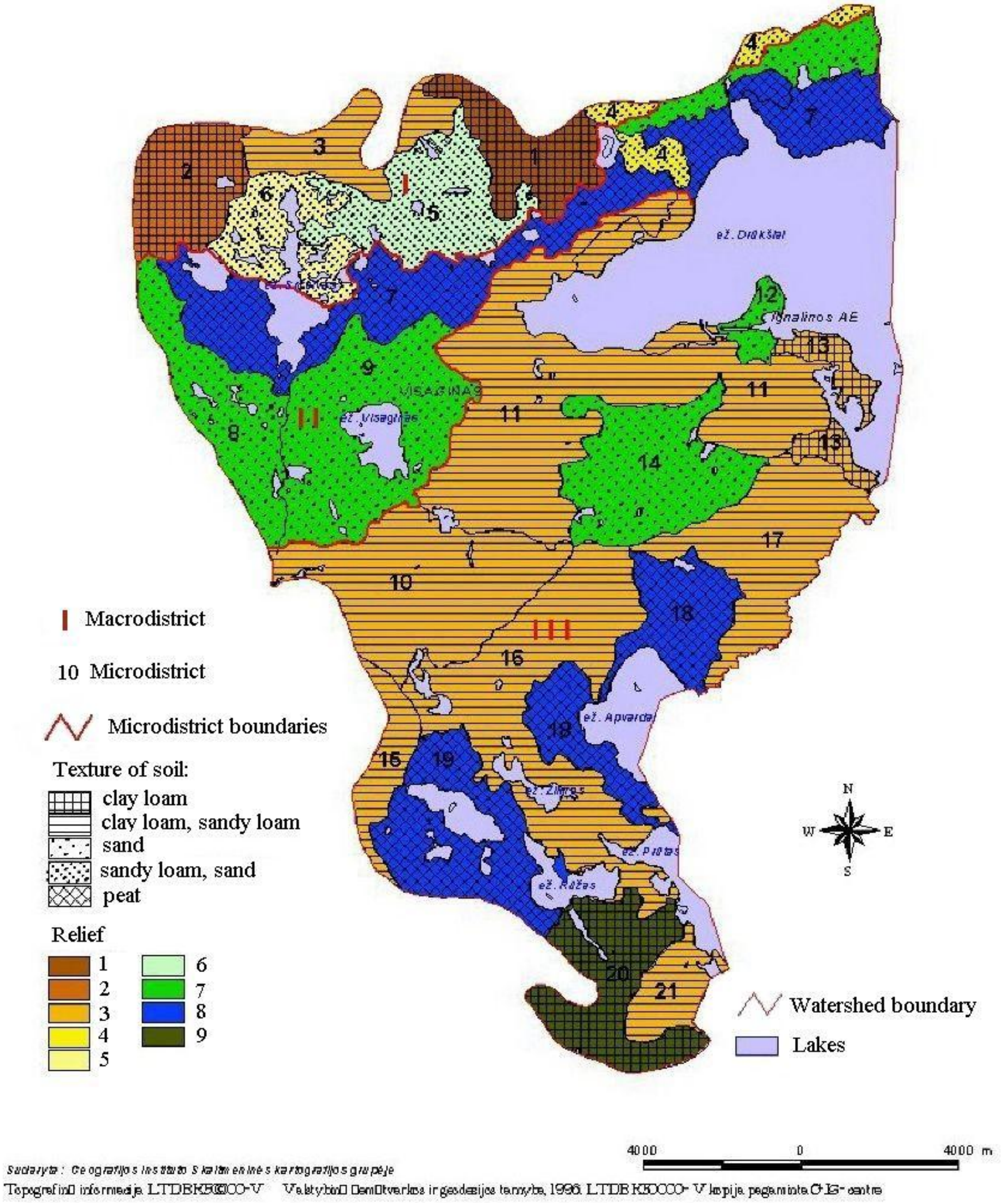


Figure 7.7-2. Landscape types in the Lake Druksiai watershed (*Pauliukevicius G. et al., 1997*).

The most valuable landscape areas are located far away from the new NPP. Smalvos hydrological reserve, Smalvos landscape reserve and Tilzes geomorphological reserve are protected territories within a radius of 10 km from the new NPP (see Figure 7.8-1 in the next Section 7.8). Pusnies protected territory is located about 13 km from the new NPP sites. Grazutes Regional Park is located about 15 kilometres from the proposed site alternatives for the new NPP.

Grazutes Regional Park covers 29 471 hectares and is aimed at preserving the landscape of the Sventoji river basin with its lakes, forests, its natural ecosystem as well as the cultural heritage values, maintaining them and rationally using them. Pine forests (72 %) and birch forests (17 %) prevail in the Park. The average forest age is 65 years.

The Smalvos protected hydrographical territory also presents landscape values with its undulated relief and particular ecological formations.

7.7.2 Assessment of impacts on landscape and land use

The landscape in the Lake Druksiai watershed has degraded because of the building and operation of INPP, Visaginas town and related infrastructure. According to the State Research (*Pauliukevicius G. et al., 1997*), it was determined that 1.43 % of the watershed (not taking the lake into account) was damaged irreversibly. There are abandoned farming lands (1.56 %) and a reduction of the forest area (3.83 %). Figure 7.7-3 illustrates damages to the initial landscape in the lake Druksiai watershed.

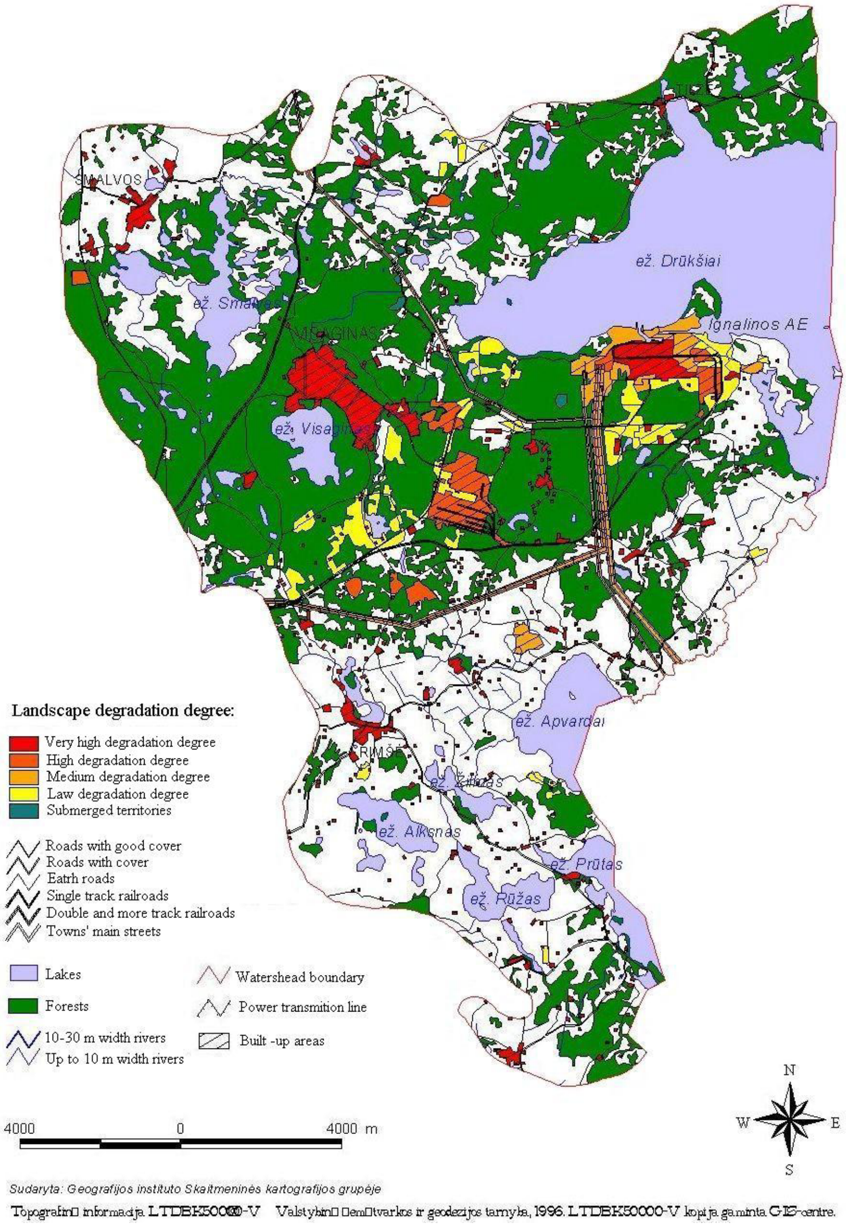


Figure 7.7-3. Landscape degradation degree in the Lake Druksiai watershed (*Pauliukevicius G. et al., 1997*).

The ratio between the natural and semi-natural territories and technogenic-urbanized areas in the Lake Druksiai watershed is 21.4. Natural and semi-natural areas also prevail in the whole 30 km area around the INPP. Though the building of INPP and Visaginas town has considerably (twice) reduced this ratio, it remains a few times higher than elsewhere in Lithuania (7.9) (Utena county – 10.6, Ignalina district – 10.9). Thus, it may be concluded that the Lake Druksiai watershed is predominated by comparatively natural and poorly culturalized landscape with a hotbed of intensive technogenization. The mentioned ratio is changing in the territory of Visaginas and INPP due to deserted farmlands and renaturalization of recultivated areas (*Environmental Impact Assessment Report U1DP0, 2007*).

The shores of Lake Druksiai are predominantly forested, thus significantly reducing the view over the lake from near-shore areas. There are only a few points where larger amounts of people occur by the lake shore. The view from two such points has been presented in photomontages prepared. Additionally photomontages using the aerial photograph of Figure 7.7-1 have been prepared. The photomontages show the landscape after the new nuclear power plant has been built. Photomontages for two units and two units with cooling towers at site 1 and site 2 are presented in this EIA Report as these represent the greatest impact on landscape. The viewing points for ground-level photomontages are presented in Figure 7.7-4. From Viewpoint 2 the NNPP at Site 2 will not be visible. The photomontage pictures showing the impact of the NNPP on existing landscape are presented in Figure 7.7-5 to Figure 7.7-14.

Figure 7.7-4. Location of viewing points in ground-level photomontages.

Figure 7.7-5. Aerial photograph - Site 1 with two NNPP units.

Figure 7.7-6. Aerial photograph – Site 1 with two NNPP units and cooling towers.

Figure 7.7-7. View 1 – Site 1 with two NNPP units.

Figure 7.7-8. View 1 – Site 1 with two NNPP units and cooling towers.

Figure 7.7-9. View 2 – Site 1 with two NNPP units.

Figure 7.7-10. View 2 – Site 1 with two NNPP units and cooling towers.

Figure 7.7-11. Aerial photograph – Site 2 with two NNPP units.

Figure 7.7-12. Aerial photograph – Site 2 with two NNPP units and cooling towers.

Figure 7.7-13. View 1 – Site 2 with two NNPP units.

Figure 7.7-14. View 1 – Site 2 with two NNPP units and cooling towers.

The following conclusion can be made: construction of the new NPP near the INPP will produce no greater effect of landscape degradation and will not disrupt the ratio between the natural and anthropogenic territories. Only at a few places by the lake shore will the NNPP be visible to larger amounts of people. The impacts on landscape will therefore not be significant.

7.7.3 Mitigation measures

Landscaping, selection of proper design, materials and construction types and planting of greenery will be used to enhance the appearance of the new NPP.

During the necessary improvement and possible restoration of the road network in the new NPP region, road culverts will be repaired or additionally installed were necessary. Therefore the existing flooded areas will be drained and restored to forest or agriculture.

7.8 Cultural heritage

7.8.1 Present state of the environment

The following territories are protected inside a radius of 10 km from the new NPP: Smalvos hydrological reserve, Smalvos landscape reserve and Tilzes geomorphological reserve (Figure 7.8-1). Pusnies protected territory is located about 13 km from the new NPP.

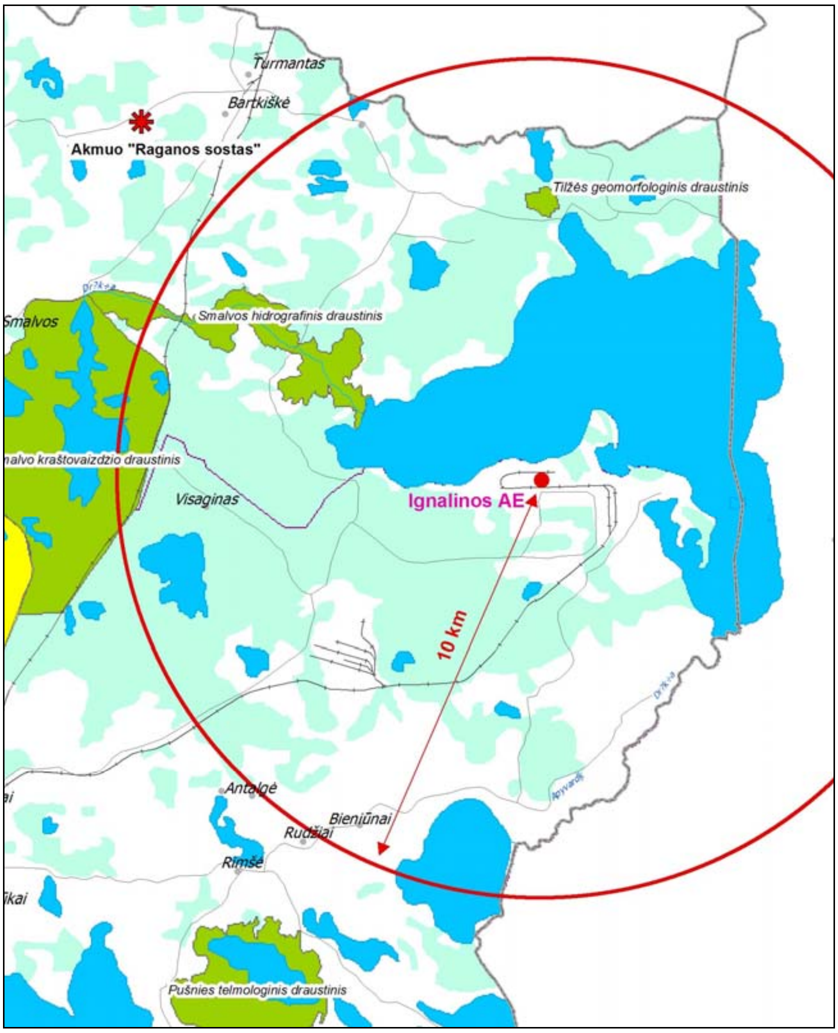


Figure 7.8-1. Protected territories (indicated in green) at a distance of 10 km from the new NPP.

There are seven cultural heritage sites in the vicinity of the new NPP: Petriskes settlement antiquities I, Petriskes mound, Petriskes settlement antiquities II, Grikiniskes settlement antiquities III, Grikiniskes settlement antiquities II, Grikiniskes settlement antiquities I and Stabatiskes manor site (Figure 7.8-2).

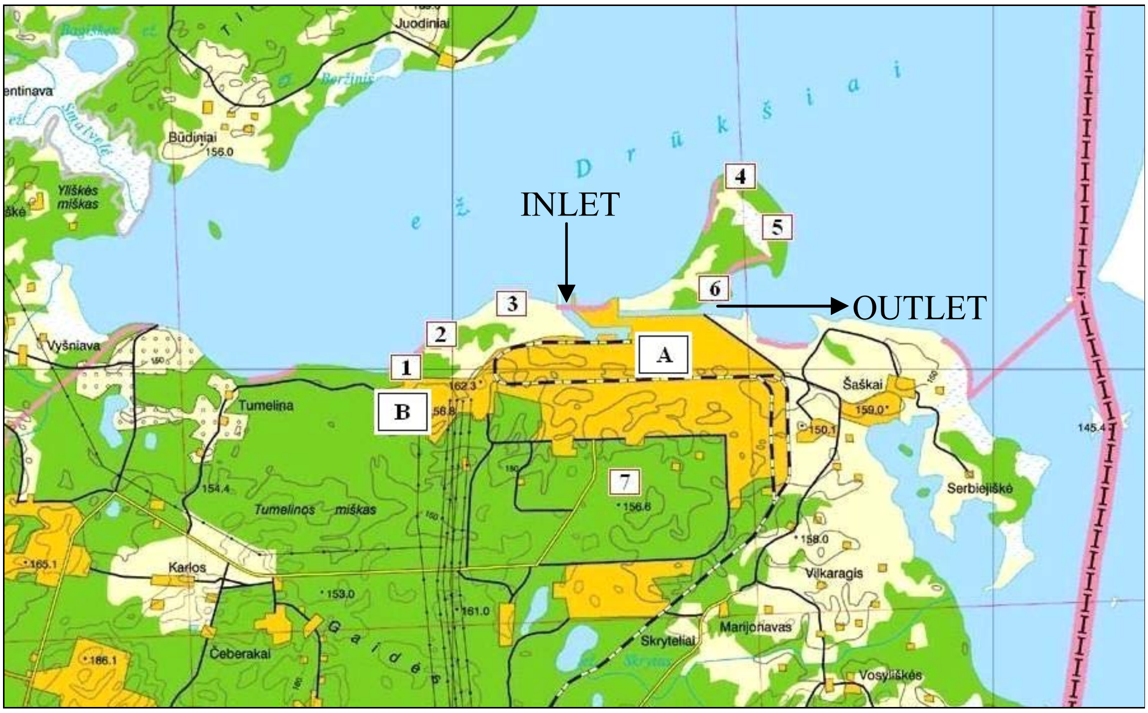


Figure 7.8-2. Cultural heritage sites in the vicinity of the new NPP sites A and B: 1 – Petriskes settlement antiquities I; 2- Petriskes mound; 3 – Petriskes settlement antiquities II; 4 – Grikiniskes settlement antiquities III; 5 – Grikiniskes settlement antiquities II; 6 – Grikiniskes settlement antiquities I; 7 – Stabatiskes manor site.

On some hills of the region, there are several mounds possibly used for timbered fortresses such as Rimses, Ceberaku, Pasamanes (so called Baznyciakalnis A1537) Svegzdziunu, Rapusiskiu etc. (*Pauliukevicius G. et al., 1997*). These mounds and other cultural heritage sites are located far from the new NPP sites.

7.8.2 Assessment of impacts on cultural heritage

During the construction of INPP, the area located within the boundaries of the plant underwent large excavation works and no outstanding elements of archaeological value were found.

The identified cultural heritage sites will not be affected by the new NPP construction as they are located outside the proposed sites. New access roads, the soil dump and other new infrastructure will not affect cultural values. There are no other sites of cultural heritage, ethnic or cultural values that could be negatively impacted by the new NPP.

7.8.3 Mitigation measures

Temporary construction and storage sites will be located away from cultural heritage sites.

7.9 SOCIO-ECONOMIC ENVIRONMENT

7.9.1 General information

The location of the new NPP (NNPP) will not substantially change the sanitary and monitoring zones or the concept of the boundaries of the region under consideration. For this reason, there is no need to include new territorial administrative subjects into the scope of the project. They should remain the same: the Ignalina district, Visaginas town and Zarasai district municipalities of the Republic of Lithuania, Daugavpils town and Daugavpils district municipalities of the Republic of Latvia and Braslav district municipalities of the Republic of Belarus. The NNPP localization will not virtually change the 30 km radius of monitoring zone. For this reason, the study of social impacts of NNPP in the Ignalina NPP region can be used as a territorial comparative basis.

For acquisition of new comparative data, an EIA model for subjects has been worked out (a special questionnaire has been handed out to local governmental institutions, largest enterprises, administrations of preserved territories, and other institutions; the data has been collected and generalized).

It should be pointed out that only parts of the territories of all territorial administrative units (except the Visaginas municipality) are included in the 30 km radius of monitoring zone. The sanitary protection zone of the NNPP will not be larger than the existing INPP sanitary protection zone with a 3 km radius, and will thus be located within the limits of Visaginas municipality.

7.9.1.1 Population and demography

The economic activity is planned to be performed in a sparsely populated territory of a transborder zone of long-lasting depopulation. The following major aspects of population distribution and demographic processes should be pointed out:

- The region is predominated by very small (1–10 residents) settlements (about 17 % of formal settlements in the Lithuanian segment are settlements without permanent residents); the local rural Rimse administrative unit is marked by the lowest relative portion of children up to 15 years of age in Lithuania;
- The Lithuanian segment includes three towns with a population from 900 to 29 000 people and about 12 settlements with a population between 200 and 900. The Latvian segment includes the southern part of Daugavpils town, 4 settlements with a population over 1000 and 19 settlements with a population between 100 and 1000. In the Belarusian segment, about 10 settlements have populations of more than 100 each. The regional centre Braslav is situated at the border of the monitoring zone (30 km);
- The number of non-permanent residents (i.e. land owners) from Daugavpils and Visaginas towns is increasing in the Lithuanian and Latvian segments. This phenomenon demonstrates rapid reduction of the isolation of Visaginas from the surrounding areas. In some territorial functional units (e.g. Rimse local rural administrative unit of Ignalina District), the numbers of registered permanent residents and non-permanent residents are comparable;
- A long-lasting depopulation of rural areas has been taking place in the all three segments of the NNPP region;
- The Lithuanian and Latvian segments include large settlements (Visaginas and Daugavpils towns) where after rapid depopulation in the last decade of the 20^{th}

century the demographic situation stabilized and approached the average national values. The sub-regional centre Braslav of the Belarusian segment is of low demographic potential still showing signs of depopulation.

According to data for 2005 the total population of the new NPP region, which includes the municipality of Visaginas (59 km^2), Ignalina district (1 496 km^2) and the Zarasai district (1 334 km^2) was 71 700 (in Visaginas 28 700 people and in Ignalina and Zarasai districts 21 400 and 21 600 people, respectively). Even if the NNPP region comprises 4.3 % of Lithuanian territory the population number is only about 2 % of the total Lithuanian population. Therefore, the NNPP region is a rather sparsely populated region of the Lithuania. During recent years, a decrease of population in the new NPP region has been observed. From 1999 to 2005 the total population of the region has decreased by 11 500 (~14 %) The information about the main demographic indicators and population distribution in the region within a radius of 30 km is presented in Table 7.9-1, Table 7.9-2 and Figure 7.9-1.

Inhabitants, living in the territories of Latvia and Belarus, which fall inside the 30 km radius zone around the INPP have been taken into account (Figure 7.9-1). Within a 30 km radius the density of population is about 48 people per km^2. This is lower than the average density of population in Lithuania (56.7 people per km^2). In fact, population density in the new NPP region is one of the lowest in Lithuania.

Within the current sanitary protection zone of INPP (radius = 3 km) there are neither farms nor settlements. Also economic activities are restricted (see Figure 7.9-2). The closest town is Visaginas, which is situated 8 km from the nuclear power plant.

Table 7.9-1. Demographic indicators of Ignalina NPP region in 2005.

Factor	Ignalina district	Zarasai district	Visaginas	INPP region
% of population < 15 years	14.58	15.81	12.70	14.36
% of population 15-44 years	34.83	36.66	48.75	40.08
% of population 45-64 years	24.62	23.92	28.74	25.76
% of population >=65 years	23.45	20.85	7.35	17.22
% of population >=75 years	10.23	9.46	1.87	7.19
Birth rate per 1000 pop.	7.45	8.49	8.16	8.03
Death rate per 1000 pop.	22.46	20.22	6.73	16.47
Natural increase per 1000 pop.	-15.04	-11.73	1.45	-8.44

Table 7.9-2. Estimated population distribution (thousands) in 2005.

Radius of circle	N	NE	E	SE	S	SW	W	NW	Amount of inhabitants	
									in the ring	cumulative within the radius
30 km	33.5	0.7	7.6	1.2	1.5	2.1	2.0	0.8	49.3	116.9
25 km	1.2	0.9	2.2	2.2	4.0	1.4	1.2	7.5	20.6	67.6
20 km	0.4	0.3	1.2	1.1	1.1	2.5	0.8	0.6	8.1	47.0
15 km	0.5	0.7	0.9	0.8	0.8	1.1	0.3	0.9	5.9	38.9
10 km	0.4	0.5	0.6	0.4	0.9	0.4	29.2	0.3	32.8	33.0
5 km	-	-	-	-	0.1	-	-	0.1	0.2	0.2
3 km	-	-	-	-	-	-	-	-	-	-
Total in the segment	36.0	3.2	12.4	5.8	8.4	7.5	33.5	10.1	Total 116.9	

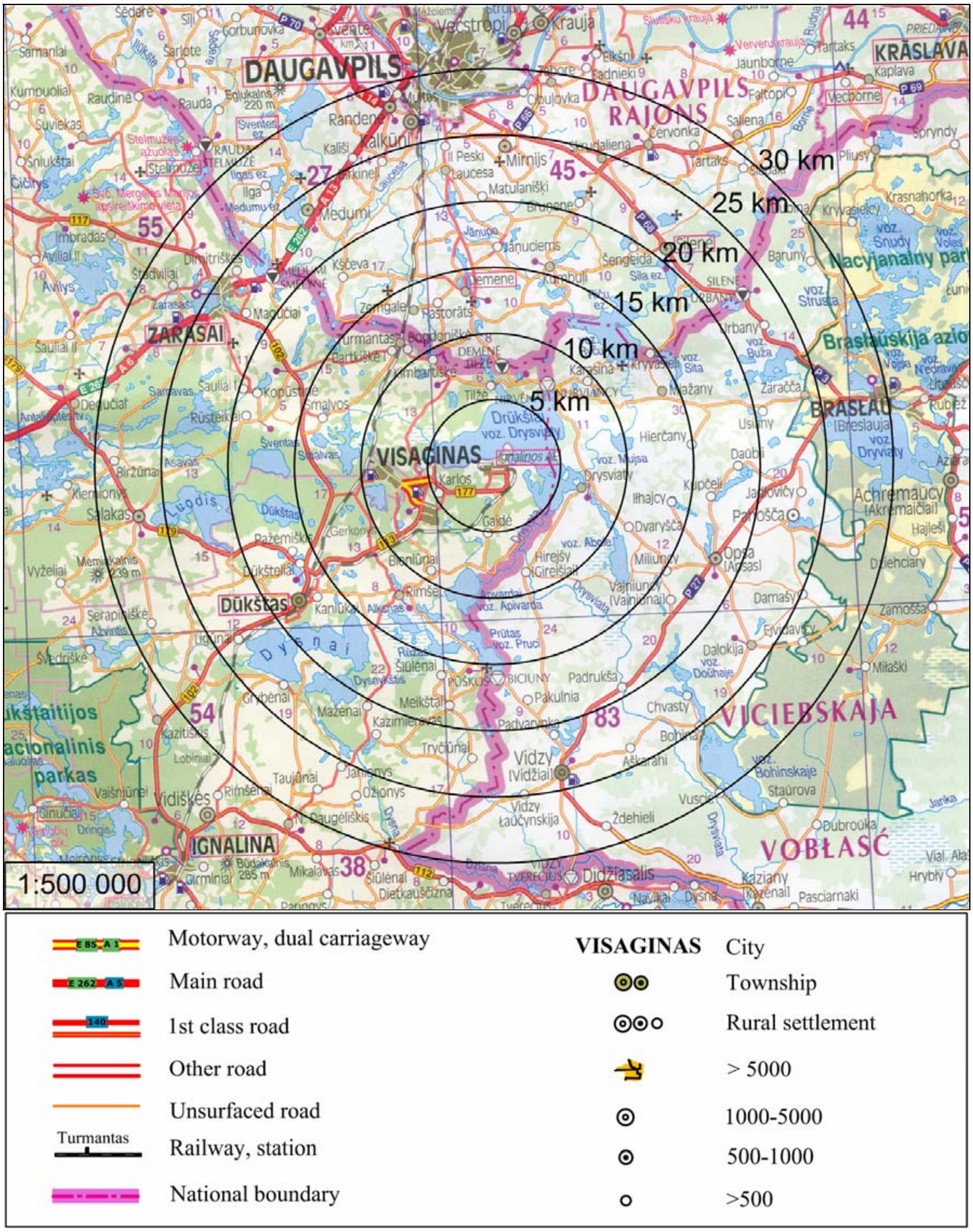


Figure 7.9-1. Population distribution within 5, 10, 15, 20, 25 and 30 km radiuses around the new NPP.

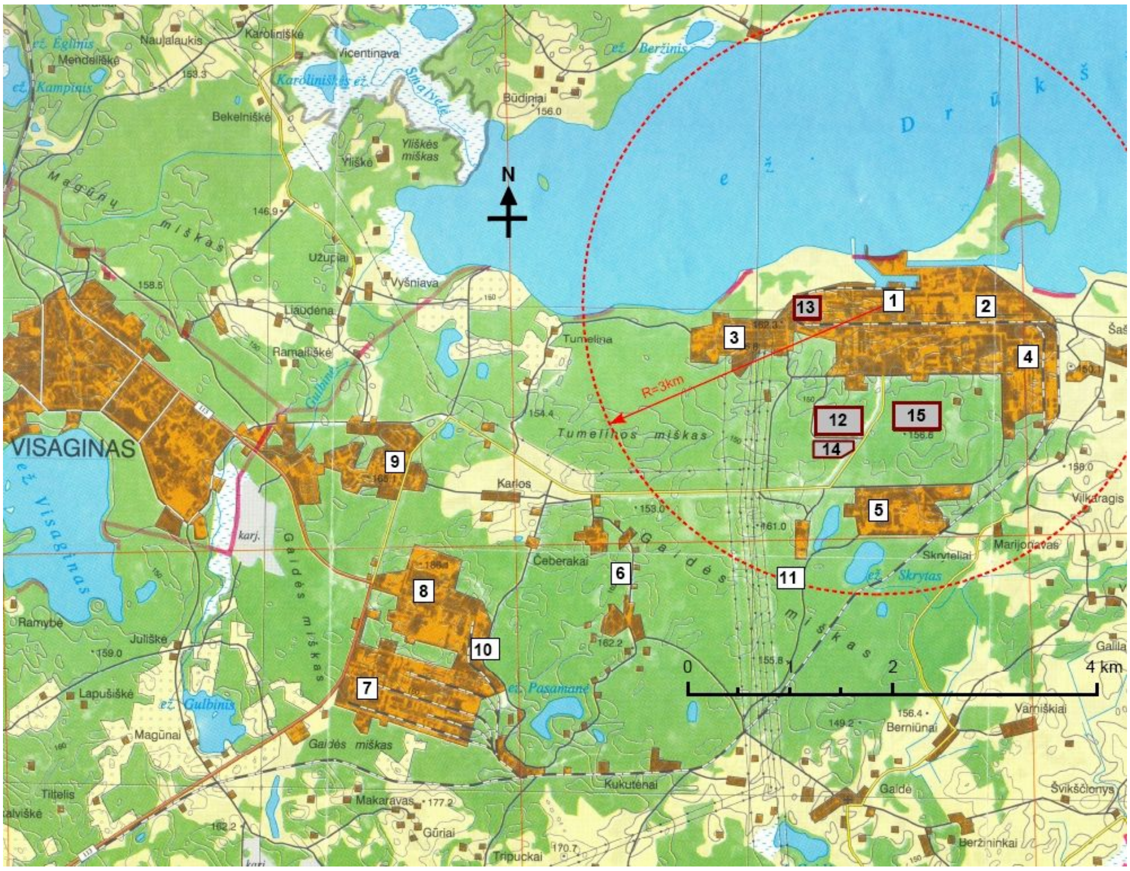


Figure 7.9-2. Existing sanitary protection zone of the INPP and facilities in the vicinity; 1 – Power Units, 2 – existing Spent Nuclear Fuel Storage Facility, 3 - open distributive system, 4 - supply base, 5 - sewage purification constructions, motor transport department, 6 – Visaginas waterworks (city artisan well site), 7 - construction base, 8 - industrial construction base, 9 - military base, health clinic, 10 - heat boiler station, 11 - Visaginas dump site, 12 – SWTSF and ISFSF site, 13 – SWRF site; 14 – site of the planned very low level radioactive waste near surface disposal facility, 15 – site of the planned low and intermediate level short-lived radioactive waste near surface disposal facility. The existing sanitary protection zone of INPP within a 3 km radius is also indicated.

7.9.1.2 Economic activities

From the economic point of view the new NPP region, except for the town of Visaginas, is a less developed region in Lithuania. Agriculture and forestry of low intensity dominate in the region. For example the intensity of cattle breeding is about 1.4 times lower than on the average in Lithuania. No important minerals with the exception of quartz sand are found in the region. The turnover of the retail trade in the region is 1.5, and the volume of services is more than 2.5 times lower than on the average in the country.

The town of Visaginas has an urban type labour force, which means a younger age structure (residents under 41 years of age is 67 %), more educated people and greater variety of professional training. Ignalina and Zarasai districts have a rural type labour force, which means an older age structure, lower education and a small variety of professional training. The number of people in working age is 66 % of population (22 200 people) in Visaginas, 52 % in Ignalina district (12 900 people) and 53 % in Zarasai district (13 000 people). Visaginas' unemployment rate is a bit higher than the average unemployment level in Lithuania.

There are 980 employers in the region (including public institutions), of which about 700 are small to medium sized enterprises with have less than 250 workers.

Main features of the economy in the region under consideration can be described as follows:

- According to the employment of population service sector, industry and energetics are the main economic activities – the majority of residents are employed there. However the most important activities from the land use point of view are extensive agriculture, forestry and development of rural tourism and ecological agriculture;
- The economy in Visaginas, which previously was a very narrowly specialized town, is becoming more and more diverse. The relations with the surrounding region and rest of the country are continuously increasing and most of Visaginas economy is now not based on INPP;
- The region and surroundings are more and more intensively used for recreation and tourism, which is starting to play one of the key roles in its economy.

It is expected that the most important impact on business expectations in this region in the context of construction of the new NPP can be caused by these factors:

- The decommissioning of the INPP and as a consequence:
  - The drop of employment in the town of Visaginas;
  - The decrease of purchasing power of the population and drop of demand for goods and services in the town of Visaginas;
  - The increase of electricity prices;
  - The demand for services and labour force needed for the process of decommissioning of Ignalina NPP;
- The construction of the new NPP and demand for goods, services and labour force related to this;
- EU support for rural and regional development and international collaboration;
- Peripheral location of the region in the conjunction of borders of three states, far from main economic centres;
- Further expansion of business relations with Latvia related to decreasing limiting impact of state borders.

The questionnaires of targeted requests were delivered to foreign subjects: to eight Latvian local municipalities, municipalities of Daugavpils region and Daugavpils town, Belarus Braslav region council, Braslav national park and other foreign institutions, which can possibly be interested in the NNPP region.

7.9.1.3 Traffic and noise

The nearest motorway passes 12 km to the west of the new NPP location. This motorway joins the city of Ignalina with those of Zarasai and Dukstas, and has an exit to the highway connecting Kaunas and St. Petersburg. The entrance of the main road from the new NPP sites to the motorway is near the town of Dukstas (Figure 7.9-3). There is another exit to Vilnius–Zarasai motorway. The length of the road from the new NPP to Dukstas is about 20 km.

The main railroad from Vilnius to St. Petersburg passes 9 km to the west of the new NPP location (Figure 7.9-3).

Figure 7.9-3. Road and railway network.

There are 3 zones where flights are prohibited in Lithuania, one of which is the territory 10 km around INPP (Figure 7.9-4).

There are about 30 000 flights per year (in 2005) from Vilnius airport, which is located 130 km from new NPP sites. About 125 000 airplanes per year cross the Lithuanian air space. Altogether 30 airports of civil, military and mixed purpose are located in the country.

The number of aircrafts that passed the Vilnius Flight Information Region in 2000–2005 is presented in Figure 7.9-5.

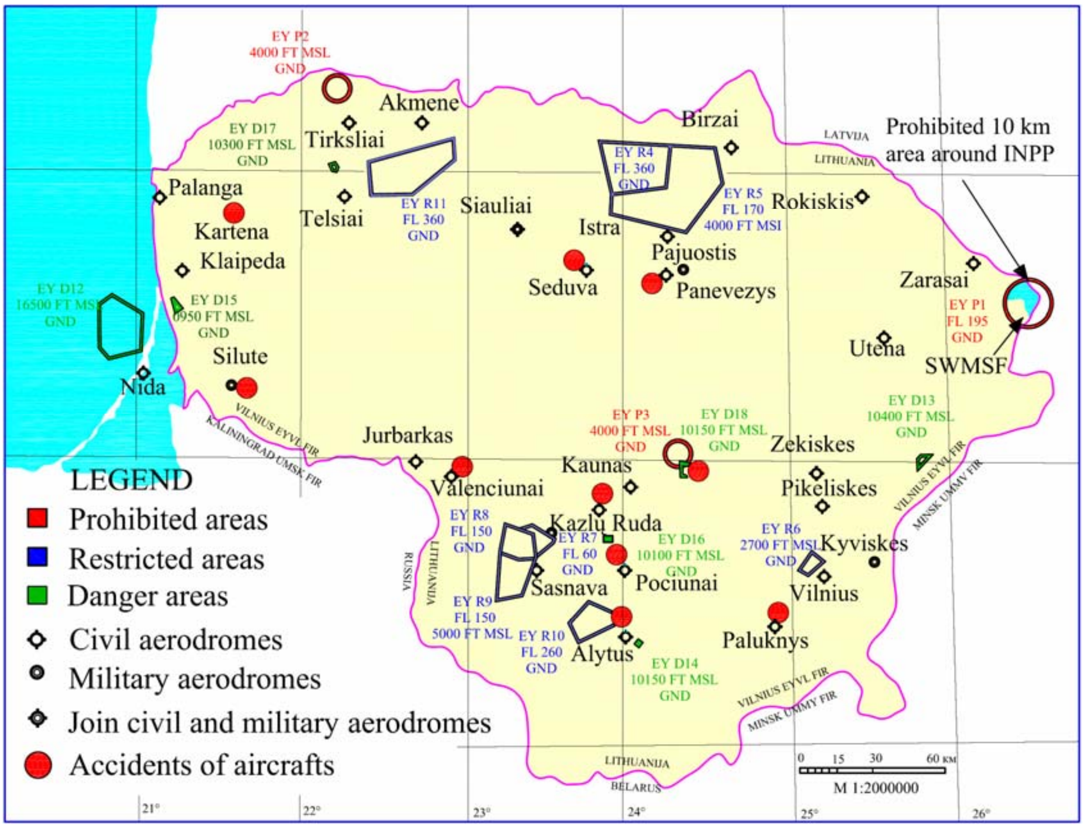


Figure 7.9-4. Airports, forbidden, restricted and dangerous areas in Lithuania.

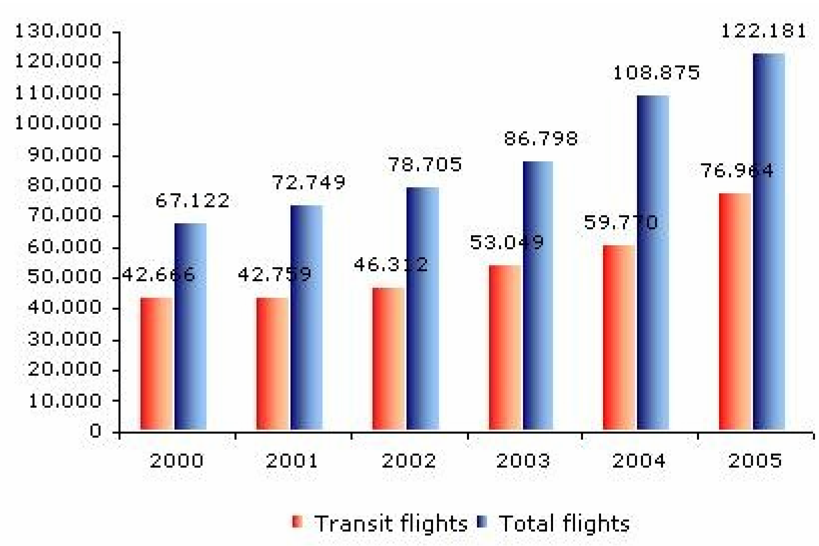


Figure 7.9-5. The number of aircrafts that passed the Vilnius Flight Information Region in 2000–2005.

7.9.1.4 Noise and vibrations

The sources of highest noise levels at an NNPP include steam ejection equipment, turbine generators, steam collectors and feeding and condenser pumps. Individual workstations with noise levels above the norms may also be found in auxiliary facilities. The noise modelling results, presented in next Section 7.10, indicate that the noise level will not exceed 55 dB during normal operation outside the immediate vicinity of the NNPP.

7.9.1.5 Existing staff prequalification and utilization possibilities

According to the information provided by potential suppliers and the experience of the EIA Consortium, the average number of staff required to operate all units of a new NPP is about 500 people. The exact number depends on the final organization and it will be determined when the decision on the type of plant has been taken. As soon as the organization becomes clear the individual functions within the structure are given. Each function requires an appropriate qualification, which can be acquired by defined training within the necessary time.

The following charts show the age structure of the existing INPP personnel by May 2008. General age structure of existing INPP personnel is presented in Figure 7.9-6.

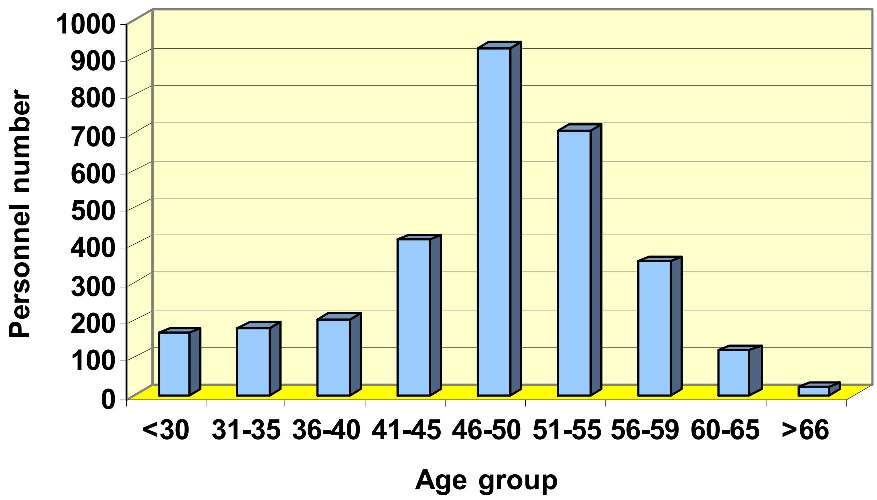


Figure 7.9-6. General age structure of existing INPP personnel.

The new NPP will most likely start commercial operation between 2015 and 2020, as it will take 7 to 12 years from now for designing, constructing, commissioning, licensing, testing and start-up. The official age for retirement in Lithuania is 62.5 for men and 60 for women. Therefore, almost all existing personnel of age 46 and older will have retired by the time the new NPP is commissioned.

Assuming that trained personnel should be able to work for at least another 5 years before retiring, this leaves about 500 people younger than 41 year (see Figure 7.9-6), who have to be examined in relation to actual position, education, training and qualification in order to decide who could be transferred to the new organization and under which prerequisites (additional education, training, retraining and other qualification programs). It is too early for detailed statements about this, but some information on existing personnel structure is presented in Figure 7.9-7.

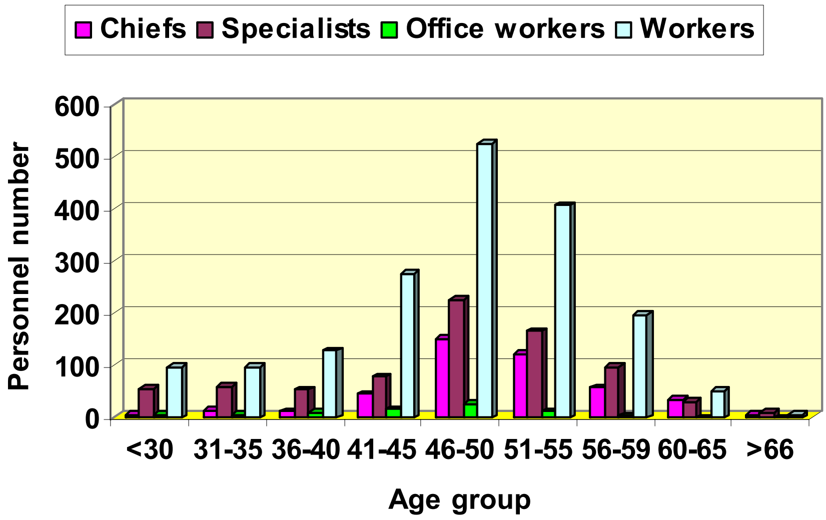


Figure 7.9-7. Personnel structure in different age groups of INPP staff in 2008.

7.9.2 Assessment of impacts on socioeconomic environment

7.9.2.1 Population and demographic processes

The preliminary observations in terms of labour force taking into consideration the planned economic activity are the following:

- The long-term demographic forecasts for the NNPP region (in the Lithuanian segment) have not come true: for the Utena County they were minus 5 % and for Visaginas city about minus 15 % and the depopulation rates exceeded the expected ones;
- The demographic situation in the cities of the region has been stabilizing whereas in rural areas it has been changing qualitatively and quantitatively: the number of owners of real estate rather than the number of residents increases. The factual density of rural population has been reducing in all territorial segments (Lithuania, Latvia and Belarus). In the cities, the population has stabilized;
- There are no premises for assumption that geodemographic processes in the Latvian and Belarusian segments follow another pattern because previous investigations have shown similar trends in these countries;
- Long-term (for 60 coming years as requested) demographic forecasts are formally not prepared on a regional level. They would require a special study;
- According to preliminary forecasts, the local resources of labour force are insufficient not only due to the scheduled scope and kind of works and demographic trends but also because diversification of economic activity and changes of lifestyles have taken place which have detracted part of the population from direct activities at the NPP. This is especially well reflected in the attitudes and expectations of the young residents of Ignalina NPP region;
- The potential of labour force in the Belarusian segment is small and prospectless due to the age structure. Participation in the first stages of construction and operation of the NNPP is also limited by political reasons;
- When evaluating the resources of labour force it is necessary to take into account the plans of the Republic of Latvia to build a large oil processing plant, waste handling

and other industrial enterprises in the monitoring zone of 30 km in radius. They may become a highly requested labour market for the regional population, in the Latvian segment in particular.

7.9.2.2 Economic activities

In a small country, the shutdown of a large NPP means a major reduction in the national electricity supply capacity, leading to higher prices, lower exports or higher imports with consequent implications for the national economy. Such situation increases the pressure to replace lost generation from a site by other nuclear means. The existing infrastructure and workforce make this particularly attractive, and such investment is likely to reduce the socioeconomic impacts of the shutdown of INPP.

Generally the construction and operation of the new NPP will have a positive impact on the social environment in the region, though some negative aspects can be expected.

The main expected positive impacts are:

- The increase of demand for labour force, maximum 3 500 persons during various stages of construction can be expected during 5 to 7 years;
- Impact of additional income due to the construction of NPP can be expected to amount to some EUR 20 million per year;
- Operation of the NPP is expected to need about 500 employees;
- Development of infrastructure and especially the housing sector in Visaginas and surrounding areas;
- Social and political stabilization of the town of Visaginas in the context of decommissioning of INPP. Positive psychological impact on Visaginas society;
- Multiplication of economic impact through increasing local demand for goods and services;
- The improvement of investment attractiveness of the region.

Main expected negative impacts are:

- A positive impact on the social environment in the foreign parts of NNPP region is hardly expected. Its possible that some minimal negative impact on attractiveness of the region for tourism and recreation can appear, though having in mind present operation of INPP and decrease of pollution after its closure this impact is not highly expected;
- New demand for land needed for the NNPP can raise some conflicts because the land use reform is not finished in the Lithuanian part of the region. Nevertheless, both alternative sites of the new NPP are within INPP SPZ which means no other economic activities are allowed there at least until the end of INPP decommissioning.

The socioeconomic impact of the new NPP on tourism and recreation sectors in the Lithuanian part of the region is not one-sided. The planned activity can cause some negative impact on attractiveness of the region but on the other hand increasing economy and incomes can generate substantial new demand for such services.

7.9.2.3 Transport and noise

Existing road and railways, which could be used for the new NPP, are located far from residential areas. The main transportation hub in the region is Dukstas. From there all roads and railways go to the NNPP through unpopulated areas though quite close to the collective gardens of Visaginas. Possible intensive transportation flows, related to the construction and operation of the NNPP, would take place in a very scarcely populated area.

Dukstas settlement would play hub role in this situation, which is a historically common phenomenon. The main communications, which at present are used for transit transportation, are mostly surrounded by industrial or similar non residential areas (except for a few houses and a school).

There is no need for impact on air transportation while this is a zone of no flights (except flights of military police and border control helicopters).

No premises of the NNPP are expected to generate noise and vibrations, which could exceed existing norms and limits.

7.9.2.4 Resident survey

A survey of the residents of the town of Visaginas and surrounding areas (*Resident Survey Report, 2008*) forms the constituent part of the evaluation of impacts on the environment that serves in evaluation of the socio-economic impact of the planned economic activity. During the assessment the attitude and opinion to the new NPP and its possible impacts on the social and economic environment of residents of the town of Visaginas and surrounding areas were surveyed.

The main survey objectives were to find out the attitude of residents living nearby the current INPP to the impact of the new NPP on the living environment, communication and transport, leisure activities, livelihood and professional life, migration attitudes of residents, value of real estate in the region, employment of the population, the most significant impacts during construction and operation of the new NPP and personal awareness of the new NPP project.

In order to implement the objectives of the survey, a representative survey of the inhabitants of the region was carried out: 518 residents of the town of Visaginas and surrounding areas in the range of 20 km were interviewed. The survey was carried out by interviewing respondents at their homes according to a standardized questionnaire, where the answers were registered. A representative probability sampling routine was used for the selection of the respondents by evaluating the distribution of the 18 years and older residents of the town of Visaginas and surrounding areas by age, sex, education and place of residence.

The main results of the survey

The residents of the town of Visaginas and surrounding areas evaluated a positive potential impact of the new NPP on the following aspects of the socioeconomic environment:

- For the living environment after the construction of the new NPP: (“*How would you evaluate your living environment, where the new power plant is constructed?”: very attractive - 42.4 %, attractive – 41.6 %: total – 84.0 %*). The present living environment is evaluated notably favorable and somewhat more favorable than it would be after the construction of the new NPP (“*How would you evaluate your living environment at the moment?”: very attractive – 36.0 %, attractive – 55.1 %: total – 91.2 %*).
- For the family livelihood and professional life: (“*What is your opinion about the impact of the new power plant on your and your family’s livelihood or professional life?”: very positive – 22.9 %, positive – 43.7 %: total – 66.6 %*).

- For the value of accommodation: ("*How will the new atomic power plant influence the value of your permanent residence in your opinion?": value will increase – 49.0 % permanent residents of the region*).
- For the level of employment of the population during the construction and operation: ("*How do you evaluate the impact of the new power plant on the employment of population (employment situation) during construction?": employment will increase greatly – 46.7 %, employment will increase – 42.8 %: total – 89.5 %); ("How do you evaluate the impact of the new nuclear power plant on the employment of population (employment situation) during operation?": employment will increase greatly – 26.6 %, employment will increase – 38.7 %: total – 65.4 %*).
- When evaluating the communication and transport: ("*How will the new nuclear power plant influence means of communication/transport (buses, automobiles, etc.) you use?": very positively – 13.9 %, positively – 35.9 %: total – 49.7 %, no effect – 41.6 %*). The residents of the region divided into two quite equal groups: one a slightly larger group agrees with the positive impact of the new NPP on the means of transport, and another slightly smaller group thinks that will not have any impact.
- According to the opinion of the majority of residents of the town of Visaginas and surrounding areas, the new NPP will not impact the following aspects in any way:
- Recreation and leisure opportunities: ("*How do you think the new nuclear power plant affects your opportunities of recreation or other leisure activities?": will have no effect – 61.5 %*).
- Desire to move out: ("*How do you think the new nuclear power plant will affect your desire to move away from the area?": will not influence the desire of moving – 70.4 %*). A fifth part (21.9 %) of the residents claimed that the wish of moving will decrease due to the new NPP, therefore, the region would become more attractive for this part of residents.

In the opinion of the residents of the region, the most important impact would be observed on the following aspects during the construction of the new NPP ("*Which environmental impacts do you consider the most important during the construction of the plant?"*):

- For the employment of population (37.7 %);
- For the feeling of safety (28.6 %);
- For Lake Druksiai (26.5 %) and
- For the traffic (23.8 %).

In the opinion of the residents of the region, the most important impact would be observed on the following aspects during the operation of the new NPP ("*Which environmental impacts do you consider the most important during operation of the plant?"*):

- For the energy market (41.0 %);
- For the employment of population (29.0 %);
- For Lake Druksiai (26.3 %) and
- For the feeling of safety (23.8 %).

A summary reveals that besides the energy market, in the opinion of the residents the most important impact would be observed on the same aspects: for the employment, safety feeling and Lake Druksiai. The impact on the other aspects would be different during construction and maintenance. The respondents assume that the traffic, landscape, land-tenure and noise would be affected, but such an impact will not be observed during operation. The respondents envisaged impact on the air quality, climate and emission of radioactive materials more often during operation, and such impacts will not be observed during construction in their opinion.

The residents of the town of Visaginas and surrounding areas are not very well informed about the project of the new nuclear power plant: (“*Have you received enough information about the nuclear power plant project?”: have little information – 52.9 %, have not heard anything about the project – 15.7 %: total – 68.6 % poorly informed or uninformed residents of the region*). The opinion of the residents of the town of Visaginas and surrounding areas is slightly different on this question. More residents of Visaginas feel informed enough and do not request more information in comparison to residents of surrounding areas, but generally, both parts of the residents are too little informed about the project of the new NPP.

The residents of the region would like to get more information on the following topics (“*On what topics would you like to get more information?”*):

- Impact on health (31.5 %)
- Do not request any more information (30.4 %)
- Impact on the energy market (23.2 %),
- Impact on employment of population (22.6 %),
- Impact on air quality and climate (20.9 %),
- Impact on habitability of the area (20.0 %),
- Impact of radioactive emissions (19.6 %) and
- Impact on the feeling of safety (18.5 %).

According to the opinion of the vast majority of residents in the region, the new nuclear power plant in Lithuania should be constructed (91.9 % agree). A vast majority agrees with the construction of the new nuclear power plant in one of the planned sites (82.8 % agree), but they do not feel able to influence which impacts on the environment are evaluated and how they are evaluated. Six residents out of ten (63.4 %) did not agree with the statement that they can influence which impacts on the environment are evaluated and how they are evaluated. Regardless of the fact that the residents do not feel able to influence the assessment process, they believe that possible impacts on the environment will be assessed comprehensively (66.3 % agree).

It was quite difficult for the residents to state their requests to the planners and evaluators of the project, but those who had their opinion stated the following requests for the planners (“*Which matters would you like to be taken into consideration in the planning of the nuclear power plant What are your requests for the planners?”*):

- To pay attention to the safety of the NNPP and safety of its operation (16.6 %);
- To pay attention to the employment of population (9.4 %);
- To pay attention to the conservation of landscape and nature (5.5 %);
- To make an effort for faster course of the construction works (5.1 %).

And for the evaluators ("*Which matters would you like to be taken into consideration in the environmental impact assessment of the nuclear power plant. What are your requests for the evaluators?"*):

- To pay attention to the safety of the NNPP and safety of its operation (17.4 %);
- To pay attention to the air quality, climate and control how ecological norms are observed (12.6 %);
- To pay attention to the conservation of landscape and nature (9.9 %).

Consequently, the main request for the planners and evaluators is to pay attention to the safety of the NNPP and its maintenance.

Conclusion

When summarizing results received during the assessment, a statement can be made that the residents of the town of Visaginas and surrounding areas evaluate the impact of the new NPP to the investigated spheres of socioeconomic life positively, and agree with the construction of the new NPP in one of planned sites. When planning and evaluating impacts of the new NPP, they require that attention is paid to the safety of the new NPP and its operation firstly. Because of the fact that half of the residents are too little informed or not informed at all about the NNPP project, they should get more information about planned works and impacts by receiving information about the opportunities of presenting opinions to the planners and evaluators at the same time, because the majority of the regions residents do not think that they can influence such a process.

7.9.3 Mitigation measures

7.9.3.1 Population and demography

The proposed measures for mitigation of adverse impacts are as follows:

- Promotion of diversification of activities related to construction and operation of the NNPP; in the sphere of long-term services to constructors and operators in particular. This would encourage trade in the neighbourhood and would stabilize the demographic situation in it in long-term activity perspective;
- Maximal recruiting of Visaginas labour forces which would contribute to avoidance of mass immigration from other countries and regions (except high class experts and special services).

When planning a long-term activity like construction and operation of the NNPP, it is necessary to take into account this important aspect. The current demographic and labour force situation is based on the census of population and housing of 2001 and current data provided by municipal structures.

In view of the scheduled construction of the NNPP, the data obtained during the population census of 2012–2013 in all the countries of the region will be very relevant while they will allow specification of demographic trends, labour force potential, etc. It would be expedient to carry out a targeted study of human potential in the NNPP region after the mentioned population census.

7.9.3.2 Economic activities

Potential measures for mitigation of negative impact are:

- The town of Ignalina and some other settlements in the district gained the status of resort only recently and they are not located in the zone of surveillance of the NNPP. However due to the name of the Ignalina NPP they can be related to the INPP and this can cause a negative impact on their attractiveness. New measures for improving the image of NNPP are needed, which could not only improve the awareness of its safety but would psychologically detach the NNPP from the surrounding region (Ignalina district municipality first of all), which depends on tourism and recreation very much;
- Tackling this contradiction of interests a new specialised research, devoted to the wider impact of NNPP of socioeconomic environment in the context of the General plan of the Lithuania, could be carried out.

7.9.3.3 Transport and noise

The construction works will be carried out in an unpopulated area so the main mitigation measure is strong observance of safety requirements. The timetable of cargo transportation and transhipment in Dukstas town could be adjusted. Noise reducing fences should be constructed along main roads at least in some residential areas.

An effective measure according to the opinion of the local population would be the construction of new roads and modernisation of existing ones.

7.9.3.4 Working language

Miscellaneous studies in the nuclear field, the aviation and the medical field in the past have analyzed the influence of the working language on the job performance in high risk environments. The results show in general a distinctly better performance when using the native language. Especially under stress condition such as disturbance or emergency conditions, the number of mistakes due to misunderstandings, which will lead to an accident or disastrous condition, is significantly lower when using the native language instead of any other foreign language.

Therefore all training programs as well as the operation of the NPP should be executed by using the native language. All instruction documents and operating procedures should be issued in Lithuanian language. In case the supplier delivers descriptions and procedures in any other language, they should be translated into Lithuanian language. The original documentation should be kept as reference in the original language, but not be used in the daily work.

7.10 PUBLIC HEALTH

7.10.1 Health status of population of Belarus, Latvia and Lithuania

7.10.1.1 Demographical indicators

The new NPP (NNPP) sites are located in the north-eastern part of Lithuania, close to the borders of Belarus and Latvia. The closest inhabitants are located about 3 km to the south-west from NNPP Site No. 2.

Data on population of the neighbouring countries and annual growth as given in World Health Organization's database "Core Health Indicators" is provided in Table 7.10-1. Data is available only for the year 2005.

Belarus' population is more than three times as great as Lithuania's and more than 4 times greater compared to Latvia.

Table 7.10-1. Population (in thousands) total.

Country	2005
Belarus	9755
Latvia	2307
Lithuania	3431

Population annual growth rate is negative in all three countries with the highest negative rate in Latvia and the lowest in Belarus. Annual growth per year 2005 is given in Table 7.10-2.

Table 7.10-2. Population annual growth rate (%).

Country	2005
Belarus	-0.5
Latvia	-0.8
Lithuania	-0.6

As seen from Table 7.10-2, all three neighbouring countries have reduced population growth and thus will generally face no such problems as increased need for food, infrastructure and services. On the other hand, negative growth, in a way, represents tense social environment, which, in turn, has negative impact on health indicators.

7.10.1.2 Population health indicators

In this chapter health status of the population of the three neighbouring countries are represented by crude mortality, standardized mortality rates and life expectancy indicators.

These indicators will only present the existing health status. Evaluation of the causes of differences in health indicators of the countries has not been carried out as it would require evaluation of relation of mortality rates with specific co-founders (e.g. radiation, smoking, social factors and similar). Such evaluation has not been included in the scope of the EIA.

Health status of the residents in proximity of the existing INPP was not assessed for the above mentioned reasons. Collection of the health data of the representative sample for all three countries would require access to crude statistics and explicit epidemiological study that is not the scope of this EIA.

Crude death rate per 1 000 of population of the three mentioned countries is presented in Table 7.10-3. As seen from this table the death rate per 1 000 of population has grown in 20 years period from 10 (1990) to 12 (2005) in Lithuania, from 12 (1990) to 14 (2005) in Latvia and from 10 (1985) to 14 (2005) in Belarus per 1000. The highest growth is observed in Belarus and the smallest in Lithuania. The highest average death rate (1985-2005) per 1 000 of population is observed in Latvia (13.4) and the lowest in Lithuania (11.4).

The source of information is the United Nations statistics division, which provides mortality rate statistics for every 5th year only.

Table 7.10-3. Crude Death Rate per 1 000 (Source: United Nations statistics division).

Country or Area	Population projections variants	1985	1990	1995	2000	2005
Belarus	Estimates (on the past)	10	10	12	14	14
Average	12					
Latvia	Estimates (on the past)	13	12	14	14	14
Average	13.4					
Lithuania	Estimates (on the past)	11	10	12	12	12
Average	11.4					

Available information on age standardized mortality statistics is extracted from World Health Organization database “Core Health Indicators”. The available indicator is age-standardized mortality rate for non-communicable diseases (per 100 000 population) and standardized mortality rate for cancer (per 100 000 population) for the year 2002.

Age-standardized mortality rate for non-communicable diseases is highest in Belarus and lowest in Lithuania (Table 7.10-4).

Table 7.10-4. Age-standardized mortality rate for non-communicable diseases (per 100 000 population).

Country	2002
Belarus	839.0
Latvia	733.0
Lithuania	640.0

On the other hand age-standardized mortality rate for cancer is highest in Lithuania and lowest in Belarus (Table 7.10-5).

Table 7.10-5. Age-standardized mortality rate for cancer (per 100 000 population).

Country	2002
Belarus	143.0
Latvia	156.0
Lithuania	161.0

Life expectancy at birth reflects the overall mortality level of a population. It summarizes the mortality pattern that prevails across all age groups – children and adolescents, adults and the elderly. It estimates average number of years that a newborn is expected to live if current mortality rates continue to apply. The database provides the indicator for the years 2004 and 2005.

The highest life expectancy at birth for both males and females is anticipated in Lithuania while the lowest is anticipated in Belarus (Table 7.10-6).

Table 7.10-6. Life expectancy at birth (years).

Males:

Country	2004	2005
Belarus	63.0	63.0
Latvia	66.0	65.0
Lithuania	66.0	65.0

Females:

Country	2004	2005
Belarus	74.0	75.0
Latvia	76.0	76.0
Lithuania	78.0	77.0

The indicator of healthy life expectancy or health-adjusted life expectancy (HALE), which is based on life expectancy at birth, but includes an adjustment for time spent in poor health, is not yet available in the WHO database.

7.10.2 Assessment of the impact on public health

7.10.2.1 Non-radiological impact

Major non-radiological population health risks

The proposed economic activity will be conducted within the INPP industrial site and within the existing 3 km radius sanitary protection zone of INPP. The shortest distance from the planned NNPP to the boundary of the existing sanitary protected zone is about 1.5-2 km. There is no permanently living population within the existing sanitary protection zone of INPP and the economic activity is limited as well. The proposed economic activity will be distant from permanently living population.

The potential public health impact sources of conventional (i.e. non-radiological) nature are presented in the tables below. Table 7.10-7 presents the risks of the construction phase and Table 7.10-8 the risks of the operation phase.

Table 7.10-7. Risks of the construction stage (duration 5–7 years).

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
1. Factors of behaviour and lifestyle (nutrition habits, alcohol consumption, smoking, consumption of narcotic and psychotropic drugs, safe sex and other)	0	National	Minor impact on national alcohol consumption.
	-	Regional	Construction workers coming from other areas may add to consumption of alcohol in the region as a result of isolation from families.
2. Factors of physical environment			
2.1. Air quality	0	National	National levels of air pollution will practically not be affected.
	-	Regional	Construction dust, welding fumes, transport emissions. Transport emissions that may affect settlements along roads are presented in Section 7.10.2.1.
2.2. Water quality	0	National	No impact on water quality on national level is anticipated.
	0	Regional	No impact on quality of potable groundwater is anticipated as underground contamination from containers of construction chemicals will be avoided as a result of proper container sealing and spill prevention. Minor impact on surface water is anticipated as a result of household water discharge and rainwater runoff. Effluent treatment such as mechanical and biological wastewater treatment and rainwater runoff oil separation is planned. Effluent amount, pollution level and receiving surface waters are detailed in Section 7.1. Amounts and quality of drinking water are presented in Section 7.1.
2.3. Food quality	0	National	No impact on food quality on national level is anticipated.
	0	Regional	Increase of traffic and transport emissions as well as contaminated road rainwater runoff will have minor negative effect on crops planted near roads. Quality of fish in adjacent lakes and rivers will not deteriorate as a result of wastewater and surface runoff treatment.
2.4. Soil	0	National	No impact on soil on national level is anticipated.
	0	Regional	Earthworks (excavation) will comprise 1 400 000 m^3 while earthworks with fill materials will comprise 1 300 000 m^3. Soil contamination from containers of construction chemicals will be avoided as a result of proper container sealing and spill prevention. Impacts on soil are assessed in Section

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
			7.4.
2.7. Noise	0	National	No specific road connection between the site of the plant and distant regions of the country will be established therefore noise is minor hazard on national level.
	-	Regional	Existing access road may be renovated or expanded. Increase of traffic may increase noise in the settlements located along access roads. Noise assessment is presented in the Section 7.10.2.1.
2.8. Home conditions	0	National	No impact on home conditions is anticipated on national level.
	+	Regional	If a large number of employees from distant areas are employed, apartment rental prices may rise in surrounding areas. It will benefit the local residents. The flat area may be insufficient for the construction employees and certain number of temporary living houses will have to be constructed.
2.9. Safety	0	National	No impact is anticipated.
		Regional	Increase of traffic and big machines may add to road accidents and injury.
2.10. Means of communication	0		Communication network is already established.
2.11.Territory planning	0	National	No impact is anticipated.
	0	Regional	Except for site planning no other territorial planning is anticipated. NNPP will be constructed at the existing INPP site and therefore the land use of the surrounding areas will not be altered.
2.12. Waste management	0	National	No impact is anticipated.
	0	Regional	Paper, glass, packaging waste, metal scrap, electronic scrap, used tires, end-of-life vehicles, sewage sludge and concrete sludge will be utilized at regional licensed waste management companies. The amounts of waste generated during the construction stage are presented in Chapter 6.
2.13. Power appliance	0	National	Construction will demand power and that will increase the national power consumption.
	0	Regional	Connection to the existing network is available. Increase of regional power consumption is anticipated.
2.14. Risk of accidents	0	National	No impact is anticipated.
	-	Regional	Construction and traffic accidents may increase. Mainly employees and areas along roads may be affected.
2.15. Passive smoking	NA		
3. Social and economic factors			
3.1. Cultural heritage	NA		Impact on cultural heritage or protected areas is

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
			not anticipated as construction will take place at the existing INPP site (Section 7.8).
3.2. Discrimination	NA		Construction activity has no discriminative elements.
3.3. Property	NA		NNPP will be constructed within the boundaries of the existing INPP site and therefore no impact on property is anticipated.
3.4. Income	0	National	Construction will have a positive impact on tax income. Also some of the electricity will be sold abroad. These will have a strong positive impact on the national income.
	+	Regional	Rise of regional income is anticipated as a result of increase in sales of goods and services.
3.5. Education possibilities	NA		No impact on education possibilities is anticipated. Education network is already established. Immigration of families of constructors, which may demand education facilities, is not anticipated
3.6. Employment, labour market, business opportunities	0	National	Minor increase in labour market on national level is expected.
	+	Regional	In the construction activity approx. 3 500 people at the maximum will be employed. This will temporarily develop regional labour market as a certain number of construction employees will be contracted from local labour market. Therefore positive impact on employment rate and reduction of unemployment (given in Section 7.9.1.2) is anticipated.
3.7. Criminality	0	National	Minor impact on the national criminality level is anticipated.
	-	Regional	In case a large number of construction workers will come from distant regions, criminal situation may worsen in the region. The cause may be social isolation related to distancing the workers from their families.
3.8. Leisure, recreation	NA		Leisure and recreation conditions will not alter.
3.9. Movement	NA		Construction activity will not affect free movement
3.10. Social security (social contact and welfare)	NA		Construction is a temporary activity and therefore the impact on social security will be minor.
3.11. Sociality, sociability, cultural contact	NA		Construction is a temporary activity and therefore the impact on sociality will be minor.
3.12. Migration	0	National	Minor impact on national migration levels is anticipated.
	-	Regional	Regional migration level may be affected in case of immigration of a number of construction specialists from other countries. Aspects of emigration of the existing population involved in Ignalina NPP operation and closure is evaluated in a special state programme of the termination of activity of the

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
			first and second units of INPP (*State Journal, 2005, No. 17-536*).
3.13. Family constitution	NA		
4. Professional risk factors (chemical, physical, biological, ergonomic, psychosocial, manual work)	Given in the next Section		
5. Psychological factors			
5.1. Aesthetical appearance	0		NNPP will be constructed within the boundaries of the existing INPP site therefore no impact on aesthetical appearance is anticipated. Impact of the NNPP on the landscape is assessed in Section 7.7.
5.2. Comprehensibility	NA		
5.3. Capability to hold the situation	NA		
5.4. Significance	+		Construction of the facility is significant for the economy of the entire country and region.
5.5. Possible conflicts	0		NNPP will be constructed within the boundaries of the existing INPP site. Therefore conflicts with the adjacent population are not anticipated.
6. Social and health services (acceptability, suitability, succession, efficiency, protection, availability, quality, self-help technique)	0		A network of social and health services is already developed and will be sufficient for the construction period. The nearest facilities are: ▪ The Centre of Primary Health Care of the town of Visaginas, Taikos av. 15 LT-31139 Visaginas ▪ „Ambulansas" – Ambulance branch of the town of Visaginas, Taikos av. 15 LT-31139 Visaginas ▪ Hospital of the town of Visaginas, Taikos av. 15 A LT-31107, Visaginas

Table 7.10-8. Risks of the operation stage (duration 60 years).

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
1. Factors of behaviour and lifestyle (nutrition habits, alcohol consumption, smoking, consumption of narcotic and psychotropic drugs, safe sex and other)	+	National	Increase of electrical power production and consequently reduction of costs of electrical power and consumer goods will result in increase of accessibility of quality consumer goods and services
	+	Regional	Better labour prospects increase social status, reduce social exclusion and shall reduce consumption of drugs and alcohol given that the workers of the existing INPP are not discriminated in terms of employment.
2. Factors of physical environment			
2.1. Air quality	+	National	Reduction of air pollution and related diseases resulting from cutting of combustion of fossil fuel.
	-	Regional	Boiler and steam plant, traffic air pollution and other industrial emissions will be discharged to ambient air. As a result of big distance to the nearest settlements air pollution will not exceed allowable levels in the surrounding close to access roads settlements. The Section below presents emission rates and impact on air quality.
2.2. Water quality	+	National	Reduction of the use of fossil fuel will result in decrease of soil and underground pollution and consequently will ensure quality of groundwater.
	0	Regional	No impact on quality of potable groundwater is anticipated. Underground contamination from containers of chemicals will be avoided as a result of proper container sealing and spill prevention. Drinking water will be used for household consumption, process water production and maintenance. Water will be supplied from Visaginas municipal water supply network. Cooling and service water will be supplied from Lake Druksiai. Detailed information of water consumption is presented in Section 7.1. Wastewater will be discharged to Visaginas waste water treatment plant from which, after treatment, to Lake Skripku, then Lake Druksiai. Waste water treatment and discharges as well as effluent pollution are presented in Section 7.1. Rainwater and industrial water, after local treatment as given in Section 7.1, will be discharged to Lake Druksiai.
2.3. Food quality	+	National	Reduction of the use of fossil fuel will result in decrease of air and soil pollution and consequently level of toxic compounds in crops or fruits and vegetables.

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
	+	Regional	Contamination of fish in Lake Druksiai will not alter compared to the present situation (see Section 7.1).
2.4. Soil	+	National	Reduction of the use of fossil fuel will result in decrease of soil pollution.
	0	Regional	Soil contamination from containers of chemicals will be avoided as a result of proper container sealing and spill prevention.
2.7. Noise	0	National	No impact is anticipated on national level
	-	Regional	NPP is not noisy industry: noise emitting machines and facilities are as a rule located inside of buildings in the area. Ventilation system mounted on the exterior wall or roofs will not cause increase of noise in adjacent settlements as a result of long distance and considerably low noise emission levels. Increase of traffic as a result of operation of the new NPP is not anticipated given existing INPP is dismantled by the start of the operation of the new plant. At certain periods when dismantling works are not finished traffic may increase and consequently noise as well.
2.8. Home conditions	0	National	Not impact on home conditions is anticipated
	+	Regional	If a large number of employees from distant areas will be employed, apartment rental price may raise in surrounding areas. It will benefit local residents.
2.9. Safety	+		Nuclear power plant could pose a terror threat. However, external threats are taken into account in the design of the plant (Chapter 5 and Chapter 10). It is anticipated that the safety will improve as modern safety measures will be implemented.
2.10. Means of communication	0		Communication network is already established.
2.11.Territory planning	0	National	Except for site planning no other territorial planning is anticipated.
	0	Regional	Except for site planning no other territorial planning is anticipated. NNPP will be constructed at the existing INPP site and therefore the land use of the surrounding areas will not be altered.
2.12. Waste management	0	National	Different non-radioactive waste types and their amounts are presented in Chapter 6. Management of non-radioactive waste will have minor impact on national level as will be disposed of or utilized in the regional waste management system. Radioactive waste generation and management are presented in Section 6.2.2.
	0	Regional	Different non-radioactive waste types and their amounts are presented in Chapter 6. Waste will be utilized or disposed of in regional waste management system. Hazardous waste will be delivered to national system. Radioactive waste generation and management are presented in Section 6.2.2.

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
2.13. Power appliance	0	National	Electrical power network is already laid in the course of construction of the existing nuclear power plant.
	+	Regional	Certain electrical cables or lines will be laid connecting the new NPP with the existing network. Operation of the new NPP will require energy in a form of electrical power, natural gas, diesel fuel and nuclear fuel. Sources of supply and annual amounts are given in Chapter 1.
2.14. Risk of accidents	0	National	National level negative impact of non-radiological accidents is hardly possible.
	-	Regional	Minor non-radiological accidents may be anticipated related to technological issues, failure of treatment facilities, failure of operation of equipment or machines, fires or explosions. As a result of not less than 2 km distance to the nearest living areas, negative impact on public health from minor non-radiological accidents is not anticipated with the exception of transportation accidents.
2.15. Passive smoking	NA		
3. Social and economic factors			
3.1. Cultural heritage	NA		NNPP will be constructed within the boundaries of the existing INPP site therefore no impact on existing cultural heritage and other objects is anticipated (Section 7.8).
3.2. Discrimination	NA		Projected activity has no discriminative elements.
3.3. Property	NA		NNPP will be constructed within the boundaries of the existing INPP site and therefore no impact on property is anticipated.
3.4. Income	0	National	Increase of gross national product (GDP) on national level is expected.
	+	Regional	Increase of GDP is anticipated for the region (Section 7.9).
3.5. Education possibilities	NA		Education network is developed already. In case foreign personnel will be employed, local education capacities for education of foreign children may be required.
3.6. Employment, labour market, business opportunities	+	National	Minor labour market increase on national level is expected.
	+	Regional	The NNPP will employ approx. 500 people. Income will increase for this group. Raise of income will increase income indicator for the region (Section 7.9).
3.7. Criminality	0	National	No effect on national criminality level is anticipated.
	+	Regional	As a result of increase of social security criminal situation should improve in the region with the precondition that the population living in the region

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
			is given worth labour opportunities.
3.8. Leisure, recreation	NA		No recreation or leisure facilities are planned. NNPP will be constructed within the boundaries of the existing INPP site therefore no impact on the existing network is anticipated.
3.9. Movement	NA		Planned activity will not affect free movement.
3.10. Social security (social contact and welfare)	0		No impact on national level is anticipated.
3.11. Sociality, sociability, cultural contact	NA		Operation activity will have no effect on these issues.
3.12. Migration	0	National	Minor impact on national migration levels is anticipated.
	0	Regional	Regional migration level may be affected in case of employment of a number of nuclear specialists from other countries. Large number of such specialists is not anticipated as there are local nuclear professionals that have competence to operate the NNPP (Section 7.9).
3.13. Family constitution	NA		
4. Professional risk factors (chemical, physical, biological, ergonomic, psychosocial, manual work)	Given in the next Section		
5. Psychological factors			
5.1. Aesthetical appearance	0		NNPP will be constructed within the boundaries of the existing INPP site. Impact of the NNPP on landscape is assessed in Section 7.7.
5.2. Comprehensi-bility	NA		
5.3. Capability to hold the situation	NA		
5.4. Significance	+		The facility is significant for the economy of the entire country.
5.5. Possible conflicts	0		NNPP will be constructed within the boundaries of the existing INPP site and therefore conflicts with the population are not anticipated with the exception of interest groups that are against nuclear power (Section 7.9).
6. Social and health services (acceptability, suitability, succession, efficiency, protection,	0		Network of social and health services is developed already and will be sufficient for the planned NNPP.

Factors influencing health	Positive (+); negative (-); minor (0)	Scale	Comments
availability, quality, self-help technique)			

As given in the tables above, certain risks are quantitative while other could be qualitative. Among those that could be predicted in detail are those related to measurable environment pollution, e.g.:

- Air pollution
- Noise

Major occupational non-radiological risks

Occupational exposure is not addressed in this EIA Report. As required by Lithuanian public health impact assessment legal acts, including Law of public health care of the Republic of Lithuania (*State Journal, 2002, No. 56-2225*), Rules of assessment of the cases of public impact not included in the law of environment impact assessment of the planned economic activity (*State Journal, 2004, No. 109-4091*) and Methodical guidelines for the public impact assessment (*State Journal, 2004, No. 106-3947*), a public health impact report shall cover occupational risks, which have to be assessed within the scope of Occupational risk assessment, which is a responsibility of the employer. The occupational exposure will be evaluated in the preliminary Safety Assessment Report (SAR), which is based on the Technical Design. In accordance with the best international practice, the safety assessment will be undertaken in conjunction with the planning and design of the proposed economic activity rather than being a separate activity. The results of the safety assessment will be used to determine any necessary changes in the design so that compliance with the safety requirements is assured. Therefore, the proposed economic activity can be implemented assuring occupational exposure to be within the limits, as prescribed by the national legal requirements of working environment.

Table 7.10-9 below presents the main occupational non-radiological risks during construction stage.

Table 7.10-9. Main occupational risks during construction stage.

Risk factor	Risk
Uncomfortable working posture resulting from level of working environment and repeated movements	Risk of injury
Motion over barriers, motion on slippery, uneven surface very close to sharp edges	Risk of injury
Delivery of instruments and materials	Risk of fall, crush, joint loading, injury of palm, injury of back
Motion of high and unsteady surfaces	Risk of fall from height
Cleaning with high pressure devices	Risk of dust, noise impact, eyes inflammation, risk of injury
Fall of stored items or materials	Risk of crush, compression or fall down
Polishing, levelling	Dust, vibration, noise and repeated movements
Work in poorly illuminated area	Risk of injury, sight disorders
Motion in areas with traffic of machines, transport and similar	Risk of injury
Excavation works	Risk of fall
Work close to sharp objects, armature, metal elements of constructions and similar	Risk of injury or punching
Work in sewage wells or confined areas	Risk of suffocation, contamination with gems
Work close to electrical power lines and installations	Risk of electrical shock
Work along or at roads and streets with traffic	Risk of accidents and injuries
Work in warm rooms or outside area	Risk of heat impact
Contact with concrete, cement, lime, glues, paints, varnishes, solvents and other chemicals	Risk of skin impairment, intoxication
Driving trucks and machines	Accident and injury risk
Storage of chemicals and gases	Risk of explosion and fire
Cutting with oxygen	Risk of burn and intoxication with fumes
Cutting, drilling and grinding of concrete, bricks and other construction materials	Dust, thermal impact, injury risk, vibration
Welding	Risk of electrical shock, burn, intoxication with welding fumes, UV, IR radiation
Use of lifting equipment	Risk of injury
Use of portable cutting, drilling, perforating machines	Noise, vibration, risk of injury
Responsibility, work intensity	Stress

The listed impacts will be avoided by the use of collective and personal safety and protection measures. Quantitative evaluation of the occupational environment impact will be evaluated by the employer according to national Occupational Risk Assessment Regulations (*State Journal 2003, No. 100-4504*).

Main occupational non-radiological risks during the operation of the NNPP are presented in Table 7.10-10.

Table 7.10-10. Main occupational risks during operation stage.

Risk factor	Risk
Responsibility, work intensity	Stress
Unergonomic working posture	Risk of injury
Delivery of instruments and materials	Risk of fall, crush, injury of joints, palm, injury of back
Work at high levels	Risk of fall, injury
Work in poorly illuminated areas	Risk of injury, sight disorders
Motion in areas with traffic of machines, transport and similar	Risk of injury
Work close to electrical power lines and installations	Risk of electrical shock
Storage of chemicals and gases	Risk of explosion and fire
Use of chemicals	Risk of intoxication, chemical burns, working area air pollution
Use of lifting equipment	Risk of injury
Work with computer	Risk of sight problems, health problems due to sedentary work

The listed impacts will be avoided by the use of collective and personal safety and protection measures. Quantitative evaluation of the occupational environment impact will be evaluated by the employer according to national Occupational Risk Assessment Regulations.

The main chemicals to be used at the NNPP and their health risks to the employees are presented in Table 7.10-11. Chemicals are used so that the Material Safety Data Sheet instructions are followed and the risk to the employees is minimized. Detailed information on quantities and use of the chemicals is presented in Chapter 1.

Listed health risks will be avoided by the use of collective and personal protection measures.

The chemical discharges from the NNPP are collected and treated so that they pose no risk to public health. Detailed information on the discharged chemicals is presented in Chapter 6.

Table 7.10-11. The main chemicals to be used at the NNPP and their health risks to the employees.

Chemical	Health risks
Boric acid (in EPR)	Inhalation: Causes irritation to the mucous membranes of the respiratory tract. May be absorbed from the mucous membranes and have toxic impact on nervous and other systems. Ingestion: Symptoms parallel with absorption via inhalation. Skin contact: Causes skin irritation. Readily absorbed through damaged or burned skin. Symptoms of skin absorption parallel with inhalation and ingestion. Eye contact: Causes irritation, redness, and pain. Chronic exposure: Prolonged absorption causes weight loss, vomiting, diarrhea, skin rash, convulsions and anaemia. Liver and particularly the kidneys may be susceptible.
Hydrazine	Potential acute health effects: Very hazardous in case of skin contact (irritant) and of ingestion. Hazardous in case of skin contact (corrosive), eye contact (irritant) and inhalation. Inhalation of the spray mist may produce severe irritation of respiratory tract. Potential chronic health effects: The substance is toxic to blood, kidneys, lungs, the nervous system, mucous membranes. Carcinogenic.
Ammonia	Ammonia is very alkaline and reacts corrosively with all body tissues. Inhalation: Corrosive. Extremely destructive to tissues of the mucous membranes and upper respiratory tract. Ingestion: Corrosive. Swallowing can cause severe burns of the mouth, throat, and stomach, leading to death. Skin contact: Dermal contact with alkaline corrosives may produce pain, redness, severe irritation or full thickness burns. May be absorbed through the skin with possible systemic effects. Eye contact: Corrosive. Can cause blurred vision, redness, pain, severe tissue burns and eye damage. Chronic exposure: Prolonged or repeated skin exposure may cause dermatitis. Prolonged or repeated exposure may cause eye, liver, kidney, or lung damage.
Lithium hydroxide	Potential acute health effects: Very hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion and of inhalation. Hazardous in case of eye contact (corrosive). Inhalation of dust will produce irritation to gastro-intestinal or respiratory tract, characterized by burning, sneezing and coughing. Potential chronic health effects: Hazardous in case of ingestion, of inhalation. The substance may be toxic to kidneys, gastrointestinal tract, upper respiratory tract, skin, eyes, central nervous system (CNS).
H_2SO_4	Potential acute health effects: May cause irreversible eye injury. Causes eye irritation and burns. Skin: Causes severe skin irritation and burns. Ingestion: Causes gastrointestinal tract burns. Inhalation: May cause severe irritation of the respiratory tract. Causes chemical burns to the respiratory tract. Potential chronic health effects: Prolonged or repeated skin contact may cause dermatitis. Prolonged or repeated inhalation may cause nosebleeds, nasal congestion, chest pain and bronchitis. Prolonged or repeated eye contact may cause conjunctivitis.
NaOH (50 %)	Inhalation: Severe irritant. Effects from inhalation of dust or mist vary from mild irritation to serious damage of the upper respiratory tract, depending on severity of exposure. Ingestion: Corrosive. Swallowing may cause severe burns of mouth, throat, and stomach. Skin contact: Corrosive. Contact with skin can cause irritation or severe burns and scarring with greater exposures. Eye contact: Corrosive. Causes irritation of eyes, and with greater exposures it can cause burns that may result in permanent impairment of vision, even blindness. Chronic exposure: Prolonged contact with dilute solutions or dust has a destructive effect upon tissue.
NaOH (10-30 %) (20 %)	Same as above. As a result of lower concentration health risks are less.
Lubricating oil	Health hazard acute and chronic. Inhalation: may cause anesthesia, headache, dizziness, nausea and upper respiratory irritation. Skin: may cause drying of skin and/or irritation. Eyes: may cause irritation, tearing and redness. Ingestion: may cause irritation, nausea, vomiting and diarrhea. Aspiration hazard: if swallowed can enter respiratory system.

Air pollution

The main air pollution sources during construction stage are exhaust gas emissions from traffic and dust from construction works. The first is constituted of the following contaminants:

- Carbon monoxide;
- Oxides of nitrogen;
- Sulphur dioxide;
- Suspended particulate matter;
- Carbon dioxide.

Estimated emissions from traffic during the construction stage are presented in Table 7.10-12 below. The figures in the table include emissions from both the traffic of the new NPP as well as the decommissioning of INPP.

Table 7.10-12. Annual amounts of emissions from traffic during construction stage, tonnes.

	Amount, units	CO	NO_x	SO_2	Solid particles	CO_2
Cars / vehicles using						
a) petrol fuel	tonnes/year	97.8	30.3	0.11	0.55	3549

During construction dust is raised from land building work, soil transport and dumping, site traffic and some separate operations such as concrete mixing stations. Sources of dust are usually located quite low and the amount is small so the impact is local and dusting will not have impact on the air quality outside the construction site.

The main air pollution sources during operation are emissions from traffic, heat and steam boilers, and back up diesel generators. The estimated emissions are presented in Table 7.10-13 below. The figures in the Table 7.10-13 include emissions from both the traffic of the new NPP as well as the decommissioning of INPP. Dust is mainly raised from traffic and does not have any significant impact.

Table 7.10-13. Annual amount of emissions from traffic during operation stage, tonnes.

	Amount, units	CO	NO_x	SO_2	Solid particles	CO_2
Cars / vehicles using						
a) petrol fuel	tonnes/year	43.6	13.6	0.05	0.25	1593

The annual emissions from the steam only boiler, the heat only boiler and diesel generators are presented for different periods of time in Table 7.10-14. It should be noted that only a minor part of the heat only boiler production goes to the NNPP so the emissions from the heat only boiler can not be considered as NNPP emissions.

Table 7.10-14. Annual emissions from stationary sources, steam only boiler, heat only boiler and diesel generators, in tonnes/year.

Pollutant	Steam Boiler		Heat boiler		Diesel generators
	2005–2009	2010–2025	2005–2009	2010–2025	2015–>
SO_2	0	0	0	0	0.2
NO_x	16	33	39	116	1
CO	6	12	14	41	
CO_2	21 300	44 620	524 500	157 046	500
Solid particles	0	0	0	0	0.5

The listed pollutants can have health effects as given in Table 7.10-15 below.

Table 7.10-15. Health effects of the main air pollutants emitted from the traffic or the stationary sources of the NPP (Source: US EPA).

Chemical compound	Health effect
Carbon monoxide (CO)	Can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. Susceptible population groups are subjects with chronic cardiac and respiratory disease, pregnant women and anaemic subjects. CO contributes to the formation of smog ground-level ozone, which can trigger respiratory problems.
Nitrogen oxides (NO_x)	NOx causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. The health effects attributed to NO_2 include decrease in lung function and increase in the risk of respiratory symptoms. Susceptible population groups to nitrogen dioxide are subjects with respiratory disease and young children.
Volatile organic compounds	Volatile compounds can cause irritation of the eye, nose and throat.
Particulate matter	Particle pollution - especially fine particles – cause health problems such as increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty of breathing; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.
Sulphur dioxide (SO_2)	Sulphur dioxide causes breathing difficulties, and irritation of the eyes, nose, throat and lungs. People suffering from asthma are particularly susceptible. SO_2 reacts with other chemicals in the air to form tiny sulphate particles. When these are breathed, they gather in the lungs and are associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. Visibility can be impaired because of haze that occurs when light is scattered or absorbed by particles and gases in the air.
CO_2	CO_2 is an aspect only for confined areas.

Annual emissions of above listed compounds in the entire Utenos county and municipalities comprising the area of the county are presented in Table 7.10-16.

Table 7.10-16. Annual emissions 2006, 1000 tonnes.

	Particles	SO2	NOx	CO	VOC
Utenos county	127.5	116.3	189.4	899.7	84.7
Anyksciu district municipality	8.3	4.8	23	99.7	18.2
Ignalinos district municipality	14.2	1.5	16.8	147.7	5
Moletu district municipality	29.3	2.3	21.9	182.5	1.2
Utenos district municipality	37.7	0.2	93.5	258.8	38.7
Visagino district municipality	2.1	16.8	12.5	51	21.6
Zarasu district municipality	35.9	90.7	21.7	160	..

Impact of the planned activity on the emission rate is presented in Table 7.10-17.

Table 7.10-17. Proportion of annual emissions of planned operation of the NNPP (transport and stationary sources) to annual emissions in 2006 on county and municipal level.

	Particles	SO_2	NOx	CO
Utenos county, tonnes	127.5	116.3	189.4	899.7
Visagino district municipality, tonnes	2.1	16.8	12.5	51
Planned activity, tonnes	0.00075	0.00025	0.0146	0.0441
Planned activity/Utenos county, %	0.0006	0.0002	0.008	0.005
Planned activity/Visagino distr. munic., %	0.0358	0.0015.	0.117.	0.086

As seen from the table above the influence of the planned activity in terms of emissions will be minor both on County and municipal level.

Given the importance of the planned activity for reduction of both national and regional emissions of air pollutants from fossil fuel combustion, emissions from the planned activity will be insignificant.

Noise

The construction of the NNPP will take approximately 5–7 years. Local noise increase might be expected during construction works. Such impact, conventional for any construction activity, could be relevant only in the close vicinity of the NNPP where no population lives permanently. Since the construction machines operate intermittently and the types of machines in use at the construction site change with the stage of the project, the noise emitted during construction will be variable. However, since the nearest residential properties are located at least 2 km away from the NNPP sites, it is expected that noise from the construction will rarely exceed the existing levels.

The main sources of noise during construction stage are construction machines and traffic. Noise power of the construction machines may average as follows:

- Pneumatic equipment – 115 dBA;
- Metal equipment – 105;
- Electric engines – 85 dBA;
- Air compressors – 105 dBA.

Predicted levels of environmental noise from traffic and machines during construction are presented in Figure 7.10-2 and Figure 7.10-3. The corresponding noise levels for the colours of the maps are given in Figure 7.10-1.

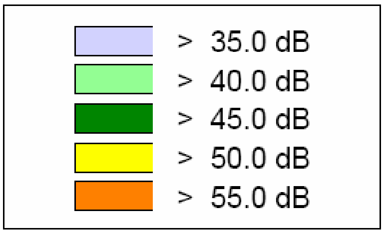


Figure 7.10-1. The colours and corresponding noise levels.

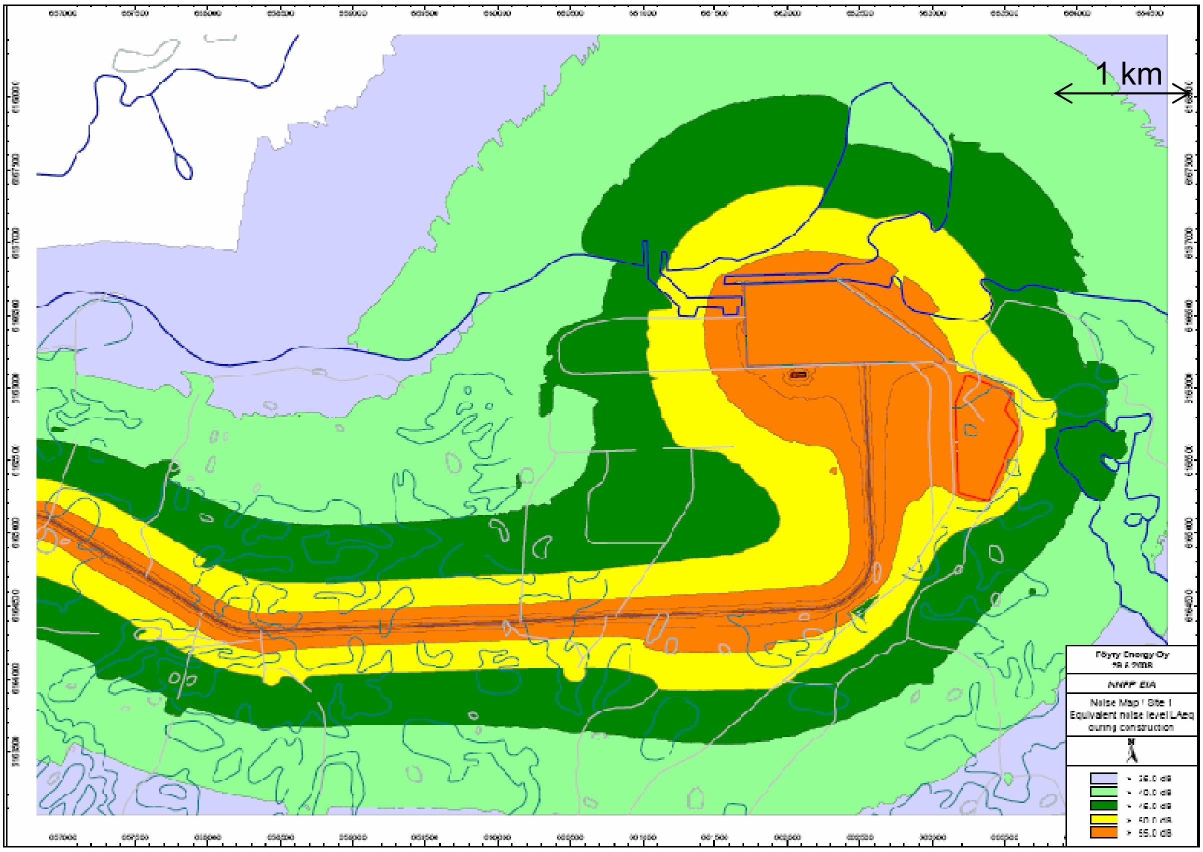


Figure 7.10-2. Noise map for Site No. 1 during construction phase.

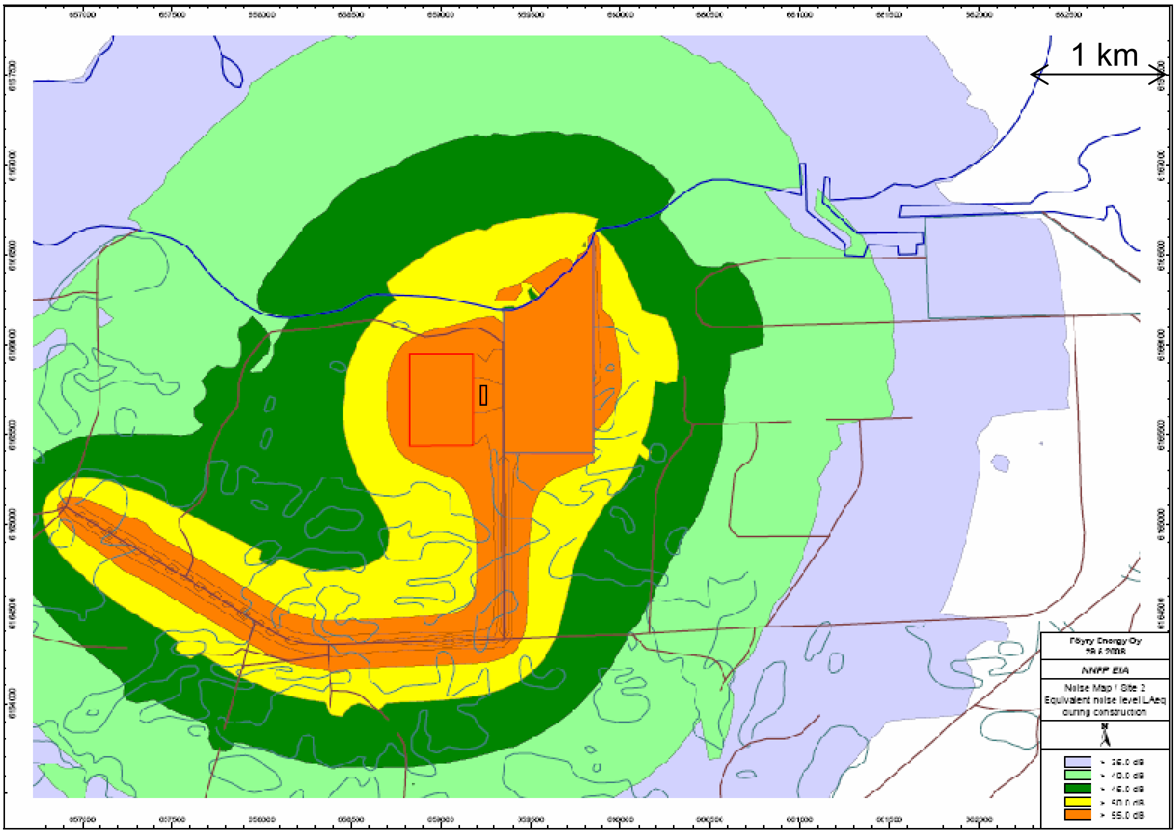


Figure 7.10-3. Noise map for Site No. 2 during construction phase

The main sources of noise during operation stage are ventilation equipment, diesel back up generators, turbines and traffic. Noise power of equipment may average as follows:

- Power generators – 90 dBA;
- Fan equipment – 100 dBA;
- Turbo generators – 92 dBA (they will be mounted inside the building, which will be shielded from noise).

What is heard outside of the plant during operation is a continuous faint humming noise around the clock. The noise is easily covered by other sources of noise like the wind. If the new plant will use a pressurized water reactor, the steam circuit will have safety valves, which will be tested during annual maintenance. When tested, the valves release high pressure steam and loud but short noise will emerge above the general noise level of the plant area.

Predicted levels of environmental noise from traffic and equipment during operation are presented in Figure 7.10-4 and Figure 7.10-5. The corresponding noise levels for the colours of the maps are given in Figure 7.10-1.

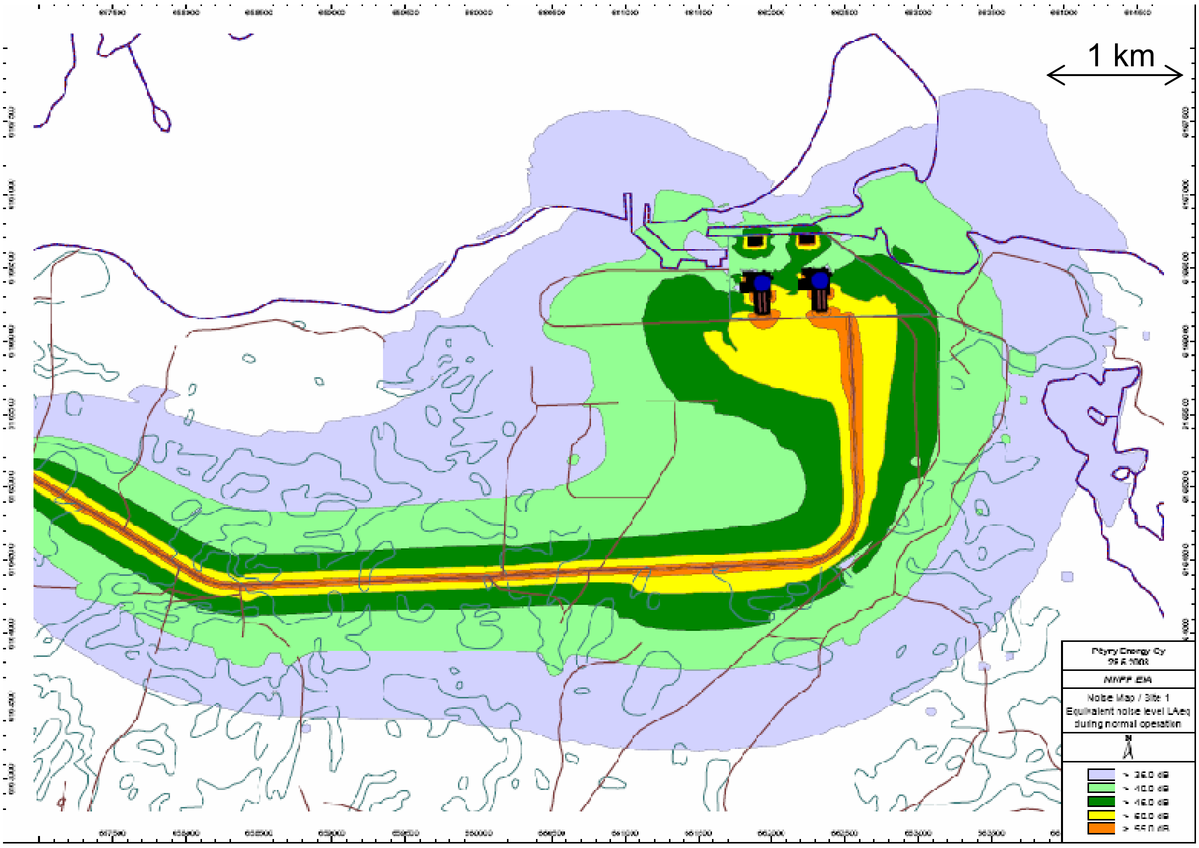


Figure 7.10-4. Noise map for Site No. 1 during operation phase.

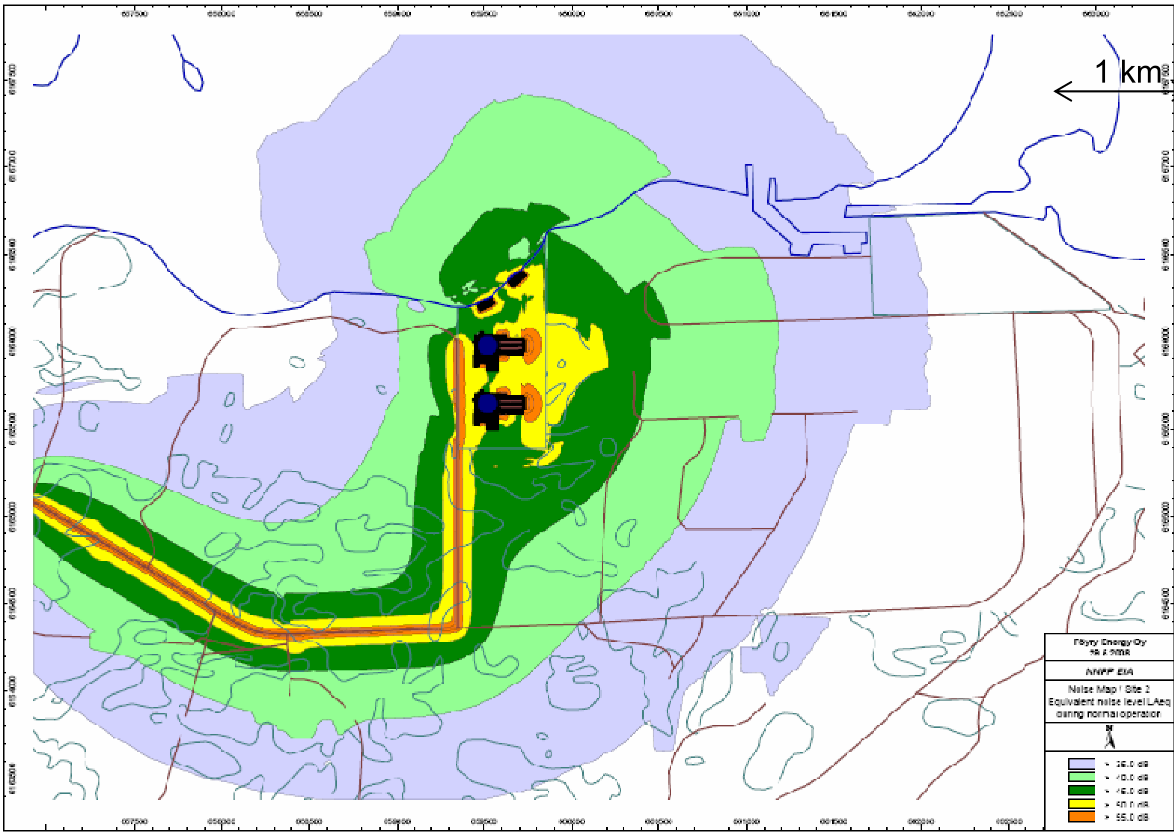


Figure 7.10-5. Noise map for Site No. 2 during operation phase.

Lithuanian Hygiene Standard HN 33:2007 (*State Journal, 2007, No. 75-2990*) requires noise not to exceed the levels presented in Table 7.10-18.

Table 7.10-18. Noise limit values (*HN 33:2007*).

Facility	Equivalent noise level, dBA	Maximal noise level, dBA	Time of day, hour	Noise levels applicable for noise mapping			
				L_{av}	L_{6-18}	L_{18-22}	L_{22-6}
007 Immediate environment of living and public buildings	65 60 55	70 65 60	6–18 18–22 22–6	65	66	61	55

As can be seen from the above presented maps, noise levels during the construction stage (including transport) will not exceed 55 dBA (night time level in urban areas) at a distance of 80-100 m from the centre of road. Noise at the construction site does not exceed 55 dBA at a distance of approx. 850 m from the centre of the area of construction.

Noise levels during operation stage (including transport) will not exceed 55 dBA (night time level in urban areas) at a distance of 30–40 m from the centre of road. Noise at the operation site does not exceed 55 dBA at a distance of approx. 80 m from the centre of the area of operation.

Obviously construction works or transportation activity during the operation stage will not be carried out at night time and therefore the zones of excess noise will not be as wide as given above.

Noise can cause hearing impairment, interfere with communication, disturb sleep, cause cardiovascular and psycho-physiological effects, reduce performance, and provoke annoyance responses and changes in social behaviour. The main social consequence of hearing impairment is the inability to understand speech in normal conditions, which is considered a severe social handicap.

Hearing impairment is mostly restricted to the work setting. Non-industrial noise is referred to as community noise, also known as environmental, residential or domestic noise.

For most people, life-time's continuous exposure to an environmental average noise level of 70 dB will not cause hearing impairment. An adult person's ear can tolerate an occasional noise level of up to 140 dB, but for children such an exposure should never exceed 120 dB. *(WHO, Occupational and community noise)*

The main health effects linked to high levels of noise are presented in Table 7.10-19 below.

Table 7.10-19. The main health effects linked to high levels of noise (* - Source: WHO, Occupational and community noise).

Environment	Critical health effect	Sound level dB(A)*	Time hours
Outdoor living areas	Annoyance	50–55	16
Indoor dwellings	Speech intelligibility	35	16
Bedrooms	Sleep disturbance	30	8
School classrooms	Disturbance of communication	35	During class
Industrial, commercial and traffic areas	Hearing impairment	70	24
Music through earphones	Hearing impairment	85	1
Ceremonies and entertainment	Hearing impairment	100	4

As can be seen from the maps of environmental noise (Figure 7.10-2, Figure 7.10-3, Figure 7.10-4, Figure 7.10-5), the levels of noise will not exceed the allowable levels set out for residential areas both in settlement along roads and settlement next to the sanitary protection zone of the planned sites. Therefore negative health effects from noise are not anticipated.

If necessary, the noise level in open air will be measured at locations in which such noise is perceived most clearly. If necessary, the works will be stopped and means for noise reduction will be implemented. Consequently, the construction activities will have minimal and temporary impacts on the levels of environmental noise at the locations of the nearest residential receptors.

When the construction works are finished, the amount of potential sources of noise will be reduced. The construction machines will be removed from the site and the transport of construction materials will be terminated.

Equipment mounted inside the buildings will be shielded by the building structure. Therefore NNPP interior equipment and machines will produce no noise that will be perceptible at the nearest residential receptors.

Premises of operators can be adequately isolated from noise.

Summary of non-radiological impact

The main qualitative non-radioactive impacts are presented in table format above. Most of the effects are minor.

Then main positive impacts are in the areas of economy and social security, while negative non-radiological effects are mainly related to environmental pollution and accidents as given in Table 7.10-20. Negative impacts can be mitigated and therefore they will be minor.

Table 7.10-20. Impacts of the proposed economic activity on factors influencing the health.

Factors influencing the health	Kind of activity or means, contamin. sources	Impact on factors influencing the health	Impact on health	Forecasted changes of the analyzed indicators	Possibilities to mitigate (eliminate) the negative impact	Comments and remarks
Construction phase						
1. Air pollution	Transport	CO, NOx, SO_2, VOC, particle emissions	Minor	Not estimated as a result of small emissions		Impacts are applicable for residents. Impact on employees will be assessed within the scope of occupational risk assessment.
2. Noise	Traffic, construction machines and equipment	Annoyance	Increase of noise level	Noise from traffic will not exceed 55 dBA at a distance of 80-100 m from the centre of road. Noise from the construction site will not exceed 55 dBA at a distance of approx. 850 m from the centre of the area of construction. Noise will not exceed allowable levels outside the existing sanitary protection zone of INPP.	Noise control of construction machines and equipment	Impacts are applicable for residents. Impact on employees will be assessed within the scope of occupational risk assessment.
3. Risk of accidents	Traffic	Construction and traffic accidents may increase. Mainly employees and areas along roads may be involved	As a result of increase of traffic more transport accidents are expected	Qualitative assessment	Traffic control and new roads	
4. Migration	Construction	Immigration of highly qualified NPP construction foreign employees	Minor	Qualitative assessment	Employment of the existing construction labour force when possible	

Factors influencing the health	Kind of activity or means, contamin. sources	Impact on factors influencing the health	Impact on health	Forecasted changes of the analyzed indicators	Possibilities to mitigate (eliminate) the negative impact	Comments and remarks
Operation phase						
1. Air pollution	Transport, steam boiler, heat boiler and diesel generators	CO, NOx, SO_2, VOC, particle emissions	Minor	Increase of emissions equalling 0.1-8.93 % on municipal level and substantially less on county level	Paving of roads, treatment of flue gases	
2. Noise	Traffic, fan equipment, turbogenerators, power generators	Annoyance	Minor	Noise from traffic will not exceed 55 dBA (night time level in urban areas) at a distance of 30-40 m from the centre of road. Noise from the operation site does not exceed 55 dBA at a distance of approx. 80 m from the centre of the area of operation. Noise will not exceed allowable levels outside the existing sanitary protection zone of INPP.	Noise shielding	
Risk of accidents	Minor non-radiological technological accidents may be anticipated	Fire, release of untreated exhaust	Minor	Qualitative assessment	More than 2 km distance to the nearest living areas will ensure that negative impact will not be noticeable	
Migration	Operation of nuclear installations	Immigration	Minor	Qualitative assessment	Employment of local nuclear professionals	Large number of nuclear specialists is not anticipated as there are local nuclear professionals that have competence to operate NPP

Anticipated negative impacts are summarized in Table 7.10-21 and Table 7.10-22.

Table 7.10-21. Possible impact of proposed economic activity on public groups.

Public groups	Kind of activity or means, contamination sources	Group size	Impact	Comments and remarks
1. Public groups (local population) outside the existing sanitary protection zone of INPP	Construction and operation	There is no permanently living population in the sanitary protection zone of INPP. Economical activity is limited.	0	Impact within the sanitary protection zone of INPP will be minimal. Outside the sanitary protection zone, the impact can be considered as insignificant.
2. Personnel	Operation	500–1000	(-)	Personnel exposure due to the proposed economic activity can be controlled and limited using, where appropriate, shielding, remote-controlled equipment, proper operational procedures etc. Personnel exposure will be optimized during the Technical Design and will not exceed the limits prescribed by occupational health and safety requirements.
3. Other	Not relevant			

Table 7.10-22. Assessment of features of quantitative impacts.

Impact induced by factor	Impact features								
	Number of persons under the impact			Evidence (possibility), strength of the evidentiary material			Duration		
	< 500	501–1000	> 1001	Clear	Probable	Possible	Short (< 1 y)	Medium (1–3 y)	Long (> 3 y)
1. Noise		+				+			+
2. Air pollution		+				+			+

7.10.2.2 Radiological impact

Radiation protection requirements

<u>Radiation Protection Requirements for Members of Personnel</u>

The Republic of Lithuania hygienic norm HN 73:2001 (*State Journal, 2002, No. 11-388; 2003, No. 90-4080*) defines dose limits for workers:

- The limit for effective dose – 100 mSv in a consecutive 5 year period;
- The limit for annual effective dose – 50 mSv;
- The limit on equivalent dose for the lens of the eye – 150 mSv in a year;
- The limit on equivalent dose for the skin, limbs (hands and feet) – 500 mSv in a year. This limit has to be averaged over 1 cm^2 area of skin subjected to maximal exposure.

The normal practice for NPPs is to supplement regulatory requirements by internal procedures on radiation protection. These procedures foresee additional requirements for assurance of permanent control and optimization of radiation impact on personnel. The implementation of principle of ALARA is also considered. For example, annual exposure of personnel members are controlled to be below 20 mSv as not to exceed yearly average for consecutive 5 year period dose limit and thus do not impose special limitations on working activities during subsequent years.

Radiation Protection Requirements for Members of General Public

The Republic of Lithuania hygienic norm HN 73:2001 (*State Journal, 2002, No. 11-388; 2003, No. 90-4080*) defines dose limits for members of the public:

- The limit for effective dose – 1 mSv in a year;
- In special circumstances limit for effective dose – 5 mSv in a year provided that the average over five consecutive years does not exceed 1 mSv in a year;
- The limit on equivalent dose for the lens of the eye – 15 mSv in a year;
- The limit on equivalent dose for the skin – 50 mSv in a year. This limit has to be averaged over 1 cm^2 area of skin subjected to maximal exposure.

In optimization of radiation protection the source related individual dose is bounded by a dose constraint. The dose constraint for each source is intended to ensure that the sum of doses to critical group members from all controlled sources remains within the dose limit.

According to requirements of the Republic of Lithuania hygienic norm HN 87:2002 (*State Journal, 2003; No. 15-624, 2008, No. 35-1251*) the exposure of population shall be limited by application of dose constraint during design, operation (both normal operation conditions and anticipated operational occurrences) and decommissioning of nuclear facilities. If more than one nuclear facility contributes to the exposure of the population, the total sum of annual effective doses to members of the public from all contributing nuclear facilities shall not exceed the dose constraint. The established dose constraint for members of the public is 0.2 mSv per year.

According to requirements of the Republic of Lithuania normative document LAND 42-2007 (*State Journal, 2007, No. 138-5693*), if radionuclides are dispersed into the environment by several pathways (e.g. by atmospheric and water paths) and the members of the same or different critical groups of population are impacted, the particular pathway resulting dose shall be limited in such a way that the total sum of doses from all pathways shall not exceed the dose constraint. The impact due to direct external ionizing irradiation shall be taken into account and the total dose (due to radioactive emissions and due to direct irradiation) to the critical group member of population shall not exceed the dose constraint.

For comparison purpose it can be indicated that annual effective doses to the Lithuanian inhabitants due to natural sources of ionizing radiation varies in range from 1.2 to 10 mSv with an average value of 2.2 mSv. The average values for the doses from the main natural radiation sources are: indoor radon – 1 mSv, cosmic radiation – 0.35 mSv, construction materials indoors – 0.45 mSv, natural radionuclides in human body – 0.34 mSv. The average dose of the world's population due to natural radiation is 2.4 mSv per year. Comparison of established annual effective dose limits, dose constraint and doses from natural sources is presented in Figure 7.10-6. Data on natural exposure is taken from the Lithuanian Radiation Protection Centre website (*RSC 2008*).

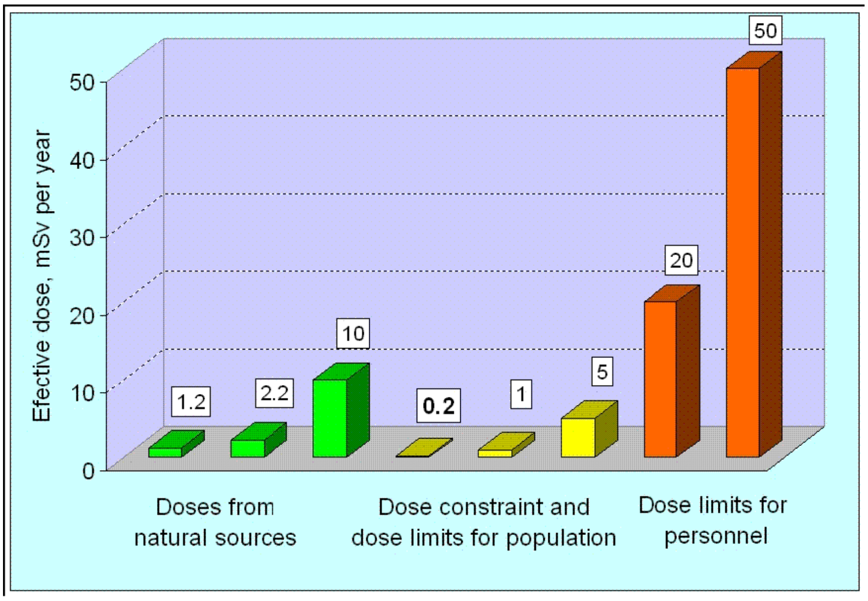


Figure 7.10-6. Annual effective dose limits, dose constraint and exposure from natural sources in Lithuania.

Radiological impact during normal operation of the NNPP

It is planned that the first unit of the new NPP will start to operate no later than year 2015. Construction and start up of additional units necessary to reach the full design capacity will depend on the project implementation schedule (see Chapter 1).

The radiological impact on the environment during normal operation of a NPP may arise from radioactive airborne and liquid effluents. The buildings and structures of a NPP, which contain radioactive materials, may be sources for external ionizing irradiation.

Radioactive liquids and gases generated in a nuclear power plant are collected, delayed to reduce radioactivity, and filtered. Even after filtering, minor amounts of radioactive substances are released into the atmosphere and water. Atmospheric emissions occur through the vent stack while discharges into Lake Druksiai take place after radiation control through the discharge and outlet channels of the NNPP.

Radiological impacts from existing and planned Ignalina NPP facilities which shall be considered in the evaluation of total impact (from the new NPP and from Ignalina NPP) are discussed in Section 7.11.

Annual releases of radioactive effluents

Evaluation of the liquid releases into the environment is given in Section 7.1. The annual releases of liquid radioactive effluents into Lake Druksiai are summarized for different reactor types, which are considered as technological alternatives.

Evaluation of the releases into the atmosphere is given in Section 7.2. The annual releases of radionuclides into the atmosphere are summarized for different reactor types, which are considered as technological alternatives.

These data serve as a basis for calculation of potential exposure of the population.

Method for calculation of annual exposure of the critical group members of population

The radiation exposure of the critical group members of the population in the environment of INPP resulting from the determined release of radionuclides into atmosphere and into Lake Druksiai have been calculated using the release to dose conversion factors as recommended by the normative document LAND 42:2007 (*State Journal, 2007, No. 138-5693*). These radionuclide specific conversion factors give a relation between a radionuclide specific permanent long term activity release and the dose caused to the critical group member at the location of the highest predicted exposure. Conversion factors are derived considering specific environmental components and taking into account the site-specific life style and nutrition features of the critical group members together with all the relevant pathways of external and internal exposure.

The normative document is supported by several references, one important among these being Nedveckaite, et al. 2000. This document describes the mathematical models implemented to assess the behaviour of the released radionuclides in the components and trophic chains and habits of the critical group members.

Conversion factors have been estimated for two critical groups, different in their lifestyle and activities. These include farmers residing in the vicinity of the Ignalina NPP, under the most unfavourable conditions, and fishermen fishing in Lake Druksiai.

In case of atmospheric releases, the atmospheric dispersion has been calculated using the Gaussian plume model, which accounts for reflection from the earth's surface and from the top of the mixing layer. The State-approved, long-term meteorological data (wind speed and direction, air temperature, cloudiness, cloud height and precipitation) from the nearest meteorological station with similar terrain (15 km from the Ignalina NPP) has been used. Corrections have been made for the influence of wind velocity at the stack height and plume rise.

The accumulation of radionuclides over a time period of 40 years on an originally uncontaminated ground surface has been considered. Radionuclide concentrations in agricultural and animal products, for the most unfavourable conditions, have been calculated using a linear transfer model. The following exposure pathways are the most significant when estimating the annual external and internal dose from atmospheric releases for the critical group of farmers: immersion in the plume, inhalation, external exposure from ground deposition, and ingestion of contaminated food. This critical group was assumed to reside in the most unfavourable conditions in the near vicinity of the INPP.

In the case of liquid releases, the highest radionuclide concentration is expected in the mixing zone of heated effluent water in Lake Druksiai. Thus, the radionuclide specific releases to dose conversion factors have been calculated for the fishermen fishing in this zone or the gardeners using the water of Lake Druksiai for the irrigation of their gardens. The annual exposure of the critical group of fishermen has been determined via the following exposure pathways: immersion in the plume, inhalation, external exposure due to the accumulation of radionuclides on the lake shore and ingestion of fish. Exposure of gardeners in small suburban gardens, situated close to Lake Druksiai and using its water for irrigation, has also been estimated. For most radionuclides, the dose conversion factors for the exposure of fishermen is greater compared to the exposure of gardeners.

Annual doses to the critical group members of population

Annual exposures of the critical group members of population due to releases of radionuclides into the atmosphere for different types of reactors are summarized in Table 7.10-23. Depending on reactor type, capacity and total number of units, annual doses vary in the range from 1.24 to 10.3 μSv. It should be noted, that freely distributed information is not available for all reactors types that are considered as technological alternatives. However, it can be expected that doses due to releases of these missing types of reactor will be in the same range.

By default LAND 42:2007 (*State Journal, 2007, No. 138-5693*) provides dose conversation factors from releases from a stack of 150 m height. There is remark in the LAND 42:2007 that for releases from a stack lower by half (i.e. of 75 m height), the dose conversation factors shall be multiplied by a factor of 3.4. Since reactor types considered in this EIA Report do not have stacks higher than 75 m, dose conversation factors multiplied by 3.4 have been used and annual exposure of the critical group members of population has been calculated for releases from a stack of 75 m height.

Table 7.10-23. Annual effective doses to the critical group members of population due to release of radionuclides into the atmosphere.

Radionuclide	Reactor type, output, MW_e and number of units					
	ABWR	ESBWR	AP-1000	EPR	CANDU-6	APWR
	1300	1550	1100	1660	750	1700
	2	2	3	2	4	2
	Annual effective dose, Sv					
Ar-41	8.50E-10	9.69E-13	4.28E-09	4.28E-09	n/a	4.28E-09
Ba-140	3.23E-09	2.53E-09	5.03E-11	5.03E-13	n/a	5.03E-11
C-14	5.10E-07	5.30E-07	4.05E-07	4.05E-07	1.57E-06	4.05E-07
Ce-141	8.43E-11	6.60E-11	3.84E-13	1.19E-13	n/a	3.84E-13
Co-58	3.33E-10	1.38E-10	3.18E-09	6.63E-11	n/a	3.18E-09
Co-60	9.32E-08	6.15E-08	6.22E-08	7.89E-10	n/a	6.32E-08
Cr-51	7.07E-11	4.22E-12	1.23E-12	1.95E-13	n/a	1.23E-12
Cs-134	6.49E-08	5.03E-08	2.40E-08	5.00E-10	n/a	2.40E-08
Cs-136	3.14E-10	2.10E-10	4.49E-11	1.74E-11	n/a	4.49E-11
Cs-137	1.43E-07	1.10E-07	5.44E-08	1.36E-09	n/a	5.44E-08
Cs-138	6.22E-14	8.40E-16	n/a	n/a	n/a	n/a
Fe-59	1.33E-10	8.57E-11	1.29E-11	4.59E-12	n/a	1.29E-11
H-3	1.65E-08	1.71E-08	7.92E-08	4.08E-08	1.01E-06	4.08E-08
I-131	1.83E-06	2.88E-06	8.47E-07	6.19E-08	3.81E-09	2.96E-08
I-132	6.60E-09	4.79E-09	1.21E-09	n/a	n/a	n/a
I-133	4.08E-07	3.15E-07	n/a	7.65E-09	n/a	1.53E-08
I-134	3.38E-09	2.56E-09	n/a	n/a	n/a	n/a
I-135	4.56E-08	3.13E-08	n/a	n/a	n/a	n/a
Kr-85m	3.18E-10	2.65E-10	5.44E-10	2.26E-09	n/a	n/a
Kr-87	2.06E-09	3.21E-09	1.23E-09	4.32E-09	n/a	n/a
Kr-88	8.09E-09	1.26E-08	9.83E-09	3.84E-08	2.83E-13	n/a
Kr-89	2.48E-08	3.91E-08	n/a	n/a	n/a	n/a
La-140	1.37E-11	2.63E-13	n/a	n/a	n/a	n/a
Mn-54	2.18E-09	1.60E-09	1.73E-10	2.30E-11	n/a	1.73E-10
Mo-99	3.22E-10	2.43E-10	n/a	n/a	n/a	n/a
Na-24	6.63E-11	2.40E-13	n/a	n/a	n/a	n/a
Nb-95	3.81E-10	2.99E-10	1.13E-10	1.90E-12	n/a	1.13E-10
Np-239	2.54E-11	4.79E-13	n/a	n/a	n/a	n/a
Pr-144	3.09E-16	5.98E-18	n/a	n/a	n/a	n/a
Rb-89	9.79E-15	1.23E-16	n/a	n/a	n/a	n/a
Ru-103	3.40E-10	2.72E-10	7.75E-12	1.65E-12	n/a	7.75E-12
Ru-106	1.86E-11	3.57E-13	7.65E-11	7.65E-13	n/a	7.65E-11
Sr-89	8.57E-10	6.05E-10	4.52E-10	2.41E-11	n/a	4.52E-10
Sr-90	6.19E-10	1.82E-10	1.06E-08	5.54E-10	n/a	1.06E-08
Sr-91	2.14E-12	3.88E-14	n/a	n/a	n/a	n/a
Te-132	6.90E-13	1.39E-14	n/a	n/a	n/a	n/a
Xe-131m	4.22E-11	2.43E-12	1.47E-09	n/a	n/a	2.13E-10
Xe-133	7.28E-09	2.54E-09	1.39E-08	2.60E-08	n/a	n/a
Xe-133m	2.39E-13	6.43E-15	2.41E-10	5.00E-10	n/a	5.54E-12
Xe-135	1.04E-08	1.49E-08	7.48E-09	2.72E-08	n/a	4.52E-11
Xe-135m	1.28E-08	1.93E-08	2.20E-10	4.42E-10	n/a	1.26E-10
Xe-137	5.68E-09	8.67E-09	n/a	n/a	n/a	4.42E-11
Xe-138	3.74E-08	5.44E-08	5.20E-10	1.04E-09	n/a	8.67E-11
Zn-65	1.14E-07	7.82E-08	n/a	n/a	n/a	n/a
Zr-95	1.29E-10	9.76E-11	8.06E-11	8.06E-13	n/a	8.06E-11
Total dose from one Unit	**3.35E-06**	**4.25E-06**	**1.53E-06**	**6.22E-07**	**2.58E-06**	**6.49E-07**
Total dose from all Units	**6.70E-06**	**8.50E-06**	**4.59E-06**	**1.24E-06**	**1.03E-05**	**1.30E-06**

Annual exposure of critical group members of the population due to release of radioactive liquids into Lake Druksiai for different types of reactors are summarized in Table 7.10-24. Depending on the reactor type, capacity and total number of units, annual doses vary in the range from 0.9 to 40.4 μSv. As it was mentioned, freely distributed information is not available for all reactors types that are considered as technological alternatives. However, it can be expected that doses due to releases of these missing types of reactor will be in the same range.

Table 7.10-24. Annual effective doses to the critical group members of population due to release of radioactive liquids into Lake Druksiai.

Radionuclide	Reactor type, output, MW_e and number of units					
	ABWR	ESBWR	AP-1000	EPR	CANDU-6	APWR
	1300	1550	1100	1660	750	1700
	2	2	3	2	4	2
	Annual effective dose, Sv					
Ag-110m	3.05E-10	n/a	9.71E-10	4.07E-10	n/a	1.67E-09
Ba-140	1.94E-10	2.33E-10	1.57E-09	1.20E-09	n/a	1.65E-09
C-14	1.84E-08	n/a	n/a	0.00E+00	n/a	n/a
Ce-141	7.10E-12	4.14E-12	5.33E-12	2.96E-12	n/a	1.72E-11
Ce-144	2.46E-09	n/a	4.09E-09	1.68E-09	n/a	7.25E-09
Co-58	8.66E-11	4.24E-10	3.23E-09	1.44E-09	1.73E-08	9.43E-09
Co-60	4.04E-07	4.00E-08	1.95E-08	7.99E-09	9.42E-08	6.22E-07
Cr-51	3.42E-11	5.77E-11	8.21E-12	4.44E-12	2.59E-11	2.66E-11
Cs-134	1.67E-06	1.86E-07	2.72E-06	7.12E-07	n/a	3.29E-06
Cs-136	2.36E-09	3.04E-09	4.66E-09	2.29E-09	n/a	1.63E-07
Cs-137	7.90E-07	1.60E-07	1.18E-06	3.11E-07	n/a	1.60E-06
Fe-59	6.29E-11	4.40E-11	1.26E-10	0.00E+00	n/a	1.45E-09
H-3	7.77E-08	1.81E-08	1.31E-06	2.63E-06	6.83E-06	2.07E-06
I-131	2.36E-09	3.10E-09	1.05E-08	2.52E-08	n/a	1.48E-09
I-132	4.52E-12	1.42E-12	2.85E-12	2.09E-12	n/a	5.39E-13
I-133	5.55E-10	1.17E-09	3.72E-10	1.94E-09	n/a	4.50E-11
I-134	1.07E-12	2.52E-14	5.09E-13	0.00E+00	n/a	5.60E-14
I-135	5.00E-11	3.60E-11	3.31E-11	9.99E-11	n/a	5.19E-12
La-140	1.07E-11	n/a	4.67E-10	4.78E-10	n/a	5.03E-10
Mn-54	7.89E-09	4.85E-10	3.94E-09	1.64E-09	2.13E-07	1.37E-08
Mn-56	1.41E-11	4.81E-12	n/a	n/a	n/a	n/a
Mo-99	1.01E-11	3.66E-11	6.96E-12	n/a	n/a	2.08E-11
Na-24	4.58E-11	8.32E-11	2.65E-11	9.93E-11	n/a	7.65E-11
Nb-95	5.18E-08	1.04E-09	1.09E-08	5.18E-09	2.93E-06	1.04E-07
Np-239	2.99E-11	1.06E-10	2.31E-12	5.58E-12	n/a	5.10E-12
Pr-143	9.14E-14	6.33E-12	9.14E-12	3.52E-12	n/a	5.55E-12
Ru-103	5.73E-12	1.27E-12	1.57E-10	7.96E-11	n/a	1.08E-10
Ru-106	2.01E-10	n/a	8.70E-08	3.67E-08	n/a	5.56E-08
Sr-89	6.11E-11	1.22E-10	5.55E-11	2.78E-11	n/a	8.33E-11
Sr-90	2.47E-09	1.41E-09	7.03E-10	n/a	n/a	1.27E-09
Te-132	6.81E-11	3.40E-10	4.08E-09	8.17E-09	n/a	8.00E-09
Y-91	2.48E-11	3.16E-11	n/a	n/a	n/a	2.03E-11
Zn-65	4.66E-09	2.34E-08	2.12E-08	8.81E-09	n/a	1.14E-08
Zr-95	1.65E-10	3.92E-12	4.51E-11	2.55E-11	n/a	2.55E-10
Total dose from one Unit	**3.04E-06**	**4.40E-07**	**5.38E-06**	**3.75E-06**	**1.01E-05**	**7.96E-06**
Total dose from all Units	**6.08E-06**	**8.8E-07**	**1.61E-05**	**7.5E-06**	**4.04E-05**	**1.59E-05**

Summary of radiological impact to population during normal operation of New NPP

Total annual exposure of the critical group members of population due to release of radioactive effluents (both airborne and liquid) into environment for different reactor types with total power of 3 400 MW_e maximum are summarized in Table 7.10-25. Depending on reactor type, capacity and total number of units, annual doses vary in the range from 8.74 to 50.7 µSv. It should be noted, that freely distributed information is not available for all reactors types that are considered as technological alternatives. However, it can be expected that doses due to releases of these missing types of reactor will be in the same range. As it was mentioned before, the established dose constraint for members of the public is 0.2 mSv (200 µSv) per year. Therefore, doses during normal operation of the new NPP will be about 4 times less than the dose constraint. Also it should be noted, that annual releases of radioactive effluents into the environment have been calculated using conservative assumptions. Actual releases from operating NPP are usually smaller than the calculated values.

Table 7.10-25. Total dose to the critical group members of population due to release of radioactive effluents into the environment.

Radioactive effluents	Reactor type, output, MW_e and number of units					
	ABWR 1300 2	ESBWR 1550 2	AP-1000 1100 3	EPR 1660 2	CANDU-6 750 4	APWR 1700 2
	Annual effective dose, Sv					
Airborne	6.70E-06	8.50E-06	4.59E-06	1.24E-06	1.03E-05	1.30E-06
Liquid	6.08E-06	8.8E-07	1.61E-05	7.5E-06	4.04E-05	1.59E-05
Total dose	**1.28E-05**	**9.38E-06**	**2.07E-05**	**8.74E-06**	**5.07E-05**	**1.72E-05**

Summary of occupational exposure based on operational experience of existing NPPs

Probably the largest amount of information on occupational doses at various nuclear power plants is gathered in the Information System on Occupational Exposure (ISOE) programme of the Nuclear Energy Agency (NEA). Thus the information given in this chapter generally is a short summary of the most recent ISOE programme report (*OECD, 2008*).

Since 1992 ISOE, jointly sponsored by the OECD/NEA and IAEA, has supported the optimisation of worker doses in nuclear power plants through an information and experience exchange network for radiation protection professionals of nuclear power plants and national regulatory authorities worldwide, and through development and publication of relevant technical resources.

A key aspect of the ISOE programme is the tracking of annual occupational exposure trends from nuclear power facilities worldwide for benchmarking, comparative analysis and experience exchange amongst ISOE members. Using the ISOE database, which contains annual occupational exposure data supplied by all participating utilities, ISOE members can perform various benchmarking and trend analyses by country, by reactor type, or by other criteria such as sister-unit grouping. The summary below provides highlights of the general trends in occupational doses in nuclear power plants.

At the end of 2006, the ISOE programme included 71 participating utilities in 29 countries (336 operating units; 42 shutdown units), as well as the regulatory authorities of 25 countries. The ISOE occupational exposure database itself included information on occupational exposure levels and trends from 401 operating reactors in 29 countries, covering about 91 % of the world's operating commercial power reactors. Table 7.10-26 summarises the participation by reactor type and status.

Table 7.10-26 Number of reactors included in the ISOE database.

	PWR	BWR	PHWR	GCR	LWGR	Other	Total
Number of operating reactors included in the ISOE database	262	88	28	22	1	0	401
Number of definitively shutdown reactors included in the ISOE database	26	15	2	31	4	2	80
Total number of reactors included in the ISOE database	**288**	**103**	**30**	**53**	**5**	**2**	**481**

A summary of average annual collective dose in 2006 by reactor type for operating reactors is provided in Table 7.10-27.

Table 7.10-27 Summary of average collective doses for 2006.

Radioactive effluents	2006 average annual collective dose (man•Sv)	For 2004-2006 (man•Sv) 3-year rolling average
Pressurised water reactors (PWR/VVER)	0.71	0.75
Boiling water reactors (BWR)	1.32	1.41
Pressurised heavy water reactors (PHWR/CANDU)	1.15	1.06
All reactors, including gas cooled (GCR) and light water graphite reactors (LWGR)	0.85	0.88

Exposure trends over the past three years for all reactor types, expressed as average annual and 3-year rolling average annual collective doses are shown in Table 7.10-28 and in Table 7.10-29 respectively. These results are based primarily on the data reported and recorded in the ISOE database during 2007, supplemented by the individual country reports.

Table 7.10-28 Average annual collective dose per unit by reactor type, 2004-2006 (man·Sv).

PWR, VVR			BWR			PHWR			GCR			LWGR			Global Average		
2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
0.77	0.77	0.71	1.46	1.47	1.31	0.84	1.19	1.15	0.04	0.06	0.12	3.41	2.11	3.06	0.89	0.91	0.85

Table 7.10-29 3-year rolling average annual collective dose per unit by reactor type, 2002-2006 (man·Sv).

PWR, VVR			BWR			PHWR			GCR			LWGR			Global Average		
'02-'04	'03-'05	'04-'06	'02-'04	'03-'05	'04-'06	'02-'04	'03-'05	'04-'06	'02-'04	'03-'05	'04-'06	'02-'04	'03-'05	'04-'06	'02-'04	'03-'05	'04-'06
0.84	0.80	0.75	1.64	1.57	1.41	0.96	1.05	1.06	0.07	0.06	0.07	4.03	3.49	3.00	0.99	0.95	0.88

Figure 7.10-7 shows the 2006 data in a bar-chart format, ranked from the highest to the lowest average dose for different reactor types. Figure 7.10-8 shows the trends in the average collective dose per reactor type for 1992-2006, with the average annual doses for 2006 maintaining at fairly low level. In Figure 7.10-7, the "number of units" refers to the number of units for which the data has been reported for the year in question.

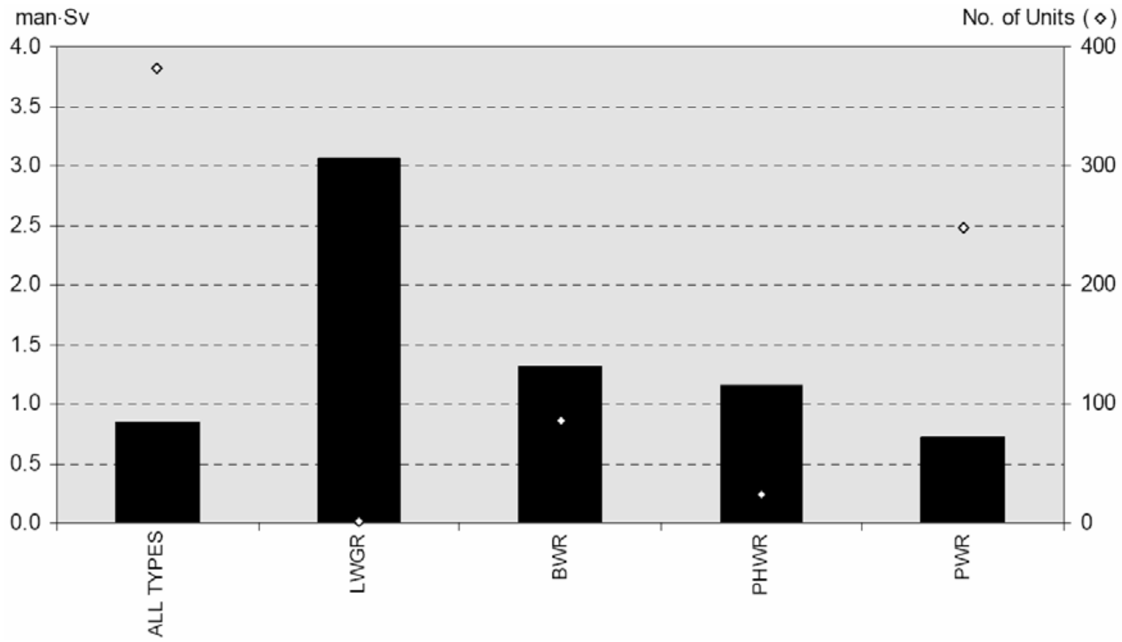


Figure 7.10-7. Average collective dose per reactor type in 2006.

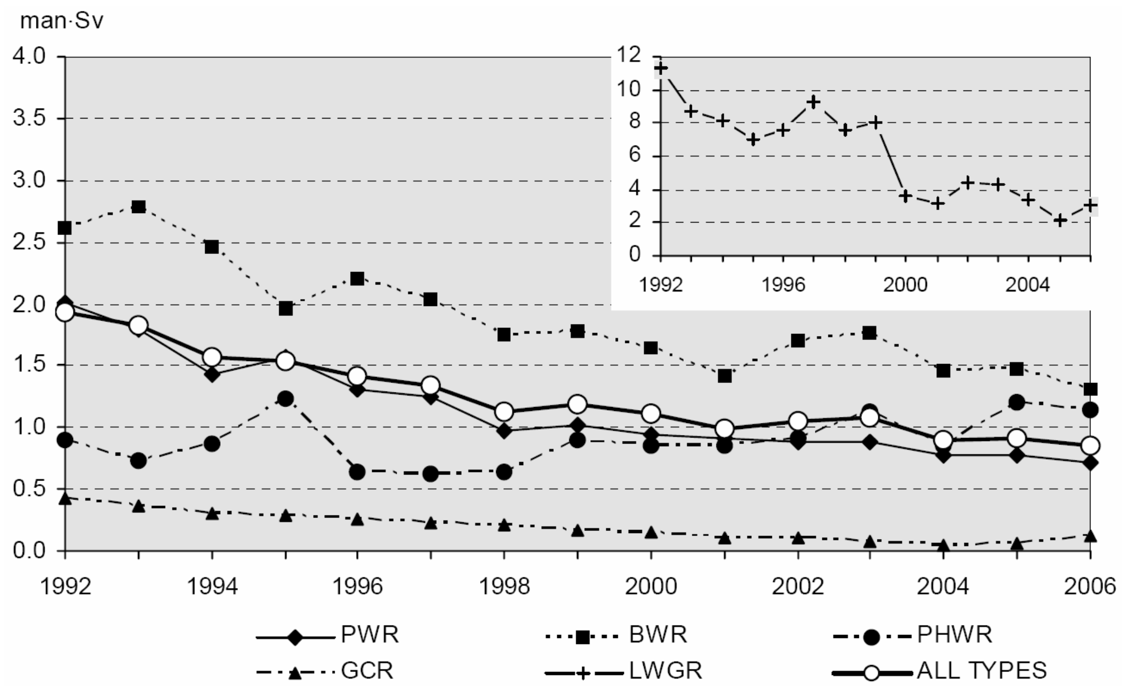


Figure 7.10-8 Average collective dose per reactor for all operating reactors by reactor type, 1992-2006 *(Note: Inserted chart shows average collective dose for LWGR*s).

In Europe, the average collective dose per reactor for PWRs and VVERs in 2006 was around 0.58 man·Sv per reactor, with most countries showing a stable or decreasing trend over the last three years. The average collective dose per reactor for BWRs in Europe in 2006 was around 1.00 man·Sv. The trend of the 3-year rolling average annual collective dose, which provides a better representation of the general trend in dose, shows a slight decrease for PWRs and VVERs, going from 0.74 man·Sv per reactor for 2002-2004 to 0.65 man·Sv per reactor for 2004-2006. The trend for BWRs appears to be more stable, with 1.01 man·Sv per reactor for 2002-2004 and 1.00 man·Sv per reactor for 2004-2006. The 3-year rolling average annual collective doses per reactor for BWRs are quite similar in all European countries, the minimum being in Sweden (0.91 man·Sv) and the maximum in Switzerland (1.08 man·Sv).

In general, the annual average collective dose per operating reactor unit has consistently decreased over the time period covered in the ISOE database, with the 2006 averages maintaining the levels reached in the last few years. In spite of some yearly variations, a clear downward trend in the levels of collective dose in most reactors has been maintained.

More detailed discussion and analyses of dose trends in various countries can be found in (*OECD, 2008*). However, it is noted that due to the complex parameters driving the collective doses and the varieties of the contributing plants, the above discussion and figures do not support any conclusions as regards to the quality of radiation protection performance in the countries addressed above.

7.10.3 Mitigation measures

7.10.3.1 Mitigation of non-radiological impacts

The new nuclear power plant will be designed so that it complies with all health and safety regulations of authorities. The previous Sections 7.10.2.1 and 7.10.2.2 list all the different types of impacts of the NNPP on public health and for some types also the possibilities to mitigate them. Many of the actions and technical solutions for the prevention and mitigation of the adverse impacts will be determined in more detail during the design of the NNPP.

The factors influencing public health, on which the NNPP can have an adverse impact either during the construction or operation stage, are air quality, noise, risk of accidents (construction and traffic), migration, alcohol consumption and criminality.

The mitigation measures of the impacts of the NNPP on air quality are described in Section 7.2.3. It discusses also the mitigation measures of the impacts of traffic to and from the NNPP. Since the heat and steam boilers are not part of the economic activity assessed in this EIA, their impacts and mitigation measures are described in the EIAs concerning them (*Ignalina NPP Decommissioning project management unit, 2004a* and *Ignalina NPP Decommissioning project management unit, 2004b*).

The noise impacts of the construction activities of the NNPP can be mitigated by timing particularly noisy or distracting actions to be carried out during weekdays and in the daytime. Heavy traffic to the construction site can also be timed similarly if necessary. The noise levels can be reduced also by using noise barriers.

The noise made by machinery and equipment during the operation of the NNPP can be effectively reduced with the choice of construction techniques and materials of the buildings. Sources of noise can also be isolated with a casing or they can be equipped with sound dampers if necessary. Noise resulting from vibration can be reduced by placing the vibrating equipment on a flexible base.

The impacts of the NNPP on traffic safety can be mitigated with appropriate traffic planning and control. The amount of traffic can be reduced by organizing bus transports for the employees of the NNPP during both the construction and the operation stage. During construction special accommodation facilities can be built near the construction site to reduce traffic. Special transport, especially during the construction stage, can be scheduled to take place outside the peak hours of everyday traffic.

Occupational risk factors and ways to reduce them are described separately in Sections 7.10.2.1 and 7.10.2.2.

The mitigation of adverse social impacts, such as any social problems caused by temporary construction labour moving to the area, should be taken into account in advance when planning the project. The adverse impacts can be minimized with the co-operation between the organizer of the NNPP and the nearby municipalities. Different leisure activities can be coordinated for the employees and the foreign employees can be provided with guidance on the local culture and practices.

7.10.3.2 Mitigation of radiological impacts

Around the new NPP site, a sanitary protection zone (SPZ) will be established, where there are no permanent inhabitants and where economic activities are limited. Radiological impact on public health within the sanitary protection zone is minimal and will not exceed the limits prescribed by radiation protection requirements. Outside the sanitary protection zone the impact can be considered as insignificant. Regulations for SPZ establishment are described in State Journal, 2004, No. 134-4878. It should be emphasized that the terms used for area name around the NPP and criteria for determination of size of this area differs in various countries. The term “Sanitary protection zone” was used in former Soviet Union and typically this zone around a nuclear power plant in former Soviet Union countries is 3 km in radius. Existing Ignalina NPP also has a SPZ of 3 km in radius. Other terms such “exclusion area” or “plant site” are used in US and Finnish legislation. A summary of requirements and criteria for establishment of the areas around a NPP in various countries is presented in Table 7.10-30.

Calculations of radiation exposure of the critical group members according to recommendations of the normative document LAND 42:2007 (*State Journal, 2007, No. 138-5693*) do not present dose variation with distance. Therefore additional dose calculations for justification of SPZ size have been performed according to recommendations of IAEA Safety Reports Series No. 19 “Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment” (*IAEA SRS No. 19*). Dose calculation results due to releases into the atmosphere are presented in Figure 7.10-9. According to LAND 42:2007, if the different release routes (e.g. into the air and water) can lead to doses for the same or different member of the critical group of population, the dose constraint value used for each route should be half of the actual dose constraint (i.e. 0.1 mSv per year). Therefore, dose constrain of 0.1 mSv per year for releases into the air is used for SPZ definition. It should be noted, that maximum estimated annual exposure of the critical group members of the population due to release of radioactive liquids is 0.040 mSv (see Table 7.10-24) which does not exceed the dose constraint for release route into water (0.1 mSv).

Two reactor types CANDU-6 and ESBWR are considered only as they result in the highest doses to a member of the critical group of population according to Table 7.10-23. As it can be seen from Figure 7.10-9, higher doses due to radioactive releases into the atmosphere are caused by 4 Units of CANDU-6 as compared to 2 Units of ESBWR. The ratio of the doses for CANDU-6 and for ESBWR is about 6.3. The highest dose in both cases is observed at locations inside 800 m radius zone around the release source. The exposure dose is decreasing with distance and at a point located 1 km from the release source is about 3.30E-04 Sv/year for CANDU-6 and about 5.25E-05 Sv/year for ESBWR. On the 3 km boundary from the release point the doses are 6.3E-05 Sv/year and 1.0E-05 Sv/year for CANDU-6 and ESBWR respectively.

Therefore, based on these estimations and depending on reactor type the size of SPZ for the new NPP shall be in the range from 1 km to 3 km.

The proposed sites for the NNPP are within the existing INPP industrial site and sanitary protection zone. The shortest distance from the proposed sites to the boundary of the existing sanitary protection zone is about 1.5 km. Thus for some reactor type there will be the need for new restrictions or relocation of people.

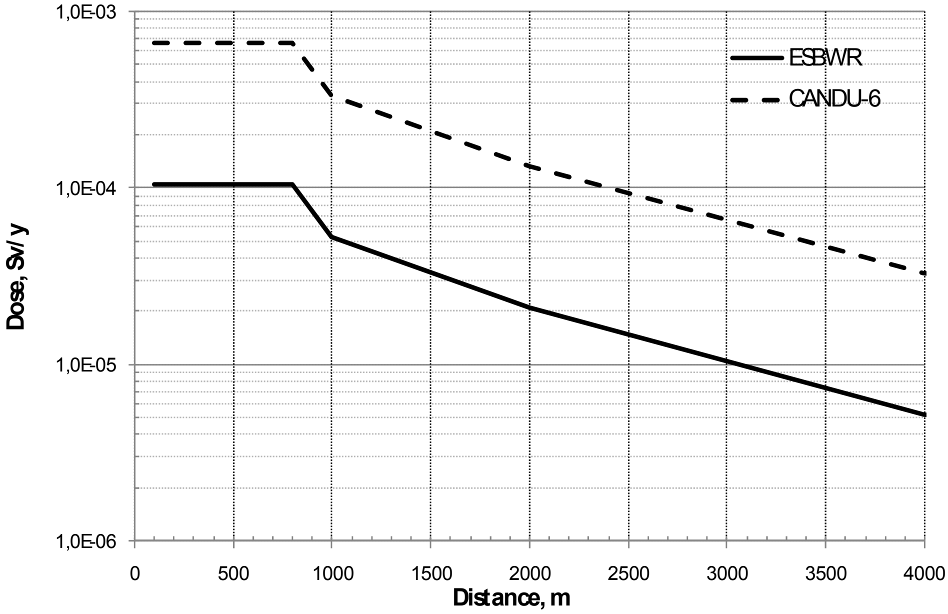


Figure 7.10-9. Dose variation with distance.

Table 7.10-30 Area around nuclear power plant.

Sanitary protection zone (*State Journal, 1996, No. 119-2771)*	**Exclusion area (*10 CFR*)**	**Plant site (*YVL 1.10*)**
Sanitary protection zone - a special territory or a site of radioactive contamination where the irradiation level may exceed the prescribed norms under the normal operational conditions of a nuclear facility. Prior to the commissioning of the facility, all the population shall be resettled from the sanitary protection zone in the manner prescribed by the Government. Activities as well as construction of installations and buildings unrelated to the operation or service of the facility shall be prohibited therein. Land, woods and water bodies in the territory of the sanitary protection zone may be used for economic purposes only subject to an approval of the facility operator and authorizations from the Ministry of the Environment and the Ministry of Health. According to (*State News, 2004, No. 134-4878*) dose constraint for members of the public (0.2 mSv/year) shall not be exceeded at the boundary of SPZ during normal NPP operation.	**Exclusion area** means that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided these are not so close to the facility as to interfere with normal operations of the facility and provided appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety. Residence within the exclusion area shall normally be prohibited. In any event, residents shall be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety will result. An exclusion area shall be of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure.	A nuclear power **plant site** extends to about a kilometre's distance from the facility. It is defined as an area where only power plant related activities are allowed as a rule. Permanent settlement is prohibited and only very limited employee accommodation or recreational settlement is allowed. The licensee responsible for the operation of the nuclear power plant shall have authority of decision over all activities in the area and shall be able to remove unauthorised individuals from the site, if necessary, or prevent such individuals from entering it. The plant site may contain other non-facility related activities provided that they do not pose a threat to plant safety. A traffic lane may traverse the site if the volume of traffic is small and if traffic can be directed elsewhere, if necessary. Visits onsite are allowed provided that the licensee has the possibility to control the movement of visitors.

Additionally, administrative and technical measures will be implemented to mitigate radiological impacts. These measures include:

- Control of radioactive sources. The measures and activities necessary for radioactive material confinement will be implemented. Multiple barriers will be provided to prevent the radioactive material releases to environment.
- Control of radioactive releases. This covers the measures and activities that will be installed at new NPP to control the radioactive releases into environment to comply with specified limits.
- Monitoring of radioactive releases. The measures and activities necessary for measurings of radioactive releases in certain emission points will be implemented.
- Environment Monitoring. The measures and activities necessary for measuring of environmental radioactivity levels, to assess the radiological impact on public health and environment due to radioactive releases from the new NPP will be available.

The more detailed impact mitigation measures will be analyzed and justified in Safety Analysis Report considering Technical Design aspects.

7.11 SUMMARY OF RADIOLOGICAL IMPACTS AND IMPACTS ON LAKE DRUKSIAI UNDER NORMAL OPERATIONAL CONDITIONS

7.11.1 Summary of radiological impacts

As stated in the EIA Program, this Section summarizes the assessment of radiological impacts on different components of the environment due to normal operation of the new NPP. Also other existing and planned nuclear facilities located in the Ignalina NPP sanitary protection zone are taken into consideration.

The radiological impact on the environment during normal operation of the NNPP arises from radioactive airborne and liquid effluents. Evaluation of the liquid and airborne releases into the environment for different types of power reactors is given in Sections 7.1.2 and 7.2.2, respectively. LAND 42:2007 (*State News, 2007, No. 138-5693*) provides principles for how assessment of radiological impact on the environment shall be performed. One of the principles states that protection measures ensuring an adequate safety for humans are sufficient to protect both the environment and natural resources. Therefore, based on data of liquid and airborne releases, the calculation of potential exposure of the population has been performed and is presented in Section 7.10. Depending on reactor type, capacity and total number of units, annual doses of the critical group members of population due to release of radioactive effluents (both airborne and liquid) into the environment vary in a range from 8.7 to 50.7 μSv. The established dose constraint for members of the public is 0.2 mSv (200 μSv) per year. Therefore, doses during normal operation of the new NPP will be about 5 times less than the dose constraint. This means that the new NPP will not cause any detrimental health effects (e.g. reduction in length and quality of life from exposure to ionizing radiation, somatic effects, cancer or genetic disorder).

Overview of existing and planned Ignalina NPP facilities

Both potential sites for the new NPP are located within the INPP industrial site with the existing 3 km radius sanitary protection zone (SPZ). The INPP will be completely shut down by the end of 2009. An immediate dismantling concept has been selected for the decommissioning of the INPP. In the course of decommissioning, new nuclear facilities will be constructed on the INPP industrial site and nearby with the purpose of management, interim storage and disposal of existing operational and decommissioning produced radioactive waste (only of certain types of waste) together with spent nuclear fuel.

Decommissioning of the existing INPP and the operation of these new nuclear facilities may last for several decades and even more. These existing and new nuclear activities may stipulate radiological impact at the sites of the new NPP during performance of construction works. Once becoming operational, radiological impact from the new NPP may be contributed by additional radiological impacts from the existing and new nuclear activities.

According to the INPP Final Decommissioning Plan (*INPP DPMU, 2004*) the INPP decommissioning process is split into several decommissioning projects (DP). Each of these DP is a process covering a particular field of activity, defining scope of works and their peculiarities and providing input for organization of the specific activity, safety analysis and environmental impact assessment. In order to ensure that environmental impact assessment is based on reliable and detailed information, which becomes available along the progress of the particular DP, the EIA Program of INPP decommissioning (*INPP DPMU, 2004*) provides to develop EIA reports separately for each DP. Every EIA report of a subsequent DP shall take into account results of previous reports. Thus the overall environmental impact due to the INPP decommissioning will be assessed and controlled on the basis of the latest information, and environmental impact mitigation measures will be adequate for the real situation.

In addition to the decommissioning activities at the Ignalina NPP existing nuclear facilities, the decommissioning project foresees construction of:

- Interim Spent Nuclear Fuel Storage Facility (ISFSF),
- Solid Radioactive Waste Management and Storage Facility (SWMSF),
- Very Low-level Radioactive Waste Disposal Facility (Landfill repository),
- Short Lived Low and Intermediate Level Radioactive Waste Near-Surface Disposal Facility.
- Landfill Buffer Storage.

Future activities foresee convertion of the presently operated Bituminized Waste Storage Facility into a disposal facility. A Liquid radioactive waste Cement Solidification Facility (i.e., for grouting of spent ion-exchange resins and filter aid deposits) began operation in the year 2006. Solidified waste will be temporarily stored in a new Temporary Storage Facility, constructed on the INPP industrial site. Later on, the waste will be disposed of in a Short Lived Low and Intermediate Level Radioactive Waste Near-Surface Disposal facility. The decision on extension of the existing Spent Nuclear Fuel Storage Facility has already been made. In the year 2006 VATESI appended the license conditions and allowed storage of additionally 18 CONSTOR RBMK-1500 casks in the storage facility. One more modification is planned, which would increase the storage capacity by an additional 10 CONSTOR RBMK-1500 casks.

Existing and planned nuclear facilities, located in the Ignalina NPP existing sanitary protection zone of 3 km radius are shown in Figure 7.11-1. Main activity phases (operation, decommissioning, institutional surveillance, etc.) of the nuclear facilities are summarized in Figure 7.11-2.

Figure 7.11-1. Existing and planned nuclear facilities, located in the INPP existing sanitary protection zone of 3 km radius.

In Figure 7.11-1 above the nuclear facilities are as follows:

(1) - Existing bituminized radioactive waste storage facility and new interim storage facility for solidified radioactive waste (spent ion-exchange resins and filter aid deposits). Both storage facilities are located inside the INPP industrial site and presently do not have their separate Sanitary Protection Zones (SPZ). During INPP decommissioning it is planned to convert the bituminized waste storage facility into a disposal facility. A separate SPZ will be foreseen during the development of the EIA documents for this disposal facility.

(2) - Power Units of Ignalina NPP. The INPP existing SPZ is an area of 3 km radius around the Power Units.

(3A) and (3B) – alternative sites 1 and 2 for the planned new NPP.

(4) - Existing Spent Nuclear Fuel (SNF) storage facility. The design of the storage facility defines a 1 km radius SPZ around this facility. SPZ of the storage facility falls within boundaries of INPP existing SPZ and is presently not allocated separately.

(5), (6) – The new interim SNF storage facility (ISFSF) and Solid radioactive Waste Treatment and Storage Facility (SWTSF). These nuclear facilities will be close to each other, their SPZ will overlap and the facilities will have a common security fence. The EIA Reports foresee a common, about 500 m wide SPZ for both facilities.

(7) – One of the proposed sites (southern) for very low-level radioactive waste disposal facility (Landfill). SPZ is not defined; preliminary proposals will be prepared during the development of the EIA documents.

(8) – Disposal vaults of the planned low and intermediate level radioactive waste near-surface disposal facility in the Stabatiskes site. The EIA Report defines SPZ as an area enveloping 300 m distance from the disposal vaults. The layout of the facility is preliminary and shall be detailed during development of Basic design.

(9) – The new Landfill Buffer Storage. The existing INPP security fence will be re-located to include this facility into the existing security zone of INPP industrial site.

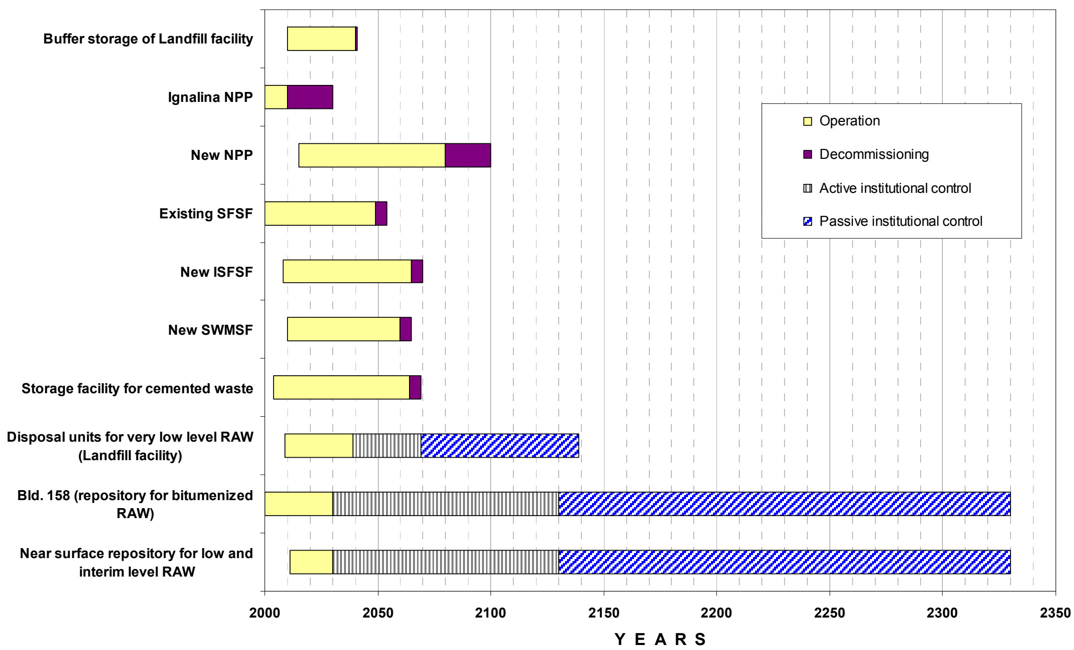


Figure 7.11-2. Main activity stages of the existing and planned nuclear facilities, located in INPP existing sanitary protection zone of 3 km radius.

It has been planned that the first unit of the new NPP will start operation no later than 2015. Therefore, total radiological impact from new NPP and existing and planned Ignalina NPP facilities located within INPP industrial site are estimated for 2015. During operation of the new NPP radiological impact from Ignalina NPP facilities due to radioactive decay of stored radioactive waste and SNF will decrease.

Radioactive releases from the existing facilities in the SPZ of INPP

Doses due to the actual waterborne releases and airborne emissions from the INPP site are presented in Figure 7.11-3. The data are taken from *INPP, PTOot-0545-15*. It can be concluded that the doses due to the actual releases from the INPP site are far below the dose constraint (0.2 mSv per year). Starting from 1995 the dose due to liquid releases gradually decreases. The dose due to airborne releases is in general considerably lower. The dose increase in 2004 is due to the increase of the release of I-131 from the INPP liquid radioactive waste treatment facility (building 150).

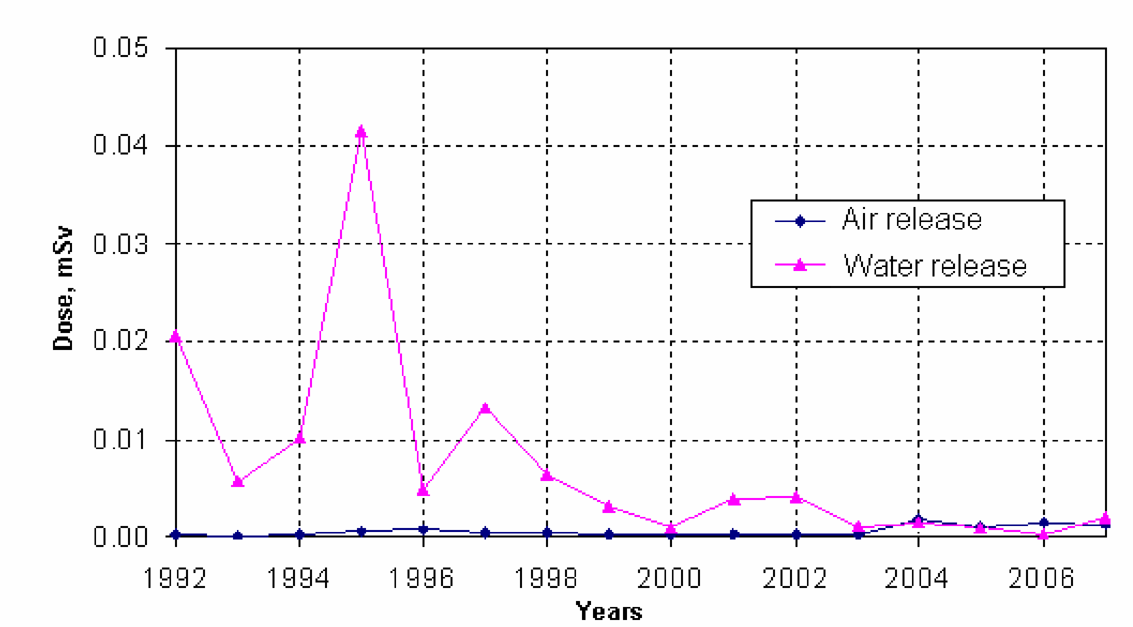


Figure 7.11-3. Annual effective dose to the critical group member of population due to radioactive releases (airborne emissions and liquid releases) from the nuclear facilities located in the SPZ of INPP for time period 1992 – 2006 (*INPP, PTOot-0545-14*)

It has been planned that INPP will be in operation till the end of 2009. To forecast future doses the last seven years' (1999 – 2006, when the spent nuclear fuel transfer was performed) observed dose maximum is selected as a conservative estimation of the impact due to the operation of INPP till the year 2010. The assumed annual effective dose to a member of the population due to airborne emissions is 1.9×10^{-6} Sv (year 2004 dose), and due to liquid releases is 4.1×10^{-6} Sv (year 2002 dose).

A forecast of the impact from the existing nuclear facilities in the SPZ of INPP also includes the dose forecast due to the emissions and discharges from the following planned activities:

- INPP Reactor Unit 1 reactor final shutdown, de-fuelling and in-line decontamination phase of the INPP Decommissioning Project (i.e. U1DP0 activities). The U1DP0 activities are planned to be implemented in the years from 2005 to 2012;
- The start-up of the operation of the new Cement Solidification Facility for liquid radioactive waste solidification and of the Interim Storage Building for the storage

of solidified waste in the year 2006. The Cement Solidification Facility will operate for about 14 years. The Interim Storage Building is designed for operation of approximately 60 years.

The forecast for the dose to the population due to airborne emissions and liquid releases from the existing nuclear facilities in the SPZ of INPP is summarized in Figure 7.11-4. It can be seen that the doses due to airborne emissions and liquid releases from the existing nuclear facilities in the SPZ of INPP are low. The observed dose maximum (9.6×10^{-6} Sv) in year 2009 is mainly due to the planned start up of the in-line decontamination activities at the Reactor Unit 1 (3.6×10^{-6} Sv) and the assumption that the doses resulting from the operation of INPP (6.0×10^{-6} Sv) are still relevant.

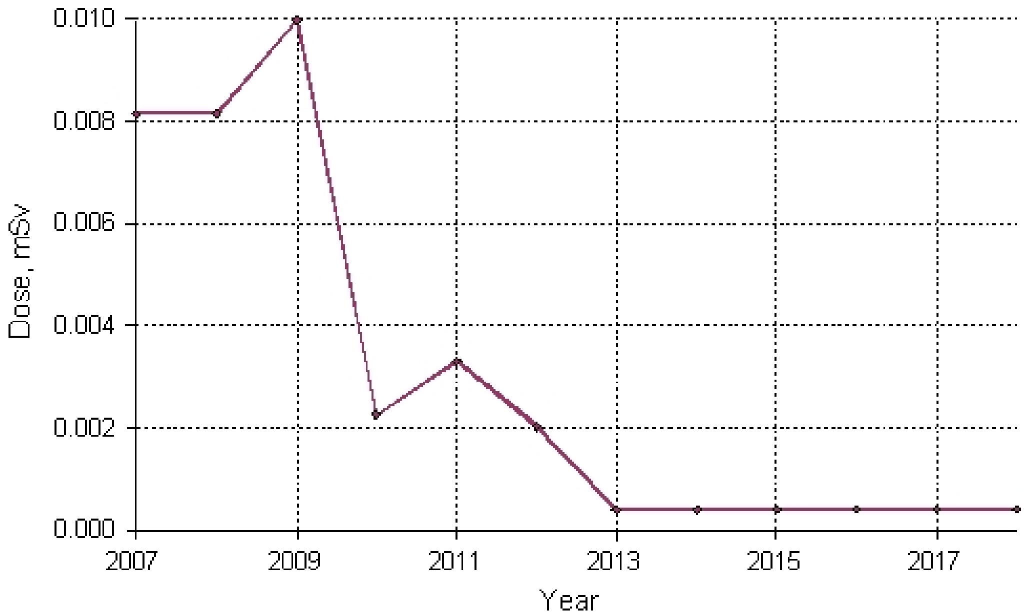


Figure 7.11-4. Forecast for the dose to the critical group member of population due to radioactive releases (airborne emissions and liquid releases) from the nuclear facilities located in the SPZ of INPP.

The dose forecast as presented in Figure 7.11-4 does not include similar in-line decontamination activities at the Reactor Unit 2. A separate project (U2DP0) will be prepared for these activities. The estimation of the doses due to activity releases is not available at the moment. Therefore only approximate assessment is possible. Considering availability of ISFSF it is planned to finish the de-fuelling of Reactor Unit 2 in several years after the final reactor shutdown. In comparison to activities at Reactor Unit 1, the equipment in-line decontamination at Reactor Unit 2 could start within a shorter time period after the final reactor shutdown. Therefore the activity of radioactive releases (short-lived Mn-54, Fe-55, Co-58, Co-60, Cs-134, etc.) will be higher and could result in higher doses as compared to the doses from the similar U1DP0 activities. It is anticipated that equipment in-line decontamination at Reactor Unit 2 can stipulate approximately two times higher annual dose to the critical group member of population (i.e. up to 8.0×10^{-6} Sv instead of 3.6×10^{-6} Sv in a single year). Therefore it is forecasted that after 2015 the annual effective dose due to airborne emissions and liquid releases from the existing nuclear facilities in the SPZ of INPP will be below 1×10^{-6} Sv.

No dose estimations due to activity releases during further decommissioning projects for existing INPP facilities are available at the moment. The EIA Program of INPP decommissioning provides that every subsequent environmental impact assessment shall take into account the results of previous reports.

Impact due to radioactive releases from the newly planned facilities in the INPP SPZ

With respect to the newly planned nuclear facilities in the SPZ of INPP the radioactive impact can be stipulated by the new Solid radioactive Waste Treatment and Storage Facility (SWTSF), the new Interim Spent Nuclear Fuel Storage Facility (ISFSF) and the new Landfill Buffer Storage. EIA Reports have been prepared for these new facilities.

Based on conservatively estimated annual effective dose to the critical group member of population from the SWTSF, dose due to radioactive airborne emissions during the waste retrieval and treatment phase (i.e. in the period 2010-2020) is equal to 7.29×10^{-6} Sv. With finishing of waste retrieval the radioactive airborne emissions and subsequently the exposure of the population will decrease.

The conservatively estimated annual effective dose to the critical group member of population due to radioactive airborne emissions from ISFSF activities will not exceed 4.15×10^{-7} Sv. In case of SNF reloading in the FIHC of ISFSF additional exposure of up to 1.67×10^{-7} Sv is possible. However, it is not anticipated that a cask will fail during its storage life. The necessity for occurrence of a fuel repacking operation is low in probability. The cask will be designed as a double-barrier welded system for a safe operation time of at least 50 years. Therefore the operation of the FIHC should not be considered as a part of normally expected ISFSF operations.

The conservatively estimated annual effective dose to the critical group member of population due to radioactive releases from the new Landfill Buffer Storage is lower than 0.04×10^{-6} Sv.

Low and intermediate level waste near-surface disposal facility is planned for solid and solidified radioactive waste packages. The repository will have no radioactive waste treatment installations. The conditioned, packaged and ready for disposal waste packages will be delivered to the repository. Packages shall meet the Waste Acceptance Criteria for a near-surface repository. No release of activity into the atmosphere either in aerosol or gas form is expected under normal operation conditions. During the waste disposal phase the vaults of the repository will be equipped with a temporary drainage system. No radioactive liquid releases into the environment will occur.

Environmental impact assessment for the planned very low-level radioactive waste near-surface disposal facility (Landfill) has not been performed yet. The INPP Final Decommissioning Plan (*INPP DPMU, 2004*), the Concept of the Disposal Facility (*J. Dahlberg, U. Bergström, 2004*) and study of Derivation of Preliminary Waste Acceptance Criteria for Landfill Facility (*LEI, 2006*) defines that only solid and solidified radioactive waste packages will be disposed of in the facility. The repository will have no radioactive waste treatment installations. The conditioned, packaged and ready for disposal waste packages will be delivered to the repository. An adequate isolation of radionuclides from the environment and from its impacts shall be ensured during waste transfer to the repository and during waste disposal.

It is planned that by the end of the INPP decommissioning (in about 2030) the INPP existing Bituminized Waste Storage Facility will be converted into a repository. Environmental impact assessment for the Bituminized Waste Disposal Facility has not been performed yet.

Forecast of the maximal annual effective dose to the critical group member of population due to radioactive releases (airborne emissions and liquid releases) from the existing and planned nuclear facilities located in the SPZ of INPP in 2015 is summarized in Table 7.11-1.

Table 7.11-1. Forecast of the impact from radioactive releases (for 2015).

Facility	Dose due to releases, mSv/year
Ignalina NPP existing facilities	1.00E-03
SWTSF	7.29E-03
ISFSF	4.15E-04
FIHC (during SNF reloading at ISFSF)	1.67E-04
Landfill Buffer Storage	3.77E-05
New NPP	5.07E-02
TOTAL	5.19E-02

It can be seen from Table 7.11-1 that in 2015 the greatest contribution to the dose is due to radioactive releases from the new NPP.

Impact due to Direct Radiation

The monitoring of radiation fields performed in the INPP industrial site and its surroundings shows that increase in direct radiation dose rates is observed locally and only close to some of radioactive material handling facilities. The dose rate measurements performed at the proposed SWTSF and ISFSF sites, which are approximately at 1.5 km distance from Ignalina NPP Reactor Units, existing dry SNF storage facility, and other facilities, demonstrate that gamma radiation background at these sites does not distinguish from gamma radiation background outside the border of the existing SPZ of INPP. The mean of measured dose rates corresponds to the mean of dose rates measured in the INPP region. This means that impacts due to direct exposure from existing Ignalina NPP nuclear facilities do not create exceptional impacts at distances greater than approximately 1 km. The conclusion is therefore that the radiological impact to population due to direct radiation at the boundary of the existing SPZ (3 km) is insignificant and does not need to be considered further.

Conclusions on radiological impacts

Depending on reactor type, capacity and total number of units of the NNPP, annual doses of the critical group members of population due to releases of radioactive effluents (both airborne and liquid) into the environment vary in a range from 8.7 to 50.7 µSv (from 0.0087 to 0.0507 mSv). The radiological impact to population due to direct radiation at the boundary of existing SPZ is insignificant.

It is forecasted that in 2015 (when the new NPP is planned to be built) the total annual effective dose to the critical group members of population due to airborne emissions and liquid discharges from the new NPP and existing and new nuclear facilities of Ignalina NPP at the boundary of the existing SPZ (with 3 km radius) will be below 5.2×10^{-5} Sv (0.052 mSv). The established dose constraint for members of the public is 0.2 mSv per year. Therefore, total annual dose in 2015 to population during normal operation of the facilities in the existing SPZ will be about 4 times less than the dose constraint.

7.11.2 Summary of impacts on Lake Druksiai

7.11.2.1 Impacts of NNPP cooling

The amount of waste heat discharged to Lake Druksiai from the NNPP depends not only on the electricity produced but also on the cooling system chosen. In direct cooling system all the heat is discharged to the lake when in case of cooling towers only a minor part of the heat enters the lake and the major part is transmitted to air.

Based on modelling results and expert assessments it can be concluded that the ecologically acceptable thermal load to the lake will be approximately 3 200 $MW_{released.}$, With this thermal load no significant impacts on the lake ecosystem are expected compared to the present state of the lake. With higher thermal load the impacts on the lake ecosystem start to be clear and significant.

If the thermal load will be negligible (cooling solely by cooling towers), the lake temperatures will return to the natural level and this can somewhat improve the living conditions of the species preferring cool water. However, recovery of the conditions or species composition before commissioning of INPP is not expected. If the general intensive eutrophication process continues, this alternative may also lead to low-oxygen conditions during periods of ice-cover. From this point of view, moderate warming of the lake can even be environmentally advantageous. Thus this option has somewhat diverse impacts on the lake ecosystem: it is the best option when the warming of lake is considered, but may result in partly adverse effects due to oxygen depletion if the eutrophication of the lake will continue.

The current outlet is the best alternative when the area warmed up is used as criteria. However, the different outlet options do not significantly differ from each other. The present NPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water. The southern outlet position is more confined and shallow, which restricts the warm outlet water mixing with cooler lake water thus reducing the surface area where the cooling to atmosphere takes place. Thus the southern outlet would lead to more distinct warming and eutrophication impacts in the southern part of the lake than other outlet options.

Dividing the outlet to two locations is not a significantly better solution than the present outlet option when comparing the average size of warmed up areas.

In the deep inlet option simulation, the cold water storage of the deeper part of the lake was depleted at the very beginning of the simulation, after which the deep inlet water temperature did not differ from the temperatures in the present inlet option. Additionally, in the deep inlet option, after the thermocline of the lake is destroyed, the mixing of warmer water to deeper layers is increased, raising the total heat storage in the lake. As a result the deep inlet option would produce higher surface temperatures in the whole lake during the warmest periods compared to the present inlet option.

The main hydrological impacts of the operation of the new NPP are the evaporative losses created when the heated cooling water will transfer the heat load to air by evaporation. The total losses depend on the plant effect and the cooling method selection.

During normal hydrological years the average lake level is not expected to fall below the normal because of the NNPP and thus the hydrological effects on the lake and their consequences are considered minor. During rare periods of three successive dry years the lake level would fall below normal, possibly reaching the minimum allowable level. As the water volume and surface area of the lake decrease only relatively little even in this case, the hydrological impacts on the lake can be estimated to be small also in this kind of rare event.

The impact of the cooling water releases on wintertime ice conditions was also simulated using three different NNPP thermal load levels. At a thermal load of 2 230 $MW_{released}$ the ice free area would be located close to the NNPP outlet. At times, depending on winter temperature in general, the impact on the ice cover would be significant, especially with thermal loads of over 3 160 $MW_{released}$. Thermal loads of

4 460–6 310 $MW_{released}$ would keep the main part of the lake open longer from the start of the winter. In general the impact on the ice cover would be smaller in the southern and western part of the lake compared to the rest of the lake.

7.11.2.2 Impacts of NNPP waste waters

The nutrient load from the new NPP will comprise only 4 to 8 % of the total nutrient load to be discharged from the Visaginas new waste water treatment plant. The nutrient load from the NNPP is thus small compared to the total load to Lake Druksiai coming from the other sources (e.g. Visaginas municipality and natural runoff). Thus the impacts of the new NPP to water quality and eutrophication are considered insignificant and they can not be distinguished from the general eutrophication development of the lake.

Waste water originating from process and technical use will be treated depending on the quality of the waste waters by mechanical, chemical or biological means according to the regulations and laws. Waste waters from process water production will be neutralized. Possible oil traces will be removed. Waste waters from the controlled area will be processed in the liquid waste treatment plant. The impacts of the treated waste waters on the lake are estimated to be minor and acceptable. However, these impacts will be monitored and if unacceptable consequences occur, the treatment of waste waters will be improved.

7.11.2.3 Landscape

The landscape in the Lake Druksiai watershed has degraded because of the building and operation of INPP, Visaginas town and related infrastructure.

Construction of the new NPP near the INPP will produce no greater effect of landscape degradation and will not disrupt the ratio between the natural and anthropogenic territories. The impacts on the landscape of Lake Druksiai and its surroundings will therefore not be significant.

7.11.2.4 Cultural heritage

No impacts on cultural heritage sites or objects related to Lake Druksiai are expected.

7.12 COMPARISON OF ALTERNATIVES

7.12.1 General

The following implementation alternatives of the new nuclear power plant in Lithuania have been assessed in this EIA Report:

- Technological alternatives for nuclear power reactors (all are generation III or III+ reactors)
  - pressurized water reactor (PWR)
  - boiling water reactor (BWR)
  - pressurized heavy water reactor (HWR)
- Power level alternatives
  - Power generation up to max. 3400 MW_e
- Location alternatives
  - Site No. 1 – east of INPP
  - Site No. 2 – west of INPP
- Cooling alternatives
  - Direct cooling
    - Different inlet and outlet alternatives
      - Present inlet
      - Deep inlet
      - Western inlet
      - Present outlet
      - Southern outlet
  - Indirect cooling
    - Wet cooling towers
    - Dry cooling methods
    - Hybrid cooling towers
  - Combination of direct and indirect cooling

The differences in environmental impacts between these alternatives are summarized in the following Sections.

7.12.2 Comparison of alternatives

7.12.2.1 Environmental impact comparison tables

In Table 7.12-1 and Table 7.12-2 the most essential environmental impacts, taking the different alternatives that have been assessed into account, are summarized. In the Sections after that different site and technical alternatives are discussed and compared.

Table 7.12-1. Summary of the most essential environmental impacts of different alternatives during the construction phase.

CONSTRUCTION PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socio-economic environment	Public health
Construction of the nuclear power plant	Slight increase in wastewater load but capacity of rehabilitated WWTP sufficient.	Temporary local dust impact. Dusting will not have significant impact on the air quality outside the construction site.	Significant earth-moving works but ground already heavily altered by man in both sites. No adverse impacts on groundwater.	Potential significant adverse impact on European otter (*Lutra lutra*) and Marsh harrier (*Circus aeruginosus*) populations (designation values for the Natura 2000 –area, European otter listed in Annex IV of the EU Habitat directive) if Site No. 2 is chosen can be mitigated to an acceptable level. Potential significant adverse impacts on Marsh harrier (*Circus aeruginosus*) and Spotted crake (*Porzana porzana*) populations (designation values for the Natura 2000 –area) if Site No. 1 is chosen can be mitigated to an acceptable level. Other adverse impacts at both sites on biodiversity are not significant or can be mitigated to an acceptable level.	Only small change to landscape, no significant difference between alternative sites. No changes in land use limitations at either site.	Significant positive impact on regional economy and society in both Lithuania and Latvia: - Significant employment impact. - Increased demand for long-term accommodation and services. Immigration of foreign NPP construction employees, diverse impacts on local society.	Noise from the construction site will not exceed 55 dBA at a distance of approx. 850 m from the centre of the area of construction. Noise will not exceed allowable levels.
Construction of the associated infrastructure	No impact.	Temporary local dust impact, not significant.	Construction of new access roads and other	No significant impact.	No significant impact as new transmission	Significant positive impact on regional economy	Noise will not exceed allowable levels.

CONSTRUCTION PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socio-economic environment	Public health
			required infrastructure will cause impacts on soil through required earthworks.		line routes and pylons are not required.	and society in both Lithuania and Latvia.	
Construction of the required cooling structures	Construction of new inlet at Site No. 2 may cause temporary clouding of water in immediate vicinity. If a new outlet is required in either site alternative the construction may cause temporary clouding of water. No significant impacts.	No impact.	No significant impact.	Potential significant adverse impacts on European otter (*Lutra lutra*) and Marsh harrier (*Circus aeruginosus*) populations (designation values for the Natura 2000 –area, European otter listed in Annex IV of the EU Habitat directive) if Site No. 2 is chosen can be mitigated to an acceptable level.	No significant impact.	Significant positive impact on regional economy and society in both Lithuania and Latvia.	Noise will not exceed allowable levels.
Raw water and waste water	No impact.	No impact.	Groundwater amount sufficient. No major new facilities or piping required.	No impact.	No impact.	No impact.	No impact.
Transportation and traffic	No impact.	Road traffic will increase emissions into the	No impact.	Potential adverse impacts on the European fire-bellied	No impact.	Local/regional impact of increased traffic.	Noise from traffic will not exceed 55 dBA at a distance

CONSTRUCTION PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socio-economic environment	Public health
		air during the construction of the new NPP. Traffic emissions during construction are not assessed to have significant long-term impacts on the local air quality.		toad (*Bombina bombina*) and the great crested newt (*Triturus cristatus*) need to be mitigated if Site No. 2 is chosen. If Site No. 1 is chosen mitigation measures for European fire-bellied toad are required. These species are strictly protected on an EU level (listed in Annex IV of the EU habitat directive).			of 80-100 m from the centre of road. Noise will not exceed allowable levels. As a result of increase of traffic more transport accidents are expected. No significant impact from traffic emissions is expected.

Table 7.12-2. Summary of the most essential environmental impacts of different alternatives during the operational phase.

OPERATIONAL PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socioeconomic environment	Public health
Operation of new nuclear power plant	Lake Druksiai utilized for cooling and as raw water source.	No significant impacts.	No significant impacts.	Cooling water discharge potentially impacts biodiversity.	Will be visible only from some points of the lake shore. Only small change to landscape, no significant difference between alternative sites. No extension of existing sanitary protection zone and no changes to land use restrictions or	Employment impact for about 500 people. Significant positive impact on regional economy and society in both Lithuania and Latvia.	No significant impacts.

OPERATIONAL PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socioeconomic environment	Public health
					regulations in the surrounding area are expected at either site.		
Releases of radioactive substances	No significant impact.	No significant impact. Releases a fraction of the permissible limits.	No impact.	No impact.	Not relevant.	No impact.	No significant impact. Fear of significant radioactive releases may cause concern and affect sense of safety, no great change to current situation.
Cooling water and waste water	Thermal load to Lake Druksiai if direct cooling is used. The lake can not tolerate significantly greater thermal load than caused by INPP so far from an ecological point of view. The tolerable thermal load is estimated to be about 3 200 $MW_{released}$. A new deep inlet will not bring any significant benefits. A new western inlet at Site No. 2 brings only small benefits. A new southern outlet will cause more	No impact.	No impact.	Potentially significant adverse impacts on designation values of the Lake Druksiai Natura 2000 –area and other biodiversity values can not be excluded if a thermal load significantly exceeding 3 200 $MW_{released}$ is discharged to the lake. Positive impact on especially bird fauna biodiversity as parts of the lake would be kept continuously ice-free in wintertime.	No significant impact.	Change in ice conditions may affect possibilities of fishing on ice at certain places. Fishing still possible, no changes in total catches expected. Species composition may change if large amounts of cooling water are discharged to the lake. No significant impact.	No significant impact.

OPERATIONAL PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socioeconomic environment	Public health
	warming of the southern and eastern parts of Lake Druksiai and will accelerate eutrophication there. Divided outlet will not bring any significant benefits. Water amount will be sufficient in all cooling solutions. The maximum of 3400 MW electric power generation is possible by combining direct cooling and cooling towers. Treated process waters containing salts will be discharged to Lake Druksiai but no significant impact is expected.						
Noise	No impact.	No impact.	No impact.	No impact.	No impact.	No significant impact.	No significant impact.
Handling and disposal of radioactive waste	No impact.	No impact.	No impact when properly handled and disposed of. Will undergo separate EIA procedures.	No impact.	No impact.	No impact when properly handled and disposed of. Will undergo separate EIA procedures.	No impact when properly handled and disposed of. Will undergo separate EIA procedures.
Other wastes	No impact.	No impact.	No impact	No impact.	No impact.	No impact when	No impact when

OPERATIONAL PHASE	State of waters	Climate and air quality	Groundwater, geology and soil	Biodiversity	Landscape, land use and cultural heritage	Socioeconomic environment	Public health
and chemicals			when properly handled and disposed of.			properly handled and disposed of.	properly handled and disposed of.
Traffic and transportation	No impact.	No significant impact.	No impact.	Potential adverse impacts on the European fire-bellied toad (*Bombina bombina*) and the great crested newt (*Triturus cristatus*) need to be mitigated if Site No. 2 is chosen. If Site No. 1 is chosen mitigation measures for European fire-bellied toad are required. These species are strictly protected on an EU level (listed in Annex IV of the EU habitat directive).	No impact.	Local/regional impact of increased traffic.	Noise from traffic will not exceed 55 dBA at a distance of 80-100 m from the centre of road. Noise will not exceed allowable levels. No significant impact from traffic emissions is expected.

7.12.2.2 Technological alternatives for nuclear power reactors

The reactor type or types to be chosen for the NNPP in Lithuania shall be safe, employ proven technology and be in line with the most recent developments in nuclear technology. The reactor type to be chosen has to comply with the safety and other requirements of Lithuanian regulations and regulators and international standards.

Safety requirements set for the pressurized water reactors (PWR), boiling water reactors (BWR) and pressurized heavy water reactors (HWR), their safety level, environmental impacts and socioeconomic impacts do not significantly differ from each other. Nor are there very significant differences in impacts in transportation, storage of fresh fuel and the handling, storage and final disposal of radioactive waste. The pressurized heavy water reactor (CANDU) requires substantially larger amounts of fuel, and thus produces larger amounts of spent nuclear fuel (SNF). The radioactivity of CANDU SNF is however significantly lower compared to SNF from other reactor types. CANDU also requires heavy water, which has to be imported. Pressurized water reactors discharge boron to the environment in small quantities.

7.12.2.3 Power generation level alternatives

The smallest reactor included in the environmental impact assessment has an output of 600 MW_e and the largest an output of 1 700 MW_e. A maximum generation capacity of 3 400 MW_e has been defined based on future power demand scenarios and limitations set by the available sites and infrastructure. The exact size and capacity of the NNPP to be built is dependent on the reactor type and supplier chosen, and on for instance technical and environmental limitations of the available sites.

The targeted maximum power generation level of 3 400 MW_e influences, depending on the reactor to be chosen, the number of reactors and also the cooling solutions as the only environmental load which in practice changes in a significant way with the power generation capacity, directly proportional to this, is the required cooling water amount. As there is an upper limit to the amount of warmed cooling water which Lake Druksiai can tolerate from an ecological point of view (as discussed in Section 7.1), it would be necessary to implement other cooling solutions in combination with direct cooling utilizing Lake Druksiai.

The power generation level and thus the size of the NNPP affects the amount of materials transported and used during construction and operation of the NNPP, the waste amounts generated, the amounts of workers and thus the traffic amounts, and the socioeconomic impacts of the project. The NNPP size will not significantly affect the transmission lines as the existing pylons have originally been dimensioned for four RBMK reactor units, nor other required infrastructure.

The NNPP size impacts the amounts of radioactive releases during normal operation, but this impact can not be considered significant as the caused doses will be significantly smaller than the defined dose constraints even at the maximum size of the NNPP.

7.12.2.4 Location alternatives

There are two site alternatives for the NNPP. Site No. 1 is located directly to the east of the existing Ignalina NPP. Site No. 2 is located directly to the west of the Ignalina NPP. Both sites border to the INPP site.

This section includes comparison of the conditions of the site alternatives, and comparison of the impacts of the site alternatives.

Comparison of conditions of site alternatives

The comparison of the alternative sites for construction and operation of the new NPP is elaborated by the Developer of EIA Report. The scope of the comparison is to identify advantages or disadvantages of the environmental conditions at alternative sites. The technical measures how to eliminate disadvantages or how the site conditions can influence the safety of NPP are not addressed in EIA. These issues will be considered during NNPP technical design and in safety analysis report. The alternative sites have been compared, assigning them ranks according to every analyzed factor (0 – not acceptable, 1 – medium and 2 – acceptable). Summarized comparison of the alternative sites No. 1 and No. 2 of the new NPP and references to the detail information given in appropriate chapters are presented in Table 7.12-3.

Table 7.12-3. Comparison of the environmental conditions of alternative sites.

Characteristic	Site No 1		Site No 2	
	Description	Rank [3)]	Description	Rank [4]
1. Geology				
1.1. Engineering geology condition	Man made soil that consists of glacial loam of medium plasticity occurs at the land surface of the site. The site is investigated in detail and the properties of soil are predictable. Man made soil is quite weak and should be removed. Glacial soils of sufficient density and strength occur below the man made soils at a depth of 1–6 meters (see Section 7.5). Occurrence of high density soils provides a stable base for building foundations.	2	Man made soil that consists of glacial silty loam of medium plasticity occurs below the fertile soil layer at the site. Soil properties are investigated up to the depth of 20 meters. Thickness of man made soil layer reaches 10 m in some places of the site (see Section 7.5). Glacial soils of sufficient density and strength that provide the stability of foundations occur below the man made soils.	1
1.2. Geomorphology	Relief of the site had been changed during former construction works. Land surface had been flattened with slight declination to the North-West. Altitude of the land surface vary between +143 and 149 m.	2	There are several knolls of 3–6 m height at the site. The land surface had been changed during the construction works of Ignalina NPP. The surface of the territory has a slight decline (altitudes 153.1–152.2) towards the north. Some wet places of the surface are swamped.	1
1.3. Geotechnical condition	Unfavourable geological processes do not take place at the site. Geotechnical properties of the soils are suitable for the stable foundations.	2	Unfavourable geological processes except the swamping at the small areas do not take place at the site. Geotechnical properties of the soils are suitable for the stable foundations.	2
<u>Conclusion</u>: Based on available information geological, tectonic, seismic and geomorphological conditions are more favourable on site No. 1.				
2. Hydrogeology				
2.1. Shallow groundwater	Groundwater level is seasonally high, following heavy storms and after snow melting, the level of groundwater comes very close to the earth surface (especially at the north-east part of the site). During the dry season, it drops to 4 m, in other places down to 9 m. This unconfined groundwater occurs in inhomogeneities of till body filled by sand and gravel. Groundwater flow is of low intensity and does not form integral aquifer. During construction and operation of NPP reduction of the groundwater level will be necessary (see Section 7.3).	2	Groundwater level is seasonally high, following heavy storms and after snow melting, the level of groundwater comes very close to the earth surface (almost at the third part of swampy area at the north-west part of the site). During the dry season, it drops to 3 m, in other places down to 13 m. This unconfined groundwater occurs in inhomogeneities of till body filled by sand and gravel. Groundwater flow is of low intensity and does not form integral aquifer. During construction and operation of NPP reduction of the groundwater level will be necessary (see Section 7.3).	1
2.2. Confined	The first aquifer (aqIII-II) confined from the surface lies at a	2	The first aquifer (aqII) confined from the surface lies at a depth	2

[3)] 2 – acceptable, 1 – medium, 0 – not acceptable, * – not relevant to the existing case
[4)] 2 – acceptable, 1 – medium, 0 – not acceptable, * – not relevant to the existing case

Characteristic	Site No 1		Site No 2	
	Description	Rank 3)	Description	Rank 4
groundwater	depth of 25 m. The aquifer is about 3–5 m thick. Confining layer from above is a clayey loam (till) of about 20 m thickness. Due to the low permeability the aquifer has very low risk of being contaminated by the planned activity.		of 32 m. The aquifer is about 4–5 m thick. Confining layer from above is a clayey loam (till) of about 23 m thickness. Due to the low permeability the aquifer has very low risk of being contaminated by the planned activity.	
2.3. Basic points of discharge	The site belongs to the watershed of Lake Druksiai; unconfined groundwater is discharged to the relief depressions of neighbouring areas to the site, ditches and Lake Druksiai. Groundwater of the first confined aquifer from the surface (aqIII-II) is discharged to Lake Druksiai.	2	The site belongs to the watershed of Lake Druksiai; unconfined groundwater is discharged to the swampy relief depressions, ditches and Lake Druksiai. Groundwater of the first confined aquifer from the surface (aqII) is discharged toward north in the valley of Daugava River.	2
2.4. Direction of water pathway, velocity of groundwater flow	Groundwater flow in confined aquifer is directed to northeast toward Lake Druksiai, water flow (Darcy velocity) is $5.2\ 10^{-6}$ cm/s (see Section 7.3).	2	Groundwater flow in confined aquifer is directed to northeast toward Daugava River, water flow (Darcy velocity) is $2.3\ 10^{-5}$ cm/s (see Section 7.3).	1
2.6. Feeding of groundwater	Infiltration recharge rate ranges from 10 to 100 mm/year, based on the model evaluations in the neighbouring areas, the infiltration recharge rate, integrated in the entire area, is about 30 mm/year.	2	Infiltration recharge rate ranges from 10 to 100 mm/year, based on the model evaluations in the neighbouring areas, the infiltration recharge rate, integrated in the entire area, is about 30 mm/year.	2
Conclusion: Hydrogeological conditions of site No. 2 are slightly more complicated than those of the first site: the conditions of unconfined groundwater are more complex due to the presence of swamp deposits and greater groundwater flow rate in confined aquifer. Both sites are suitable for the planned economical activity, but the conditions at site No 1 are slightly more favourable.				
3. Hydrology				
Cooling of heated water	Location of cooling water input and output are in favourable places, since almost the whole lake surface area takes part in the cooling process.	2	The location of cooling water input is in favourable place, whereas the place for water output demands long (4 km) channel to reach the existing cooling water output place (see Section 4.2).	1
Conclusion: Considering the usage of lake water for cooling purposes, the Site No. 1 can use existing INPP inlet and outlet channels. In the Site No. 2 a new intake and a long cooling water channel has to be constructed to prevent recirculation of cooling water and the site is therefore considered as less favourable.				
4. Geochemistry				
4.1. Sorption/ solubility of radionuclides	Based on lithological characteristics of the soil and chemical analysis of groundwater, the conclusion may be drawn that impact of colloids and organic materials is possible for migration of radionuclides.	1	Based on lithological characteristics of the soil and chemical analysis of ground water, the conclusion may be drawn that impact of colloids and organic materials is possible for migration of radionuclides.	1

Characteristic	Site No 1		Site No 2	
	Description	Rank [3)]	Description	Rank [4]
4.2. pH of the groundwater	Shallow unconfined groundwater is attributed to the category of bicarbonate water type; pH changes from 7.2 to 7.7 (see Section 7.3).	2	Shallow unconfined groundwater is attributed to the category of bicarbonate water type; pH changes from 6.8 to 7.3 (see Section 7.3).	2
4.3. Natural colloids and organic materials	Clayey soil predominates at the site. Existing colloid and organic materials can affect the characteristics of radionuclide migration.	1	Clayey soil predominates at the site. Existing colloid and organic materials can affect the characteristics of radionuclide migration.	1
4.4. Corrosiveness of groundwater towards the concrete	Groundwater is low corrosive towards concrete.	2	Groundwater is low corrosive towards concrete	2
Conclusion: According to geochemistry, both sites are favourable and equally acceptable.				
5. Tectonics and seismicity				
5.1. Tectonics	There are no tectonic faults defined in the territory of the site. The site is approximately 1 kilometre away from the zone of Druksiai (Visaginas) regional fault and about 5–6 kilometers away from the regional Skirnas fault (see Section 7.5).	2	The site is crossed by a tectonic fault from the north west to the south east. This fault was defined during the mapping according to the seismic data (see Section 7.5).	1
5.2. Estimation of seismicity	Taking into account domination of soils of the 3rd seismic category in the upper part of the geological cross-section at the site, seismic micro-zoning works and research data provided the determination of the 6 point seismic level (SL-1) and 7 points seismic level (SL-2) in the MSK –64 (or EMS-98) macro-seismic scale.	2	The site is located in the Ignalina NPP industrial zone. According to the results of investigations from surrounding area the seismic levels could be estimated. The 6 point seismic level (SL-1) and 7 points seismic level (SL-2) in the MSK-64 (or EMS-98) macro-seismic scale are characteristic to the site.	1
5.3. Neotectonic processes	There is a junction of neotectonically active zones below Lake Druksiai. Absolute values of the measured shifts indicate that the area is not in the zone of active tectonic faults and the differentiated rise of infinitely small amplitude of the earth surface is caused by geodynamic processes taking place in the adjacent graben of the Druksiai Depression (see Section 7.5).	2	Neotectonically active zones cross the site No. 2 from the west to the east. These zones were defined during the mapping according to the morphometric and morphostructural data. Precise instrumental measurements were not performed (see Section 7.5).	1
5.4. Liquefaction of soil	Water bearing soils of silty or fine grained sand (geologic indices tpIIV; IIV; gIImd; fIImd; lgIIžm; gIIdn) could have high liquefaction potential. Those soils are of the 3rd seismic category (see Section 7.4).	1	Water bearing soils of silty or fine grained sand (geologic indices tpIIV; ftIIIbl) could have high liquefaction potential. Those soils are of the 3rd seismic category (see Section 7.4).	1
Conclusion: Site No. 1 is acceptable. The site No. 2 is medium suitable as the site is crossed by a tectonic fault. It would be a complicated task to locate buildings far enough				

Characteristic	Site No 1 Description	Rank [3)]	Site No 2 Description	Rank [4]
from this fault at site No 2.				
6. Surface processes				
6.1. Flooding	Altitudes of the land surface are between +143 and 149 m. There are no possibilities for flooding of the site. Dominant incline of ground surface creates very favourable conditions for surface run-off.	2	Altitudes of the land surface are between +153.1 and 152.2 m. There are no possibilities for flooding of the site. Dominant incline of ground surface creates very favourable conditions for surface run-off.	2
6.2. Landslides	Land surface of the site is almost flat, landslides do not occur.	2	Land surface of the site is almost flat, landslides do not occur.	2
6.3. Erosion	Soil or ravine erosion was not observed. Fertile soil is absent and geomorphology is unfavourable for ravine erosion.	2	Fertile soil is covered by vegetation and soil erosion has not been observed. Geomorphology is unfavourable for ravine erosion.	2
<u>Conclusion</u>: Both sites are equally suitable.				
7. Meteorology				
7.1. Extreme winds *7.2. Precipitation* *7.3. Extreme snow pack* *7.4 Extreme temperatures* *7.5. Spouts (Tornadoes)* *7.6. Lightning*	The distance between the sites is only about 1 km therefore the same meteorology conditions are for the both sites. Detailed analysis how the meteorological conditions of the site can influence the operation of the NNPP will be estimated in technical design and safety analysis report according to Lithuanian legislation and IAEA safety guides (i.e. IAEA Safety Guide No. NS-G-3.4 “Meteorological Events in Site Evaluation for Nuclear Power Plants”, etc.).			
<u>Conclusion</u>: Meteorological conditions are the same for both sites. Analysis of how meteorological events can influence the safety of NNPP will be performed in the safety analysis report.				
8. External man-induced events				
8.1. Explosion (wave and projectiles impacts) *8.2. Fire* *8.3. Release of*	Since the distance between the sites is only about 1 km the same external man-induced events are relevant for both sites. Detailed analysis what hazards can cause external man-induced events and influence on safety will be performed in technical design and safety analysis report according to Lithuanian legislation and IAEA safety guides (i.e. IAEA Safety Guide No. No. NS-G-3.1 “External Human Induced Events in Site Evaluation for Nuclear Power Plants”, etc.).			

Characteristic	Site No 1		Site No 2	
	Description	Rank 3)	Description	Rank 4
flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances				
8.4. Aircraft crash				
8.5. Ground collapse				
8.6. Blockage or damage to cooling water intake structures				
8.7. Electromagnetic interference				
Conclusion: The same external man-induced events are relevant for both sites. Analysis of how external man-induced events can influence the safety of NNPP will be performed in the safety analysis report.				
9. Land use				
9.1. Jurisdiction over the land or ownership	The considered sites for the new NPP are within an industrial land area allocated for State Enterprise Ignalina NPP. The legal analyses of both sites, which may be needed for a NNPP construction, are under preparation. After analyses are ready, the changes and amendments of legal acts will be done and detailed planning will be initiated (see Section 1.7).	2	The considered sites for the new NPP are within an industrial land area allocated for State Enterprise Ignalina NPP. The legal analyses of both sites, which may be needed for a NNPP construction, are under preparation. After analyses are ready, the changes and amendments of legal acts will be done and detailed planning will be initiated (see Section 1.7).	2
9.2.Foreseeable development of land in the area of interest	The land usage purpose is defined as “of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)”. Due to the proposed economic activity the land usage will not need to be changed.	2	The land usage purpose is defined as “of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)”. Due to the proposed economic activity the land usage will not need to be changed.	2
Conclusion: Both sites are favourable and equally acceptable.				
10. Population distribution				
10.1. Population exposure	There are no residents in the sanitary protection zone. Distance between the alternative sites is only about 1 km. therefore the	2	There are no residents in the sanitary protection zone. Distance between the alternative sites is only about 1 km. therefore the	2

Characteristic	Site No 1		Site No 2	
	Description	**Rank [3)]**	**Description**	**Rank [4]**
	population exposure due to NNPP will be the same.		population exposure due to NNPP will be the same.	
10.2. Population density	The proposed site for the new NPP is within the existing INPP industrial site. A 3 km radius sanitary protection zone has been defined for Ignalina NPP site. There is no permanently living population within the existing sanitary protection zone and the economic activity is limited as well. The site is distant from residential areas (see Section 7.9).	2	The proposed site for the new NPP is within the existing INPP industrial site. A 3 km radius sanitary protection zone has been defined for Ignalina NPP site. There is no permanently living population within the existing sanitary protection zone and the economic activity is limited as well. The site is distant from residential areas (see Section 7.9).	2
<u>Conclusion</u>: Both sites are favourable and equally acceptable.				
11. Protection of the environment				
11.1. Biodiversity	There are endangered species at or close to the site. Special mitigation measures for protection of biodiversity are necessary (see Section 7.6).	2	There are endangered species at or close to the site. Special mitigation measures for protection of biodiversity are necessary (see Section 7.6).	1
11.2. Protected areas and ecological networks	There are no protected areas or ecological networks at the site. In a radius of 30 km from the site, there are eight NATURA 2000 network Sites of Community Importance (SCI), valuable for habitat and animal species protection and four NATURA 2000 network Special Protection Areas (SPAs), valuable for bird protection, as well as 5 protected territories of national importance and two water body protection zones (protection reglement is based on surrounding terrestrial areas and targeted on achievement or maintenance of good water quality) (see Section 7.6).	2	There are no protected areas or ecological networks at the site. In a radius of 30 km from the site, there are eight NATURA 2000 network Sites of Community Importance (SCI), valuable for habitat and animal species protection and four NATURA 2000 network Special Protection Areas (SPAs), valuable for bird protection, as well as 5 protected territories of national importance and two water body protection zones (protection reglement is based on surrounding terrestrial areas and targeted on achievement or maintenance of good water quality) (see Section 7.6).	2
11.3. Areas of significant public values	There are no areas of significant public value at the site. There are seven cultural heritage sites in the vicinity of the new NPP site (see Section 7.8).	2	There are no areas of significant public value at the site. There are seven cultural heritage sites in the vicinity of the new NPP site (see Section 7.8).	2
11.4. Social economic sphere	The site is located in a sparsely populated territory of trans-border zone of long-lasting depopulation. From the economic point of view the new NPP region, except the town of Visaginas, is a less developed region in Lithuania. Agriculture and forestry of low intensity dominate in the region. There are 980 employers in the region (including public institutions), about 700 of whom are small to medium sized enterprises, which have no more than 250 workers. No important minerals (with the exception of quartz sand) are	2	The site is located in a sparsely populated territory of trans-border zone of long-lasting depopulation. From the economic point of view the new NPP region, except the town of Visaginas, is a less developed region in Lithuania. Agriculture and forestry of low intensity dominate in the region. There are 980 employers in the region (including public institutions), about 700 of whom are small to medium sized enterprises, which have no more than 250 workers. No important minerals (with the exception of quartz sand) are found	2

Characteristic	Site No 1		Site No 2	
	Description	Rank [3)]	Description	Rank [4]
	found in the region (see Section 7.9).		in the region (see Section 7.9).	
11.5. Infrastructure	There is good infrastructure of roads and railway connection at the site. The nearest motorway passes 11 km to the west of the site. This motorway joins the city of Ignalina with those of Zarasai, Dukstas and has an exit to the highway connecting Kaunas and St. Petersburg. The entrance of the main road from the site to the motorway is near the town of Dukstas. There is another exit to Vilnius–Zarasai motorway. The extension of the road from the site to Dukstas is about 20 km. The main railroad from Vilnius to St. Petersburg passes 8 km to the west of the site. There is a 10 km zone of no flights around the site (except flights of military police and border control helicopters).	2	Better road connection and new railway connection have to be built to the site. The nearest motorway passes 12 km to the west of the site. This motorway joins the city of Ignalina with those of Zarasai, Dukstas and has an exit to the highway connecting Kaunas and St. Petersburg. The entrance of the main road from the site to the motorway is near the town of Dukstas. There is another exit to Vilnius–Zarasai motorway. The extension of the road from the site to Dukstas is about 20 km. The main railroad from Vilnius to St. Petersburg passes 9 km to the west of the site. There is a 10 km zone of no flights around the site (except flights of military police and border control helicopters).	1
11.6. Landscape	The landscape of the site is industrial and is characterized by power production units and buildings connected to power production operation. The landscape around the site is mainly composed of forests and wetlands. Residential areas consist of small villages with traditional houses. Lake Druksiai is a major natural landscape element with associated activities (fishing, recreational use) (see Section 7.7).	2	The landscape of the site is industrial and is characterized by switchyard and buildings connected to power production operation. The landscape around the site is mainly composed of forests and wetlands. Residential areas consist of small villages with traditional houses. Lake Druksiai is a major natural landscape element with associated activities (fishing, recreational use). (see Section 7.7)	2
Conclusion: Both sites are suitable but Site No. 1 is more favourable because of less important biodiversity values and better infrastructure of local roads.				
12. NNPP erection conditions				
12.1. Place and features of surroundings	The site is situated east of Unit 2 of the present power plant and comprises the area, which was previously planned for Units 3 and 4. The site area is approximately 0.493 km^2 and ends at its northern side (length 0.6 km) directly at the cooling water discharge channel common for existing INPP Units 1 and 2. To the south of Units 1 and 2, the area is limited by the road from west to east. The length of the western border is approximately 0.58 km. The perimeter of this site is approximately 3.5 km. At its southern border (length of 1.255 km) the interim spent nuclear fuel storage facility is located.	2	The site is situated in an area west of the existing switchyard and it is currently unbuilt area (swamp, bushes). Its size is approximately 0.424 km^2. Its northern border is the shoreline of Lake Druksiai (length approximately 0.75 km). The other three borders are straight, forming a rectangular area, the eastern side of which is 1.1 km and the western 0.66 km long. The existing Building No. 106 (open switchyard) is in the area. Better road connection and new railway connection have to be built to the site.	1

Characteristic	Site No 1		Site No 2	
	Description	Rank [3)]	Description	Rank [4]
12.2. Peculiarity of subsurface	Subsurface of the assessed site and its surroundings do not have specific features according to present knowledge and data. There are no solid minerals and valuable protected geological objects. Groundwater (confined) is well protected from possible contamination. The site is located at a distance of about 1 km from the third level limit of sanitary protection zone of well-field of the Visaginas town (see Section 7.3).	2	Subsurface of the assessed site and its surroundings do not have specific features according to present knowledge and data. There are no solid minerals and valuable protected geological objects. Groundwater (confined) is well protected from possible contamination. Southwest part of the site boarders with the third level limit of sanitary protection zone of well-field of the Visaginas town. (see Section 7.3)	1
12.3. Underground peculiarities	There are no deposits of mineral resources at the site and it's closest vicinities. According to existing data valuable properties of the underground have not been observed. Groundwater has not been used for drinking purposes at the site territory.	2	There are no deposits of mineral resources at the site and it's closest vicinities. According to existing data valuable properties of the underground have not been observed. Groundwater has not been used for drinking purposes at the site territory. More detailed investigations are needed.	1
12.4. Exploration level of the site and demand on extra data	Many geological investigations have been performed at the site (see Section 7.5). Demand of extra data (soil, geotechnical characteristics) will be clarified before the design.	2	More detailed geological investigations of the site are needed (see Section 7.5). Demand of extra data (soil, geotechnical characteristics) will be clarified before the design.	1
12.5. Melioration importance	Level of surface water will depend on the depth of building foundations. Unconfined groundwater is discharged to the underground areas next to the site, ditches and Lake Druksiai.	2	Level of surface water will depend on the depth of building foundations. Unconfined groundwater is discharged at the swampy descents, ditches and Lake Druksiai.	2
12.6. Change of land usage	The land usage purpose is defined as "of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)". Due to the proposed economic activity the land usage will not need to be changed (see Section 1.7).	2	The land usage purpose is defined as "of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)". Due to the proposed economic activity the land usage will not need to be changed (see Section 1.7).	2
12.7. Public evaluation	The residents of the town of Visaginas and surrounding areas have a positive attitude towards construction of the new NPP at the site No. 1.	2	As a result of the currently ongoing process of the public participation in the discussion of the environment impact assessment of the new NPP, the site No. 2 has got negative feedback due to vicinity of the sanitary protection zone to the garden-plots.	1

Characteristic	Site No 1		Site No 2	
	Description	Rank [3)]	Description	Rank [4]

Conclusion: Conditions for construction and operation of the new NPP at the first site are favourable. At the second site, conditions are less favourable.

The following conclusions were drawn from the comparison of the suitability of the location alternatives for construction and operation of the new NPP:

- Conditions of geochemistry, surface processes, meteorology, man induced events, land use and population distribution are equally favourable for both sites.
- Geological, tectonic and seismic conditions are more favourable at the site No. 1. The geological and soil data on site No. 2 is quite old and not comprehensive; therefore, additional investigations are necessary on site No. 2.
- Hydrogeological conditions of the site No. 2 are slightly more complicated than those of the site No.1 and therefore the first site is considered more favourable.
- Considering the hydrological conditions for heated water cooling in the lake, the site No. 1 is more favourable. At the site No. 2 an efficient direct cooling system would demand construction of a long cooling water channel.

The final conclusion of the site evaluation is that both of the sites are suitable for construction and operation of the new NPP. However, the site No. 1 is considered more favourable.

Comparison of environmental impacts of location alternatives

Site No. 1 was originally intended for the third and fourth Ignalina NPP reactors. Some foundation structures were constructed in the 1980's and have since then mostly been removed. The whole site has been totally altered by man and now consists of a large open and empty area with bare man-made soil. The direct impacts if construction at Site No. 1 will thus be small.

Site No. 2 mainly consists of scrubland altered by man during the construction of the INPP. Some forest needs to be cleared as part of site preparation.

The NNPP will at Site No. 1 be able to utilize the existing cooling water inlet and outlet structures, only minor extensions of these will be required. At Site No. 2 a new inlet and a significant extension of the outlet channel have to be constructed.

Both sites will potentially cause some impacts on biodiversity due to the direct construction measures and to disturbance of habitats of valuable species. As Site No. 1 has already been prepared the impacts of this site will be slightly less compared to Site No. 2.

Both sites are located in the immediate vicinity of the existing INPP. Construction of the NNPP will thus not change the landscape very much in either site alternative.

Site No. 2 will be located closer to settlements and Visaginas town. The distance to the nearest settlements will however still be at least 2 km, and the distance to Visaginas town centre will be 6-8 km. Thus this factor can not be considered very significant.

From an environmental point of view Site No. 1 is preferable as it has already been prepared, and as it is more or less surrounded by technological structures of the INPP. The difference between the two sites from an environmental point of view is however not very significant.

7.12.2.5 Cooling alternatives

The most essential factor in the cooling system selection process is the availability of sufficiently large body of water and the environmental impact of the thermal releases on the ecology of the body of water. If there is sufficient cooling capacity and if the environmental impacts are acceptable, direct cooling is the preferred solution. The wet cooling tower solution is the second choice, if the impacts of water evaporation and discharge of blow-out waters on the body of water utilised are acceptable. If these criteria are met size of available sites, impact on efficiency and investment cost considerations are the main determining factors.

Direct cooling

The direct cooling system is the most efficient cooling system but it requires a relatively large watercourse with adequate water supply and cooling capacity. Its advantages are the usually lower investment costs and higher plant efficiency. In the once-trough cooling (direct cooling) the receiving water body acts as a heat sink from where the heat is transferred to air by evaporation. The discharge of heated water can have various environmental impacts on the receiving water body. In direct cooling the cooling water does not necessarily need any other treatment than mechanical removal of larger particles.

The location of the cooling water inlet and outlet may influence the environmental impacts significantly. The impacts on Lake Druksiai water temperature of different direct cooling water inlet and outlet alternatives and combinations at different power levels have been assessed. Six alternative NNPP inlet and outlet location combination scenario sets were computed using a three-dimensional (3D) hydrodynamic lake model specifically constructed for surface water modeling. The following inlet and outlet combinations were used:

- PP – present inlet and present outlet
- DP – deep inlet and present outlet
- PS – present inlet and southern outlet
- WP – western inlet and present outlet
- WS – western inlet and southern outlet
- PD – present inlet and divided outlet

Of the different outlet options the current outlet is the best when the warmed up water area of the lake is used as a criteria. However, the different outlet options do not significantly differ from each other. The present INPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water. The southern outlet position is more confined and shallow, which restricts the warm outlet water mixing with cooler lake water thus reducing the surface area where the cooling to atmosphere takes place. Dividing the outlet to two locations would be no better than the present outlet option when comparing the average size of warmed up areas. However, the divided outlet option has a small advantage in the warmest days giving a somewhat smaller value for the area exceeding 28 °C, which is explained by higher than 30 °C temperatures near the southern outlet.

Of the simulated inlet options, using the warmed area as a criteria, the western inlet is marginally better that the present inlet and both are better than the deep inlet option. The western inlet option had on the average 0.1°C cooler inlet water temperature compared to the present inlet, otherwise this option was similar to the present inlet option in the modelling. The temperature difference is explained by a larger distance to the outlet. In the deep inlet option simulation, the cold water storage of the deeper part of the lake was depleted in the beginning of the simulation, after which the inlet temperatures were no different from the present inlet option. Additionally, in the deep inlet option after the thermocline of the lake is destroyed, the mixing of warmer water to deeper layer is increased raising the total heat storage in the lake. As a result the deep inlet option produced higher surface temperatures during the warmest periods compared to the present inlet option.

The different power levels do not significantly change the behaviour between different inlet and outlet location alternatives.

Direct cooling also causes evaporation of lake water and thus may affect the water level and water amount of the lake. The hydrological effects on the lake and their consequences are considered minor. During rare periods of several successive dry years the lake level would fall below normal, however staying above the minimum allowable level. Evaporation of water by cooling the NNPP would periodically reduce the overall volume of water in the lake somewhat, thereby impacting the quantity of water discharged to River Prorva in Belarus.

Based on the 3D modelling and assessment it is clear that because of ecological reasons only part of the planned maximum total power generation level of 3 400 MW_e can be generated utilising Lake Druksiai for direct cooling. The ecologically acceptable thermal load to the lake is estimated to be approximately 3 200 $MW_{released}$.

Indirect cooling

Indirect cooling should be considered when the thermal load to the lake exceeds 3 200 $MW_{released}$.

Possible indirect cooling solutions are:

- Wet cooling towers
- Dry cooling methods
- Hybrid cooling towers

Wet cooling towers utilise lake water for cooling through evaporation, convection and radiation. Wet cooling tower is the commonly used system at locations with restricted water resources or special needs to limit the thermal load to the watercourse. It is the second most efficient cooling system after the direct cooling system. It also has higher investment costs. Its power consumption as well as demand for area depends on the design type. The natural draft towers consume more energy but demand less space than the forced draft towers. Cooling towers usually need treatment of cooling water for biofouling, scaling and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively. Since most of the heat is evaporated to the atmosphere and not discharged to the water systems, the impacts on the receiving watercourse remain smaller than in direct cooling.

Wet cooling towers can also be used as a part of the direct cooling system to decrease thermal discharge to the receiving body of water. With this solution, condenser cooling water discharge is led (entirely or partly) through this so called “helper cooler” which cools down the exiting water.

Wet cooling towers cause visible steam plumes at certain weather conditions.

Dry-cooling systems can be air-cooled condensers or so called Heller-systems. In the dry-cooling systems the cooling efficiency is lower than in the wet cooling systems but also the demand of water is lower. Specific features of an air-cooled condenser (ACC) and Heller system are insignificant make-up water consumption but also rather ineffective cooling. In ACC the cooling occurs with convection and radiation. Due to relatively low heat transfer efficiency, ACC also requires a large area to be placed. Heller is an indirect dry cooling method. There’s a closed circulation between the condenser and the dry cooling tower whose structure is very similar to ACC’s. The condenser is jet type which sprays the cooled water directly to the boiler water circulation. Therefore the cooling water has to be demineralised water.

The dry cooling systems are not regularly used as a primary cooling system in large (> 1 000 MW) power plants since they demand a relatively large area (up to ten times as large as wet cooling towers) and decrease the plant efficiency significantly. The electricity demand is also high due to the fans, which are required for air circulation. The investment costs of dry cooling systems are substantially higher than those of wet cooling. Also, the dry tower system alone can be unable to produce the needed performance required during periods of ambient high temperature. The advantage of the dry cooling systems is that they barely consume water at all, thus there are typically no evaporation losses. Since it does not produce any thermal discharges it does not cause any heat impacts on the surrounding water systems.

In conditions where water can be a limiting factor for some time periods it can be favourable to combine both dry and wet cooling methods. It is possible to use separate wet and dry towers or to incorporate both wet and dry cooling sections into the same tower design (hybrid). The construction of a hybrid tower may vary significantly along the various manufacturers. The basic idea is, however, that the wet cooling part is located at the bottom of the tower and the dry cooling at the top. The cooling system can be operated based on the prevailing conditions. When sufficient amount of water is available the dry cooling, which consumes more electricity, is turned off and heat removal relies on wet tower cooling. During times of limited water resources the heat or, depending of the design, some proportion of it, would then be dissipated by the dry towers.

7.12.2.6 Comparison of non-implementation of the project

The most significant impact of non-implementation of the project is of socio-economic character. Considering the planned shutdown of Unit 2 of Ignalina NPP in 2009 the non-implementation situation will not be the same as today. After shutdown of Ignalina NPP the socioeconomic situation of the Visaginas region will change for the worse due to unemployment. The new nuclear power plant would counter-effect this adverse change as it would offer employment and other economical benefits. If the NNPP is not constructed its significant positive impact on employment and the socioeconomics of the NNPP region, including Latvian territory, would not be realised.

After shutdown of Ignalina NPP the thermal load currently discharged to Lake Druksiai will be absent, which will have impacts on lake ecology and biodiversity changing it from what it is today. This may very well have significant impacts also on biodiversity such as the designation values of the Lake Druksiai Natura 2000 –area, especially on the birdlife. It is difficult to exactly predict how the lake will develop during decades after stopping the thermal load, but it can be assumed that it will not return to the situation before commissioning of the Ignalina NPP because of other factors influencing the development of the lake to another direction. The thermal load from the NNPP would make it possible for some of the biodiversity values of today to continue existing or, should they disappear after the shutdown of INPP, make it possible for them to return to the lake after commissioning of the NNPP. This is especially true for certain bird species.

If the project is not executed the electricity that would have been produced by the NNPP will be produced by alternative forms of electricity generation. Substituting the amount of electricity with fossil fuels will cause substantially more emissions of sulphur dioxide, nitrogen oxides, carbon dioxide and particles. The immediate impacts of these emissions will not be realized in the Visaginas region, but instead in the areas close to the power plants generating this alternative electricity and close to the fuel sources in Lithuania and abroad. The impacts of carbon dioxide releases on climate change are global.

7.12.3 The environmental feasibility of the planned activity

Utilization of Lake Druksiai for direct cooling is for ecological reasons only possible approximately up to a thermal load level of 3 200 $MW_{released}$. By combining direct cooling with wet cooling towers and/or dry or hybrid solutions the planned maximum power generation level of 3 400 MW_e is achievable from an environmental point of view.

Site No. 1 is slightly more preferable than Site No. 2 for the construction of the NNPP from an environmental point of view. Site No. 1 will impact the designation values of the Lake Druksiai Natura 2000 –area and endangered species less, although constructing the NNPP would potentially impact biodiversity values negatively at both sites. Mitigation measures are required to achieve an acceptable level of impacts on biodiversity values.

The environmental impact assessment did not find any environmental or social impacts of such significance caused by construction or operation of the NNPP that they could not be accepted or mitigated to an acceptable level.

The EIA doesn’t take a position on the acceptability of a serious accident risk in terms of an individual point of view on ethical or other personal grounds. The assessment has aimed at presenting, as clearly as possible, the probability of a serious accident and comparison information regarding the related consequences so that the readers can use them as needed in the formation of their own opinion. The fundamentals of nuclear safety and the probability of a serious nuclear accident have been examined in Section 5.3 and Chapter 10.

When handled properly, the spent fuel and other radioactive waste of the new nuclear power plant do not cause harmful impacts on the environment or people. The solutions for handling of these radioactive wastes will undergo their own environmental impact assessment procedures where the environmental feasibility of these solutions will be assessed.

8 TRANSBOUNDARY IMPACTS

Potential transboundary impacts during construction and normal operation of the new nuclear power plant (NNPP) have been summarized in this chapter. The impacts are discussed more thoroughly in Chapter 7 of this Environmental Impact Assessment Report.

8.1 WASTE

8.1.1 Radiological impacts

According to Lithuanian legislation, management of radioactive waste must ensure among others the following:

- At all stages of the radioactive waste management, by applying appropriate methods, individuals, society and the environment in Lithuania and beyond its borders are adequately protected against radiological, biological, chemical and other hazards that may be associated with radioactive waste;
- Safety of radioactive waste management facilities is guaranteed during their operating lifetime and after it.

Radioactive waste is stored, abiding by the above mentioned factors, in the NNPP region on Lithuanian territory. The solution for long-term storage and disposal of spent nuclear fuel (SNF) has not been chosen yet. The handling, storage and disposal of radioactive waste from the NNPP will be the subject of separate environmental impact assessment procedures in the future.

The European Atomic Energy Community (Euratom) Treaty requires that each Member State provides the Commission with plans relating to the disposal of radioactive waste (Article 37) and that the licensee declares to the Commission the technical characteristics of the installation for its control (Article 78) and submits an investment notification (Article 41).

Handling of radioactive waste is not expected to cause any significant transboundary radiological impacts.

The transboundary impacts of NNPP liquid effluents containing radionuclides are discussed in Section 8.2.1.

8.1.2 Non-radiological impacts

Non-radioactive waste will be handled regionally in Lithuania complying with the Lithuanian Law on Waste Management (*State Journal, 1998, No. 61-1726; 2002, No. 72-3016*) and the requirements of the Regulations for Waste Management (*State Journal, 2004, No. 68-2381*).

Handling of non-radioactive waste is thus not expected to cause any transboundary non-radiological impacts.

The transboundary impacts of treated waste water discharge from the NNPP to Lake Druksiai are discussed in Section 8.2.2.

8.2 THE STATE OF WATERS

This Section concentrates on the impacts on Lake Druksiai as a whole, as this lake is partially located in Belarussian territory as well as on the River Prorva in Belarus, the river, via which the waters flow out from Lake Druksiai.

8.2.1 Radiological impacts

The radioactivity of the monitored nuclides in the aquatic environment around Ignalina NPP has been continuously decreasing during the last ten years. The new NPP will be constructed and operated using the best available techniques and practises, which means an essential improvement to the environmental performance. Thus, the total releases to aquatic ecosystem are assumed to decrease. The realised releases from the new NPP will be so small that they will not cause any significant harmful impacts on the environment.

8.2.2 Non-radiological impacts

8.2.2.1 Waste water impact

The nutrient load from the NNPP will be small compared to the total load to Lake Druksiai coming from other sources (e.g. Visaginas municipality and natural runoff). Thus the impacts of the new NPP on water quality and eutrophication are considered insignificant. The impacts of the treated waste waters on the lake are estimated to be minor and acceptable. However, these impacts will be monitored and if unacceptable consequences occur, the treatment of waste waters will be improved.

8.2.2.2 Cooling water impact

The amount of waste heat discharged to Lake Druksiai depends not only on the electricity produced but also on the cooling system chosen. In direct cooling system all the heat is discharged to the lake when in case of cooling towers only a minor part of the heat enters the lake and the major part is transmitted to air.

Model computations of the effect of release of warm cooling water to Lake Druksiai in direct cooling were carried out using a three dimensional hydrodynamic water flow model, specifically designed for modelling lakes and coastal areas. The effects of different NNPP electric production capacities and different NNPP cooling water inlet and outlet locations on the water temperature of Lake Druksiai as a whole, including the Belarusian territory, were investigated.

Based on modelling results and expert assessments it can be concluded that the ecologically acceptable thermal load to the lake will be approximately 3 200 $MW_{released.}$, With this thermal load no significant impacts on the lake ecosystem are expected compared to the present state of the lake. With higher thermal load the impacts on lake ecosystem start to be clear and significant.

If only cooling towers are utilized the lake temperatures will return to the natural level and this can somewhat improve the living conditions of the species preferring cool water. However, recovery of the conditions or species composition before commissioning of INPP is not expected. If the general intensive eutrophication process continues, this alternative may also lead to low-oxygen conditions during periods of ice-cover. From this point of view, moderate warming of the lake can even be environmentally advantageous. Thus this option has somewhat diverse impacts on the lake ecosystem: it is the best option when the warming of lake is considered, but may result in partly adverse effects due to oxygen depletion if the eutrophication of the lake will continue.

The current outlet is the best alternative when the area warmed up is used as criteria. However, the different outlet options do not significantly differ from each other. The present NPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water. The southern outlet position is more confined and shallow, which restricts the warm outlet water mixing with cooler lake water thus reducing the surface area where the cooling to atmosphere takes place. Thus the southern outlet would lead to more distinct warming and eutrophication impacts in the southern Belarusian part of the lake than other outlet options.

Dividing the outlet to two locations is not a significantly better solution than the present outlet option when comparing the average size of warmed up areas.

The deep inlet option would produce higher surface temperatures in the whole lake during the warmest periods compared to the present inlet option due to destruction of the thermocline of the lake.

The main hydrological impacts of the operation of the new NPP are the evaporative losses created when the heated cooling water will transfer the heat load to air by evaporation. The total losses depend on the plant effect and the cooling method selection.

During normal hydrological years the average lake level is not expected to fall below the normal and thus the hydrological effects on the lake and their ecological consequences are considered minor. During dry years (with a 1-in-20 year return period) the lake level would fall below normal, however staying above the minimum allowed regulation level (for approximately three successive dry years). Thus also the consequences of this kind of event can be estimated to be small.

Impacts on River Prorva

Evaporation of water by cooling the NNPP would reduce the overall volume of water in Lake Druksiai, thereby impacting the quantity of water discharged to River Prorva. The operation of the new NPP would result in a net decrease of water available to the River Prorva equal to the evaporation caused by the cooling systems. The discharges out through River Prorva have not been measured during the operation period of INPP. Thus the outflow has been estimated by subtracting the additional evaporation (0.8 m^3/s), estimated to be caused by the INPP with average production[5] of 1 800 MW, from the natural average outflow (MQ=3.3 m^3/s). The estimated present mean discharge to the River Prorva is thus 2.5 m^3/s.

The new mean discharge is calculated similarly (by subtracting the additional evaporation due to the NNPP from the natural MQ).

The evaporation from the new plant (assuming effect of 3 400 MW) would be approximately 0.7 m^3/s higher than at present (corresponding to the increase of 1 600 MW). Consequently, the present mean annual discharge to River Prorva would decrease approximately by 28 %.

The decrease of mean flow would impact the approximately 50 km long stretch of River Prorva before the confluence of River Dysna. Reduced flows could alter the riparian

[5] The average production has been calculated as a yearly average from period 1993–2004 when both units were in operation.

vegetation and habitat for riparian and wetland species along the River Prorva. They could also have adverse impacts on the river water use for e.g. irrigation or cattle watering. However, the minimum allowable discharge in River Prorva will remain at the present level (0.64 m^3/s) in all of the scenarios.

The decrease in the mean discharge in River Dysna is so small (7 % of the mean discharge 10 m^3/s) that after the confluence with River Dysna the impact of NNPP can be considered negligible.

Ice conditions

The impact of the cooling water releases on wintertime ice conditions was also simulated using three different NNPP thermal load levels. At thermal load of 2 230 $MW_{released}$ the ice free area would be located close to the NNPP outlet. At times, depending on winter temperature in general, the impact on the ice cover would be significant, especially with thermal loads of over 3 160 $MW_{released}$. Thermal loads of 4 460–6 310 $MW_{released}$ would keep the main part of the lake open longer from the start of the winter. In general the impact on the ice cover would be smaller in the southern and western part of the lake compared to the rest of the lake. Impacts on the ice cover of the Belarusian part of Lake Druksiai are possible at higher power levels utilizing direct cooling.

Monitoring of the impacts of the NNPP cooling waters on Lake Druksiai and the discharging rivers will be performed, thus allowing changes in operation of the NNPP if necessary.

8.3 CLIMATE AND AIR QUALITY

8.3.1 Radiological impacts

All nuclear power plants during operation cause certain radioactive releases to the atmosphere. According to Lithuanian legislation radioactive materials may be released into the environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2007 “On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring” (*State Journal, 2007, No. 138-5693*).

Radioactive emissions from the NNPP to the atmosphere will be well under permissible levels defined to protect people and the environment against adverse effects from radiation. The radioactive emissions will be continuously monitored.

Transboundary annual exposure of the population due to gaseous releases into the environment is discussed in Section 8.11.1.

8.3.2 Non-radiological impacts

The NNPP would not cause carbon dioxide (CO_2) emissions into the atmosphere during the operational phase. The total amount of CO_2 emissions from thermal power plants producing the same amount of electricity as the NNPP with maximum capacity (3 400 MW_e) if the NNPP is not built would be about 5.8 million tonnes per year of which about 3.8 million would be produced in Lithuania. This corresponds to 45 % of Lithuania’s total CO_2 emissions from fuel combustion in the energy sector in 2006. CO_2

is a so called greenhouse gas which contributes to global warming. The NNPP will thus have a positive transboundary impact as it counteracts global warming.

The construction and operation of the NNPP will only have very local adverse impacts on air quality, mainly during the construction phase. Transboundary impacts on air quality are not expected.

8.4 GROUNDWATER

8.4.1 Radiological impacts

Based on experiences from INPP operation there will not be harmful impacts on any confined aquifers or shallow unconfined groundwater even locally.

Transboundary radiological impacts on groundwater are therefore not expected.

8.4.2 Non-radiological impacts

Transboundary non-radiological impacts on groundwater are not expected.

8.5 SOIL

8.5.1 Radiological impacts

It is expected that during normal operation of the new NPP the radiation doses due to radionuclides in the soil will be negligible.

Transboundary radiological impacts on soil are therefore not expected.

8.5.2 Non-radiological impacts

The main impacts on soil will occur during the construction stage and will be confined to the construction areas.

Transboundary non-radiological impacts on soil are therefore not expected.

8.6 GEOLOGY

8.6.1 Radiological impacts

The construction and operation is not expected to affect the deeper geological layers.

The new NPP has to be built on a stable foundation which is not located on a tectonic fault. Both NNPP site alternatives are located on the same tectonic block which is quite stable. The absolute values of shifts at the sites are infinitely small in practice and negative impact due to the tectonic movements on the construction or operation of the new NPP is not expected.

Transboundary radiological impacts on or because of geological conditions are therefore not expected.

8.6.2 Non-radiological impacts

Transboundary non-radiological impacts on or because of geological conditions are not expected.

8.7 BIODIVERSITY

8.7.1 Radiological impacts

Based on available analysis data, it may be stated that the radioecological state of soil, flora and fauna in the Ignalina NPP region and its surroundings is quite good. The radioecological state of flora and fauna in the neighbouring countries can therefore also be considered good. The impact of the new NPP on the radioecological state of the region is estimated to be lower than the impact of the existing Ignalina NPP.

Transboundary radiological impacts on flora, fauna and biodiversity are therefore not expected.

8.7.2 Non-radiological impacts

Cooling water thermal discharge to Lake Druksiai, direct damage of the NNPP construction site as a habitat, disturbance to the surroundings of the construction site and traffic will potentially impact biodiversity.

The impacts of the thermal discharge of the NNPP on Lake Druksiai have been assessed. The animal species depending on fish, insects and other aquatic animals and plants as a food resource would have enough food also in the future since the amount of fish, insects etc. is not predicted to decrease – only the species composition can be expected to change if a very significant amount of cooling water is discharged to Lake Druksiai. However, taking the precautionary principle into consideration, it can not be ruled out that thermal load significantly exceeding 3 200 $MW_{released}$ discharged to Lake Druksiai could cause significant negative impacts on the ecology of the lake and thus on biodiversity values of the lake through complex interaction chains. This could have transboundary implications on biodiversity of the lake as well.

The NNPP can have a positive transboundary impact on especially bird fauna biodiversity as it would keep parts of the continuously lake ice-free in wintertime. This is especially true keeping in mind that the Ignalina NPP will be shut down in 2009, after which there will be no significant thermal load to the lake, which will lead to the lake being ice-covered at least periodically in wintertime which will have a negative impact on the diversity of the bird fauna.

No significant transboundary impacts on terrestrial and semi-aquatic fauna, flora and biodiversity are expected. Potential adverse impacts on animal populations will be small or can be mitigated to an acceptable level where the future of the species at Lake Druksiai is not threatened because of the NNPP.

8.8 LANDSCAPE AND LAND USE

8.8.1 Radiological impacts

Not relevant.

8.8.2 Non-radiological impacts

The landscape in the Lake Druksiai watershed has changed because of the building and operation of INPP, Visaginas town and related infrastructure.

Construction of the new NPP near the INPP will not significantly change the landscape as perceived from the shores of Lake Druksiai, also from the shores in Belarus. Only at a few places by the lake shore will the NNPP be visible to larger amounts of people.

The NNPP will not be visible to Latvian territory.

Significant transboundary impacts on landscape are therefore not expected.

8.9 CULTURAL HERITAGE

8.9.1 Radiological impacts

Not relevant.

8.9.2 Non-radiological impacts

No transboundary impacts on cultural heritage objects will occur.

8.10 SOCIO-ECONOMIC ENVIRONMENT

8.10.1 Radiological impacts

Not relevant.

8.10.2 Non-radiological impacts

A significant positive impact on the socio-economic environment in the foreign parts of the NNPP region is expected. A need for Latvian workforce will occur. A significant part of the total workforce, which is in the order of 3 000 – 3 500 workers, during the construction phase will come from other countries than Lithuania and Latvia, and will need accommodation for several years. A part of this workforce will bring their families with them. As the border between Lithuania and Latvia is open it can be predicted that the workforce will be spread out living not only in Visaginas or its vicinity, but potentially also on the Latvian side at least as far as Daugavpils. During the operational phase a significant amount of foreigners, about 800 – 1000 workers also needing accommodation, will periodically work at the NNPP when yearly overhauls are being conducted.

The workforce will to a significant extent utilize the services of the regional main town Daugavpils on the Latvian side, which will bring significant positive socio-economic impacts to this region of Latvia.

There is no need for impact on international air transportation while this is already a no flight zone because of the Ignalina nuclear power plant.

The NNPP project has met some resistance among the public abroad, for instance in Latvia, which indicates that the project causes concern among at least a part of the public abroad. This is at least partially an indication of a negative attitude against nuclear power as such.

Significant positive transboundary socio-economic impacts are expected. No significant negative socio-economic impacts are expected as the NNPP will be constructed next to an existing NPP, to which the surrounding areas have adjusted.

8.11 PUBLIC HEALTH

8.11.1 Radiological impacts

An evaluation of aquatic routine releases from the new NPP has been performed in terms of public individual doses as is recommended in international practice (*IAEA Safety Reports Series No. 19*). This approach is following from an analysis of INPP routine releases, which is presented in detail by Mažeika and Motiejūnas (*2003*).

Calculations of radionuclide transfer through lakes and rivers as well as the maximum annual effective doses for the critical group members was performed using PC CREAM (Consequences of Releases to the Environment Assessment Methodology) model (*Simmonds et al., 1995*). However, the PC CREAM 97 code does not include a lake module. Therefore, a simple box model for lakes was combined with the river PC CREAM model. The simulation included a Lake Druksiai model (two-compartment - water and bottom sediments), a river dynamic model Prorva-Dysna (as far as Disna town in Belarus), a river dynamic model Daugava (as far as Daugavpils in Latvia), and simple dilution models for the rest of Daugava and the Gulf of Riga.

Radionuclide activity concentrations, associated with suspended sediments and with bed sediments as well as with filtered water were calculated for three operational durations (1, 5, 50 years) for each simulated compartment and were then used to derive external irradiation (gamma and beta radiation in shoreline material and in fishing gear in lake assessment, gamma and beta radiation in shoreline material in river assessment), intakes by fish ingestion and intakes by spray inhalation in lake assessment, intakes by fish and drinking water ingestion in river assessment) and subsequent individual committed doses to infants, children and adults. The site-specific and generic radionuclide transfer parameter values applied during the calculation using PC CREAM 97 code were: freshwater sediment distribution coefficients K_d, sedimentation coefficients k' and concentration factors for freshwater fish (*Simmonds et al., 1995*); gamma energies and decay constants λ for each radionuclide (*ICRP, 1983*); beta doses for each radionuclide (*US DoE, 1988*); and dose coefficient for intakes by ingestion (*IAEA, 1996*). For photon exposure the reduction factors recommended by NRC (*1977*) (0.3 for lake shoreline, 0.2 for river shoreline) were applied.

Ten typical radionuclides (^{3}H, ^{14}C, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{90}Sr, ^{95}Nb, ^{131}I, ^{134}Cs, ^{137}Cs) with more significant abundance in the releases and in environmental objects were selected for calculations. For comparison of doses received in the environment of different hydrological pathway chains, only members of one critical group (fisherman) were investigated.

Main hydrological parameter values were obtained from the state hydrological networks of Lithuania, Belarus and Latvia. Mean river flow rates were evaluated as follows: R. Prorva 3 m^3/s (observation in 1980-1983, below locality Drisviaty in Belarus), R. Dysna 10 m^3/s (observation in 1945-1960, below confluence with Druksa rivulet), R. Dysna 30 m^3/s (observation in 1945-1981, below locality Sharkovshchina in Belarus), R. Daugava 288 m^3/s (observation in 1944-1988, below Dysna town in Belarus), R. Daugava 451 m^3/s (observation in 1921-1980, in Daugavpils town).

For calculations of radionuclide activity in water in the lower reaches of River Daugava and in Gulf of Riga the flow rate of 700 m^3/s and water volume of $1.1 \cdot 10^{12}$ m^3 respectively were adopted (the length of the hydrological path from INPP site to Gulf of Riga is 550 km).

Exposure pathways for Lake Druksiai include ingestion of fish, inhalation of spray, external gamma and beta radiation from bank sediments and from fishing gear.

Exposure pathways for river compartments include ingestion of fish, ingestion of drinking water (which assumed to be filtered river water without water treatment processes) and external gamma and beta radiation from bank sediments.

As was shown by Mažeika and Motiejūnas (*2003*) for the Lake Druksiai compartment the fishermen dose is mainly caused by ^{137}Cs, ^{90}Sr and ^{134}Cs. Contribution of ^{90}Sr is growing downstream and gets to prevail due to water transport, while total dose decreases. Contribution of immobile radionuclides (for example, ^{60}Co) among considered exposure pathways (fish consumption, water ingestion, spray inhalation, external gamma and beta radiation from shoreline sediments) to the irradiation reduces significantly along the hydrological stream. The main exposure pathway for Lake Druksiai is ingestion of fish, however for downstream compartments contribution of fish ingestion decreases while importance of external gamma exposure increases significantly. Partial contribution of the mobile radionuclides (for example, ^{3}H) to the dose along the hydrological pathway changes only little. For critical groups related to downstream river compartments the main exposure pathway is water ingestion, while fish ingestion makes up to 10 % of the dose. This assumption is very conservative because water supply from rivers is hardly possible.

Radionuclide environmental transfer factors (Sv/year:Bq/year) evaluated for INPP aquatic routine releases dispersed downstream the hydrological pathway (Lake Druksiai – Gulf of Riga) can be applied to the new NPP located close to Lake Druksiai assuming the same environmental features and radionuclide-dependent parameters. Based on radionuclide environmental transfer factors and predicted annual releases (^{3}H, ^{14}C, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{90}Sr, ^{95}Nb, ^{131}I, ^{134}Cs, ^{137}Cs) from reactors of different types (see Chapter 7.1), radiological impact of the new NPP on the downstream water course has been evaluated in Table 8.11-1 and Figure 8.11-1.

Table 8.11-1. Radiological impact of new NPP on downstream water system in terms of effective dose, mSv/year.

	Reactor type	ESBWR	ABWR	AP-1000	APWR	EPR	EC-6
	Number of Units	2	2	3	2	2	4
Downstream location (Compartment No)	Outflow from Lake Druksiai – Prorva rivulet (1)	2.20E-04	1.20E-03	1.04E-02	1.64E-02	1.96E-02	5.20E-02
	Dysna r. at confluence with Drisviata rivulet (2)	2.40E-05	1.40E-04	1.18E-03	1.96E-03	2.40E-03	6.20E-03
	Dysna r. locality Sharkovshchina in Belarus (3)	1.32E-05	8.20E-05	6.20E-04	1.04E-03	1.22E-03	3.20E-03
	Daugava R., below Dysna town in Belarus (4)	4.00E-06	1.90E-05	2.60E-04	4.20E-04	5.20E-04	1.38E-03
	Daugava r., in Daugavpils (5)	1.72E-06	8.80E-06	1.08E-04	1.74E-04	2.20E-04	5.80E-04
	Daugava R., Riga (6)	4.80E-07	2.40E-06	3.20E-05	5.00E-05	6.20E-05	1.64E-04
	Gulf of Riga, Baltic Sea (7)	1.40E-07	7.20E-07	8.80E-06	1.42E-05	1.78E-05	4.60E-05

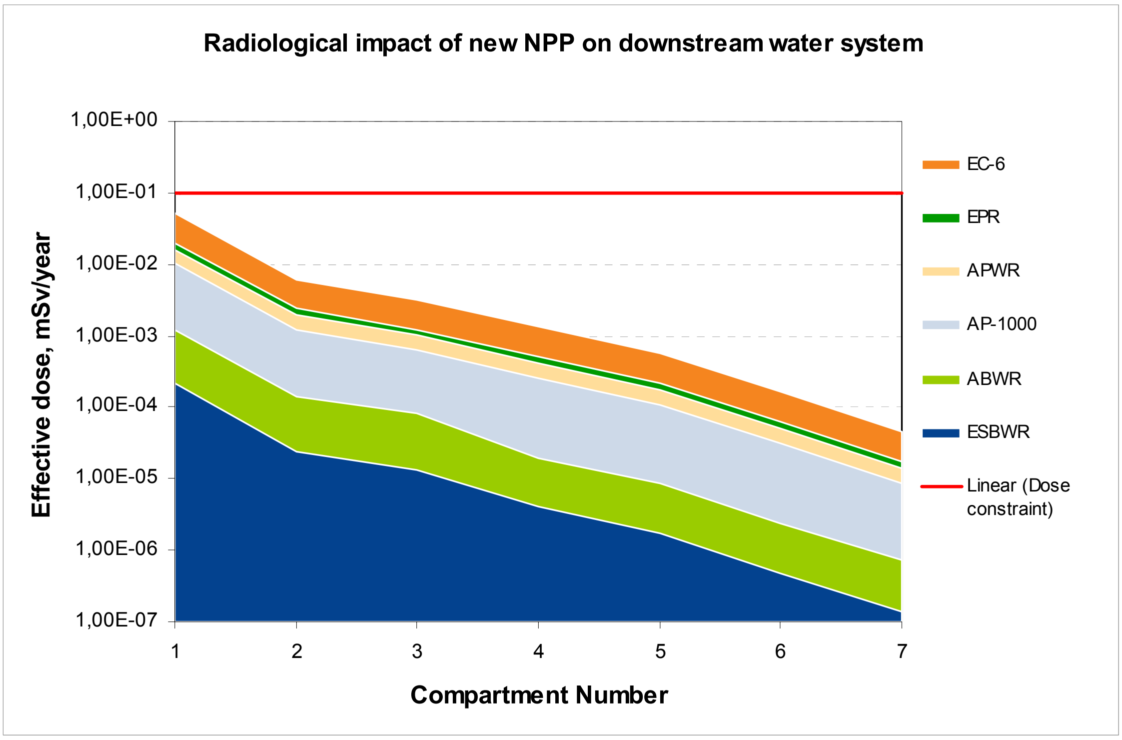


Figure 8.11-1. Radiological impact of new NPP on downstream water course. Location of compartment is given in Table 8.11-1.

The calculated individual committed dose due to new NPP effluents is less than the dose constraint for all reactor types and reduces significantly with distance from the release point. Highest doses were calculated for the EC-6 reactor which is characterized by the highest ^{3}H release rate compared to other types of reactors.

The cross border transfer of new NPP effluents via hydrological pathway to Belarus and especially to Latvia is insignificant. In downstream Lake Obole compartment (Belarus) the committed dose is less then the exemption level (0.010 mSv/year).

In order to investigate the change in dose due to radioactive releases into atmosphere with distance, the dose for the population at different locations from the release point was evaluated. The radiation exposure at distances up to 20 km was calculated using appropriate models as recommended by the IAEA Safety Report Series No. 19 “Generic Models for use in Assessing the Impact of Discharges of Radioactive Substances to the Environment”.

According to the results of the calculations, the change in dose with distance is presented in Figure 8.11-2. The highest exposure dose is expected at the release point and up to a distance of 800 m. A gradual decrease in radiation dose is then observed. At a distance of 1 km the radiation dose to the population is lower than the maximal radiation dose by a factor of 2, at a distance of 3 km by a factor of 10, and at a distance of 10 km by a factor of 100. According to calculations the dose due to releases from all types of reactors, except CANDU, is less then the exemption level (0.010 mSv/year) at a distance of 3 km from the NNPP; for CANDU this distance is about 8 km.The transboundary impact due to releases is therefore insignificant.

Transboundary radiological impacts in case of accidents are evaluated in Chapter 10.

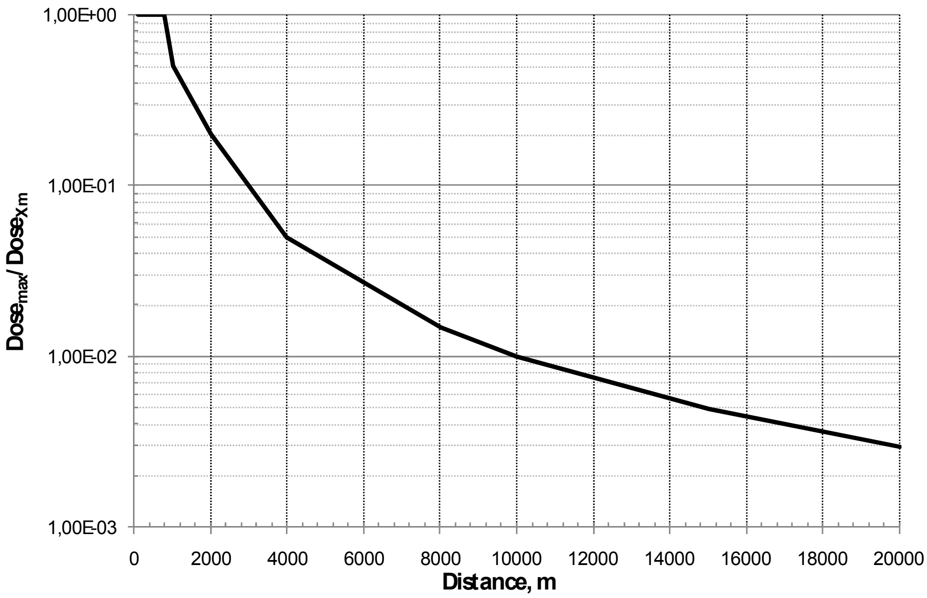


Figure 8.11-2. Dose decrease rate with a distance.

8.11.2 Non-radiological impacts

The new nuclear power plant will be located within the Ignalina NPP industrial site and within the existing 3 km radius sanitary protection zone of INPP. The NNPP will be located at a considerable distance from permanently living population in Latvia and Belarus.

No significant transboundary non-radiological impacts on public health are therefore expected.

9 MONITORING

9.1 INTRODUCTION

Monitoring is the collection of specific data about selected environmental variables (impact indicators) in space and time, with the objective of supplying information on the amplitude and rate of change in these variables so that, in turn, it allows assessment of related environmental impacts. The purpose of the environmental monitoring is to detect impacts as they occur, to estimate their magnitude and ensure that they are the consequence of a well identified project or activity. Monitoring includes the follow-up of impacts and their verification against predictions. Monitoring also allows the assessment of the effectiveness of mitigation and remedial measures. This information should be the basis for modifying either the activity or the mitigation measures. In this chapter a proposal for the monitoring system of the new NPP is presented. Applicable parts of the new monitoring should be implemented as soon as possible, well in advance of commissioning of the NNPP in order to ensure sufficient knowledge about the conditions of the environment after INPP has been shut down.

The Ministry of Environment of the Republic of Lithuania controls implementation of environmental monitoring, quality of monitoring data and information, and compliance with the standards and other normative legislation. The monitoring is to be performed in accordance with a regulatory approved Environmental Monitoring Program. The monitoring program shall be prepared according to the Lithuanian legislation and Regulations on Environmental Monitoring (*Law on Environment Protection I-2223, State Journal, 2005, No. 47-1558; Law on Environment Monitoring No. X-595, State Journal, 2006, No. 57-2025; Regulation on Performance of Environment Monitoring of Economy Entities, State Journal, 2004, No. 181-6712; Regulation on Ground Water Monitoring of Economy Entities, State Journal, 2003, No. 101-4578*), Lithuanian Radiation Protection Standards (*Lithuanian Hygiene Standard HN 73:2001 "Basic Standards of Radiation Protection", State Journal, 2002, No. 11-388*) and Regulatory Documents on the Environment (*Regulatory Document on the Environment LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorization of Release of Radionuclides and Radiological Monitoring", State Journal, 2007, No. 138-5693; Regulatory Document on the Environment LAND 36-2000 "Measurement of Environmental Elements Contamination with the Radionuclides", State Journal, 2005, No. 59-2083*). The monitoring data is being summarized and submitted to the competent institutions annually.

According to Article 5 of the Law on Environmental Monitoring (*No. X-595, State Journal, 2006, No. 57-2025*), the following shall be observed, evaluated and forecasted during the environmental monitoring:

- State of the ambient air, waters, underground, soil and biota;
- State of the natural and anthropogenically affected natural systems (natural habitats, ecosystems) and landscape;
- Physical, radiological, chemical, biological and other sources of anthropogenic impact and influence thereof upon the environment;
- The change and tendencies of the global processes taking place within the environment (acid rain, change in the ozone layer, greenhouse effect etc.).

Environmental monitoring in the vicinity of the nuclear power plant supplements monitoring of the radioactive materials which are inevitably released from the power plant with the exhaust air and liquid effluents. Furthermore, it records the radiological impact of accidents. For this purpose, the path-ways (air and precipitation, ground and vegetation, food chains on the ground, surface water and groundwater, and food chains in water) are each kept under surveillance for radioactivity.

Meteorological factors such as wind direction and velocity, precipitation and inversion phenomena, which are of significance for the dispersion of radioactive materials, are surveyed in order to assess the exposure path-ways in the vicinity of the nuclear power plant.

The existing Ignalina NPP environmental monitoring program covers the following parts:

- Monitoring of concentration of radionuclide activity in the air and atmospheric precipitation;
- Monitoring of the chemical composition of water in the discharge channel and storm sewage drainage from the INPP territory;
- Monitoring of water quality in Lake Druksiai and of groundwater (physical-chemical parameters);
- Monitoring of nuclides concentration in the lake, the outlet channel, the rain sewerage system channels and groundwater;
- Meteorological observations;
- Monitoring of dose and dose rate in the sanitary protection (3 km) and surveillance (30 km) areas;
- Monitoring of radionuclide activity concentration in fish, algae, soil, grass, sediments, mushrooms, and plants;
- Monitoring of radionuclide activity concentration in food products (milk, potatoes, cabbage, meat, grains).

9.2 ENVIRONMENTAL MANAGEMENT SYSTEM

An environmental management system (EMS) will be implemented during both construction and operation of the NNPP. The EMS will be certified according to the ISO 14001 standard or a similar standard. The system will cover all the operations at the NNPP. The EMS involves measures for the benefit of the environment as part of everyday operation of the NNPP. Environmental impacts can be managed systematically through the EMS and the system obligates to commitment of the constant improvement of the level of environmental performance. One of the objectives of the EMS is to limit the negative environmental impacts caused by releases from the NNPP. The EMS thus requires monitoring measures to be implemented in the vicinity of the NNPP.

9.3 MONITORING OF RADIOACTIVE RELEASES AND LOADS TO THE ENVIRONMENT AND PEOPLE

9.3.1 Current monitoring system

A radioecological monitoring program (for observing of radionuclides in components of the ecosystem) in the surroundings of Ignalina NPP has been implemented since 1978, i.e. five years prior to commissioning of the first reactor. Works for observation of changes in the environment of Ignalina NPP were performed according to the Complex radiation-ecological analysis program (1978–1985–1995). The program was carried out by the Moscow Institute of Energotechnological Science Research and Construction (general designer of Ignalina NPP) and five institutes of the former Lithuanian Research

Academy – Institute of Physics, Energetics, Zoology and Parasitology, Geography and Botany. The fundamental radioecological status in the environment of the constructed power plant is described in the general report of all institutions (*Radiological-Ecological Investigation of INPP Region Before Start of Operation, 1985*).

Measurements of radioecological observations increased especially during research of consequences of the Chernobyl NPP accident to Lithuania and Ignalina NPP region. Monitoring results of the constant concentrations of radionuclide activities in the air, precipitation, soil, in the water of Lake Druksiai and bottom sediments after commissioning of the first Ignalina NPP reactor (1983), and after the Chernobyl NPP accident, are summarized in a monograph type publication (*Thermal Power Generation and Environment, 1992*).

Scientific research work in the environment of INNP was partially interrupted after the independence and was renewed following the State Scientific Program “Atomic Energy and the Environment,” approved by the Lithuanian government (*Collection of Research Reports, 1993–1997, Vilnius, Vol. 1–5*).

The Institute of Physics in 1998, based on the research results of the Chernobyl NPP accident consequences and the Ignalina NPP environment, initiated the foundation of the Lithuanian radioecological monitoring system (*11 November, 1998, Decision of Council of Ministers No. 332*). Analysis of earth surface contamination by radionuclides brought from Chernobyl was performed. The dosimetric data registration system with 17 monitoring points in Lithuanian Meteorological Stations (AGIR), and the system for automated radionuclide emission registration (RADIS) were established.

9.3.1.1 Monitoring of radioactive releases

The Environment Protection Agency of the Ministry of Environment is responsible for the system AGIR, supplemented with monitoring points with gamma specter registering scintillating detectors, which operates as an early warning system in Lithuania. Furthermore the Environment Protection Agency controls the system RADIS while custom monitoring observations have gradually been transferred to the Radiation Protection Center.

All emissions from the Ignalina nuclear power plant, made exclusively through the vent stack and the waste water, are systematically monitored. The system RADIS is installed in the Ignalina NPP as an automated radiation control system (ASKRO) showing real time activities of radionuclides on a computer screen and on three various scale maps. The automated radiation control system includes automated registration of radiation of radionuclides in the surface air and in the nuclear power plant stack releases and a system for calculation of radionuclide transfer in the air. The system reflects real time concentrations of radionuclide activity in the air of the sanitary protection zone. The RADIS system is also to be applied in case of accidents. The calculations give the radiation dose at the height of both Ignalina NPP stacks.

Content of radionuclides in releases is determined on the basis of gamma specter measurement of spectrometric aerosol particles and inert gases in samples from the ventilation air stacks, and this allows evaluation of penetration of every radionuclide to the surface air. Measuring of concentrations of radionuclide activities in the surface air at seven observation points in the area is conducted every tenth day.

Monitoring of radioactivity in water is performed at the waste water collection point (on the INPP site), at the waste water receiving point (at waste water treatment plant) and halfway down a stream between the waste water treatment plant and Lake Druksiai.

Monitoring of the radioactivity releases with aqueous waste is also performed batch-wise in specific discharge containers. Other measurements cover 5 discharge points and 6 stations in Lake Druksiai (Figure 9.3-1).

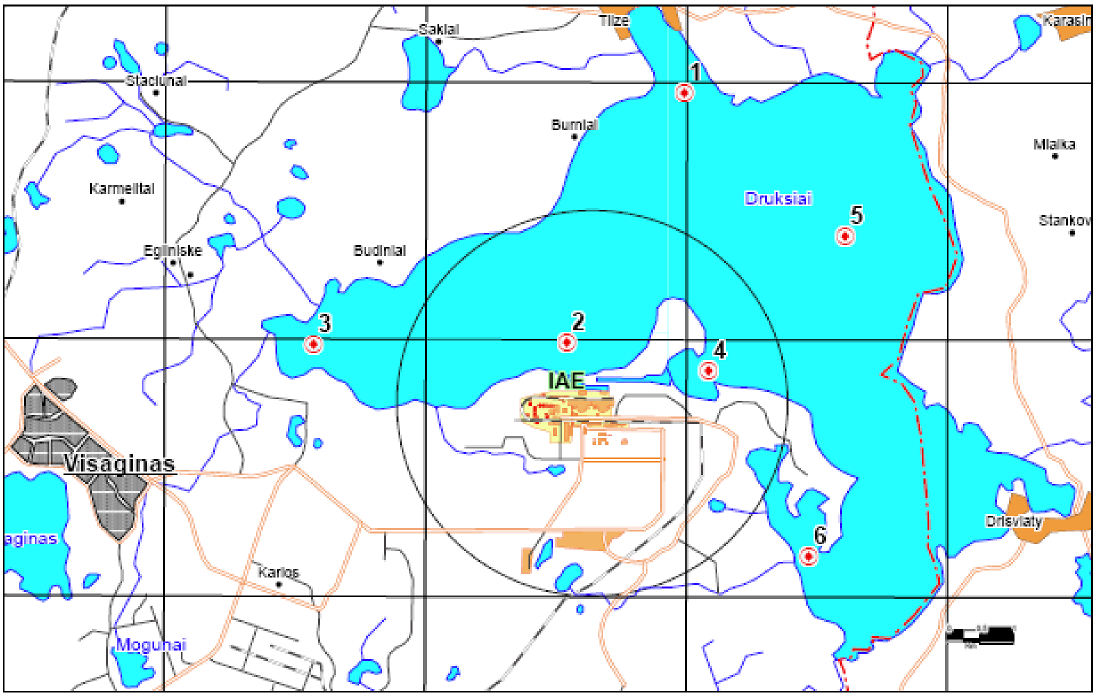


Figure 9.3-1. Sampling points in Lake Druksiai.

Concentrations of tritium activity in waste water have been monitored since 1999. Beta radiation of low energy tritium gives a greater input to the ecological dose in Lake Druksiai than radiation of other radionuclides. Measurement results show that tritium in water of Lake Druksiai accumulates via industrial storm and household waste water channels. A summary of the radiation monitoring of the INPP liquid discharges into the environment is presented in Table 9.3-1. A summary of the radiation monitoring of the INPP aquatic environment is presented in Table 9.3-2.

Table 9.3-1 Summary of the radiation monitoring of the INPP liquid discharges to the environment.

RADIATION MONITORING OF LIQUID DISCHARGES	
Total β activity	Weekly: service water taken by Reactor Units 1,2; water, discharged by reactor and turbine compartments; water, discharged from Bld. 150; monthly: service water after the heat exchangers; at every discharge – water from special laundry.
Volumetric activity of radionuclides	Monthly: water, discharged by reactor and turbine compartments; service water after the heat exchangers; water, discharged from Bld. 150, pit of corridor 003 (D1, D2); at every discharge – spent water from Bld. 150.
Activity of ^{89}Sr, ^{90}Sr	Monthly: water, discharged by reactor and turbine compartments.
Total α activity	Monthly: water, discharged from Bld. 150

Table 9.3-2 Summary of the radiation monitoring of the INPP aquatic environment.

RADIATION MONITORING OF AQUATIC ENVIRONMENT	
Activity of γ nuclides	20 times a month (on working days) – discharge of technical water and water of intake channel; once in 10 days – sewage water, water of industrial site PLK-1,2, PLK-3, PLK-SFSF; once a month – water from channel surrounding landfill of industrial waste, drainage water of the INPP industrial site; once per quarter (in January, April, July, October) – water of heating networks; twice a year (in spring, autumn) – water of surveillance boreholes in the industrial site and area of SFSF; four times a year (in February, May, August, November) – potable water from water supply (watering-place), potable water from wells in Tilze and Gaide; once a year (in summer) – water of Lake Druksiai; once a year (in winter) – snow at points of permanent surveillance, sampling points of precipitation of industrial site and SFSF site.
Activity of ^{90}Sr	Twice a year (in spring, autumn) – discharge of technical water and water of intake channel, sewage water, water of surveillance boreholes in the industrial site and area of SFSF; once a year (in summer) – water of Lake Druksiai; annually (in winter) – water of heating networks, water from channel surrounding landfill of industrial waste, snow at points of permanent surveillance, sampling points of precipitation of industrial site and SFSF site, water of industrial site PLK-1,2, PLK-3, PLK-SFSF, drainage water of INPP industrial site.
Activity of Pu isotopes	Twice a year (in spring, autumn) – discharge of technical water and water of intake channel.
Activity of ^{3}H	Monthly – discharge of technical water, sewage water, sampling points of precipitation of industrial site and SFSF site, water of industrial site PLK-1,2, PLK-3, PLK-SFSF; once a quarter – water from channel surrounding landfill of industrial waste; twice a year (in spring, autumn) – water of surveillance boreholes in the industrial site and area of SFSF; four times a year (in February, May, August, November) – potable water from wells in Tilze and Gaide.
Total α activity	Four times a year (in February, May, August, November) – potable water from water supply (watering-place), potable water from wells in Tilze and Gaide.
Total β activity	Four times a year (in February, May, August, November) – potable water from water supply (watering-place), potable water from wells in Tilze and Gaide.

Information on the monitoring of the radioactivity in waste waters is also given in this report in Section 7.1.1.5.

9.3.1.2 Monitoring of the radioactive loads to the environment and people

Minimal detectable activities

Minimal detectable activities for the different samples are given in Table 9.3-3. If not mentioned differently, values are given for the case of Cesium-137 activity measurement typical for each kind of samples, sampling preparation and geometry. Cesium-137 is the most significant synthetic radioactive substance existing for instance in food and mainly originates from the Chernobyl NPP accident.

Spectrum completion time span is no less than 12 hours. Determination error is about 100 % during measurement at the sensitivity level of the method, while if measuring activities consist of 10 and more minimal detectable activities, the error goes down to 30 %.

Table 9.3-3. Minimal detectable radioactivities in the environmental samples.

No.	Sample type	Minimal detectable activity
1	Atmospheric air	$1.5 \cdot 10^{-6}$ Bq/m^3
2	Water.Tritium measurement.	3 Bq/l
3	Water	$1 \cdot 10^{-3} \div 0.5$ Bq/l *
4	Fish	3 Bq/kg
5	Soil	3 Bq/kg
6	Bottom sediments	3 Bq/kg
7	Waterweeds	3 Bq/kg

* - large range is conditioned by the differentiating volumes of samples.

Current monitoring program

The environmental monitoring includes the measurements of the dose rate, external absorbed dose and activities of radionuclides in various components of the environment. The program includes the monitoring of all the environmental exposure pathways that may exhibit long term concentration effects, such as the sediments, silts, algae, mussels and milk.

The measurements of radiation are performed in the sanitary protection zone of the INPP nuclear facility and at some distances from it towards the nearest main settlements, taking into account the location peculiarities of the nuclear facility territory. The samples are taken with a frequency corresponding to the alternation of components of the environment and the quantity of gathered data allows assessing the exposure of the members of the critical groups.

The monitoring is performed applying measurement methods and using devices which allow a sufficient accuracy of measurements of the activities of individual isotopes that can lead to doses higher than 0.005 mSv/y.

The Environment Protection Agency of the Ministry of Environment, according to the State Environmental Monitoring Program, performs radiological monitoring of gamma dose rate, air aerosols, precipitation, surface water and bottom sediments in rivers, lakes, the Baltic Sea and the Curonian Bay.

Cooperating with the Ministry of Natural Resources and Environmental Protection of Belarus, samples are taken annually in the presence of the Environment Protection Agency, the Ignalina NPP and Belarusian specialists.

Monitoring of the radioactive loads to the environment and people is described in general in the following paragraphs. The locations of the sampling points, the periodicity of analyses and the sample analytical techniques are determined more exactly in the INPP Environmental Monitoring Program (*INPP Code PTOed-0410-3V2*).

External radiation and airborne radioactive particles

Air radiation monitoring in the INPP area is performed by means of air suction. Seven observation stations are arranged in the INPP sanitary protective area and radiation control area for air sampling. The periodicity of the filter replacement is three times a month. The observation stations are located in the vicinity of the INPP.

The INPP Environmental Monitoring Program also includes the monitoring of changes of in-situ dose rate in the region. The monitoring is performed with the help of sensors of the system “SkyLink”. Ten sensors are installed in the settlements of the observation zone and twelve sensors are installed in the sanitary protection zone. Thus, radiation monitoring is carried out at the major vitally important objects, including INPP personnel and the people living not far from the INPP.

The Institute of Physics performs continuous collection of aerosol particles. The radioecological monitoring station of the Institute of Physics is located at 3.5 km to the south of the Ignalina NPP. The station was founded in 1978. Releases from the power plant reach ground surface in the vicinity of the station and the concentration of radionuclides generated at the power plant and emitted via the 150 m high stacks to the atmosphere doubles. The direction of wind in 16 % of cases corresponds to the direction of transfer from the power plant. The location of the monitoring station of the Institute of Physics is presented in Figure 9.3-2.

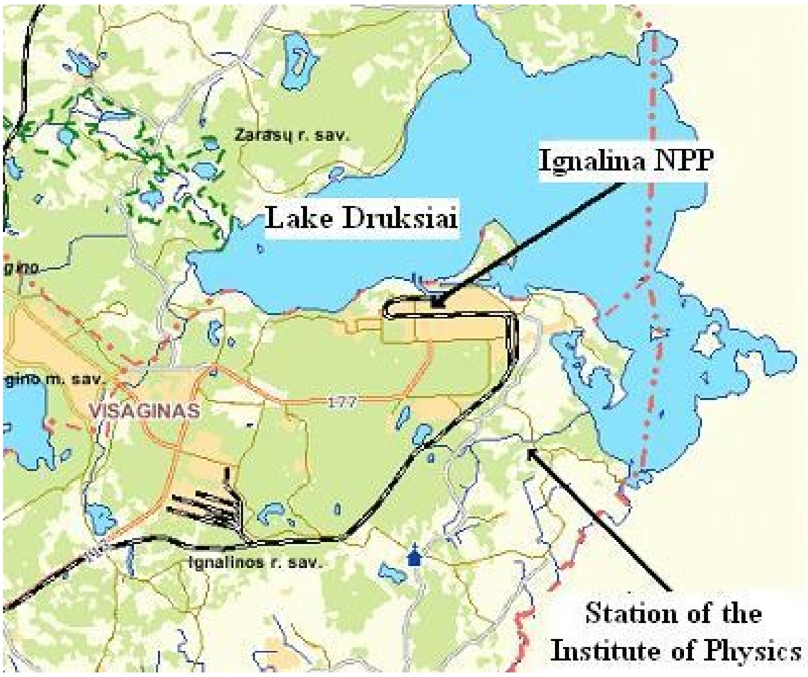


Figure 9.3-2 Location of the monitoring station of the Institute of Physics.

Aerosol particles at the Institute of Physics monitoring station are collected weekly. The gamma specter of the samples is measured. Shift of concentrations of cosmogeneous, emitted by the Ignalina NPP, and anthropogenic gamma radiation activities in the air are observed. The computer program Interras has been used in order to present the results of measurements conducted in one figure. The program allows calculation of exposure doses on the basis of measured concentrations of activities of radionuclides in the air. Annual doses of cosmogeneous radiation ^{7}Be have been calculated collectively after exploded nuclear loads in China (1980, 1982). Annual doses of radionuclide radiation (^{137}Cs) from the Chernobyl accident and annual doses of radiation of radionuclides (^{60}Co, ^{54}Mn) emitted by the Ignalina NPP are also calculated.

Aerosol samples are also continuously collected in Utena. Shifting of volumetric activity of cosmogeneous and anthropogenic gamma radiation is monitored.

Concentration of gamma-radiating radionuclides is determined by intensity of the typical gamma-quantum with the use of semiconductor gamma spectrometry method. Indices of separate radionuclide doses Bq/Sv enable calculation of general radiation dose. Beta-radiating radionuclides are measured by the scintillation spectrometry method.

The effective exposure dose is measured using thermo-luminescent dosimeters and portable devices. Thermoluminescent dosimeters are located in the sanitary protective area and radiation control area in different directions and at different distances from INPP (Figure 9.3-3). Exposure time of thermo-luminescent dosimeters is one year.

Lithuanian Hygiene Standard HN 87:2002 "Radiation Protection in Nuclear Installations" (*State Journal, 2003, No. 15-624*) requires that the annual effective dose to the critical group members due to operation and decommissioning of a nuclear facility shall not exceed dose constraint – 0.2 mSv/year. Different release routes (e.g. to the environment through air or water) can lead to doses for the same or different critical group members. Therefore the dose constraint value used for each route should be one half of the actual dose constraint (i.e. 0.1 mSv per year) (*LAND 42-2007*).

The part of radionuclides, which are transferred 8 km with the wind direction from the Ignalina NPP toward Visaginas, is assessed to make estimations of the dose to the population, i.e. to the inhabitants of Visaginas. Precise dose assessment results for critical groups of the population are also obtained through the automated registration of radiation of radionuclides in the surface air and in the nuclear power plant stack releases and a system for calculation of radionuclide transfer in the air (ASKRO). Each hour is summed up for the annual distribution of the calculated dose.

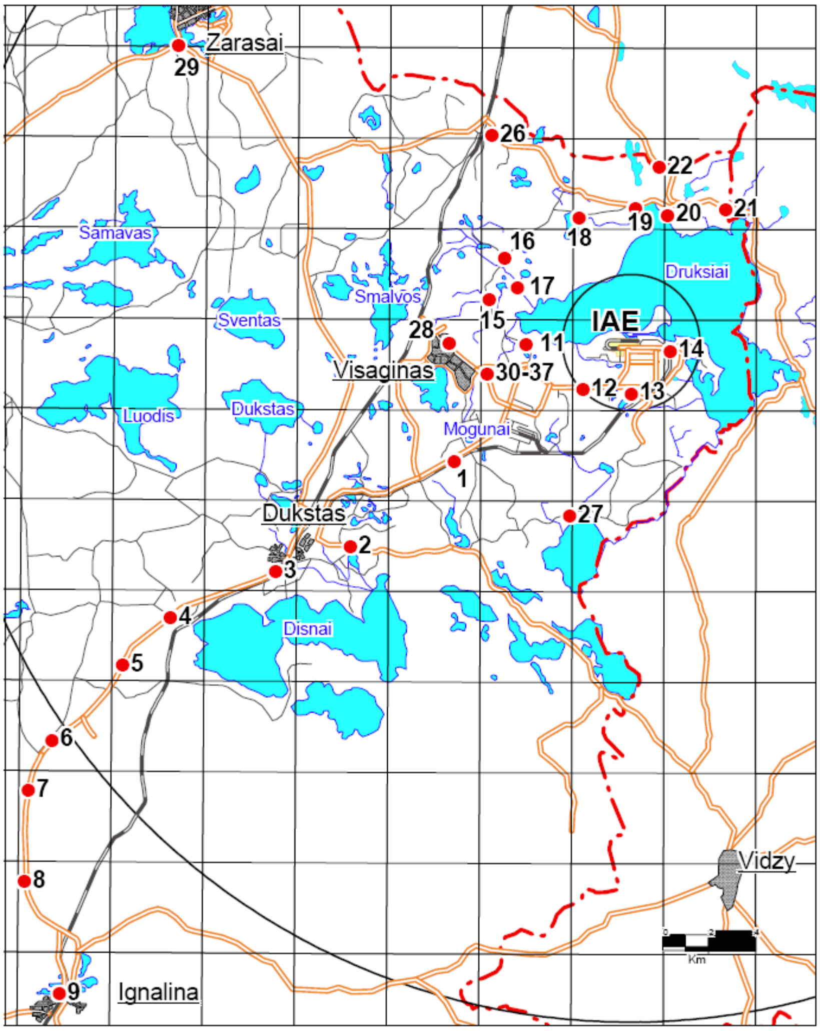


Figure 9.3-3. Location of thermoluminescent dosimeters around the INPP.

Deposition

Atmospheric deposition is continuously collected at five stations (Vilnius, Kaunas, Klaipeda, Utena and Dukstas). Collective beta activity is measured. Every quarter gamma specter analysis of integrated samples is performed and ^{90}Sr activity is measured.

Soil

Samples of the soil in the region of Ignalina NPP (at 8 points of permanent surveillance and in Grikeniskiu peninsula) are monitored annually (in autumn). Activity of γ nuclides, ^{90}Sr and total β activity are measured in the samples of the soil. Location of permanent surveillance points are shown in Figure 9.3-4.

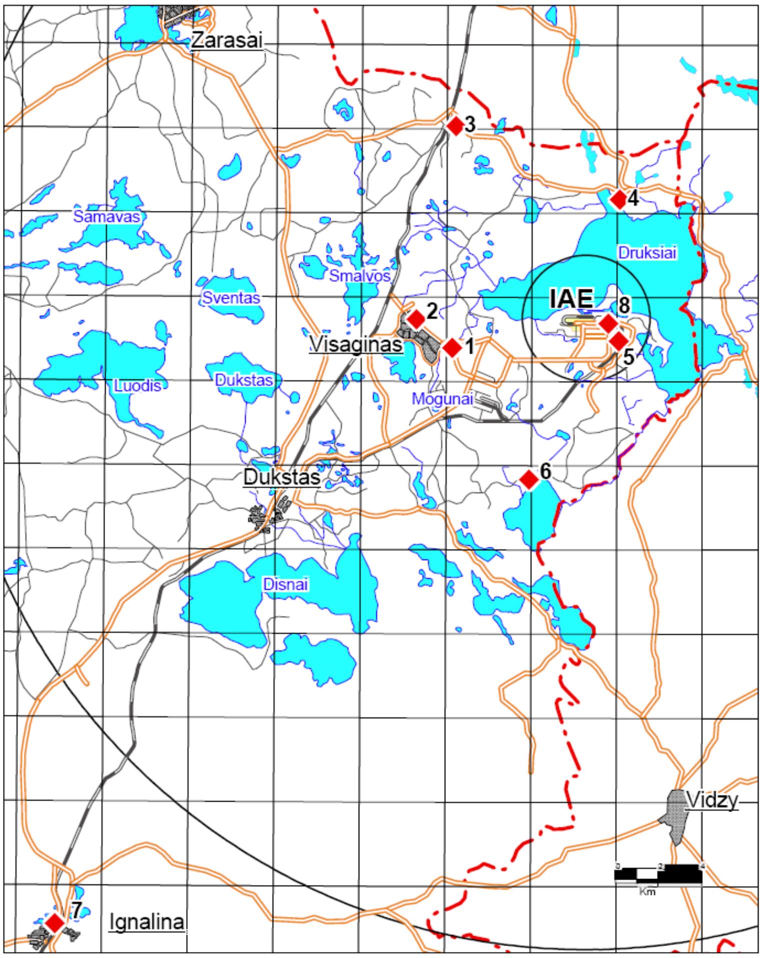


Figure 9.3-4. Location of permanent surveillance points in the INPP region.

Aquatic environment

Samples of surface water are taken every quarter. Samples of discharge of technical water and water of the inlet channel of Lake Druksiai are taken 20 times per month (on working days). Volumetric activities of ^{137}Cs and other gamma radiation and ^{90}Sr are determined. Samples of bottom sediments are taken 2–4 times per year, and specific activities of ^{137}Cs and other gamma nuclides and ^{90}Sr are measured.

The groundwater monitoring program has been developed in accordance with the normative document "Regulation on Ground Water Monitoring of Economy Entities" (*State Journal, 2003, No. 101-4578*) and approved by the Geological Survey of Lithuania.

The measurements, observation points and groundwater monitoring network related to ^{3}H and ^{14}C activity concentration in the lake environment are described in this report in Section 7.1.1.5.

Terrestrial wild plants and natural products

Samples of mushrooms and moss are monitored annually (in autumn) at the locations Vilaragis, Grikeniskes, Tilze, Gaide and Visaginas. Samples of roe deer meat are monitored annually (in autumn) in the radius of 10 km around the INPP. Grain crops (rye and oats), cabbage and potatoes are monitored annually (in autumn) in Tilze. Milk is monitored monthly in Tilze. Samples of meat (pork, beef) are monitored annually (in autumn) in Tilze and at the location Turmantas.

Grazing grass

Samples of pasture grass in the region of Ignalina NPP (at 8 points of permanent surveillance and in Grikeniskiu peninsula) are monitored monthly (from May to October). Activity of γ nuclides, ^{90}Sr and total β activity are measured in the samples of the pasture grass. The location of permanent surveillance points are shown in Figure 9.3-4.

Food and drinking water

Radiological monitoring of food and drinking water is performed by the Radiation Protection Center (RPC). Samples of milk, meat, fish, vegetables (potatoes, cabbage) have been taken for analysis since 1976 in the Ignalina region, and since 1979 in the Zarasai region. Samples of the food products from Utena and grain samples from the Ignalina and Zarasai regions have been monitored since 1992. In 1998–2000 samples have also been taken in the Svencioniu region.

Since 2002, RPC has executed state radiological monitoring of food products and drinking water based on Recommendations of the European Commission (*2000/473/Euratom*) in accordance with the Order of Ministers of the Environment and Health Protection of the Republic of Lithuania from October 7, 2002 No. 528/490 *(State Journal, 2002, No. 100-4460*). Measurements of specific activities (and volumetric – in milk) of total alpha and beta, ^{90}Sr and ^{137}Cs in samples of food products are performed. Analysis of total alpha and beta (except $^{3}H_{1}$, ^{14}C, ^{40}K) and tritium volumetric activities are performed in samples of drinking water.

Specific activity of ^{137}Cs is regulated in food. In addition it is recommended to analyze ^{90}Sr in food products during radiological monitoring because it easily penetrates into bone tissue and accumulates in it. Analysis of total alpha and beta activities is also performed in food. According to the Lithuanian Hygiene Standard HN 24:2003 "Requirements on safety and quality of drinking water" (*State Journal, 2007, No. 79-3606*) volumetric activity of tritium and total alpha and beta activity are regulated in drinking water (for evaluation of annual effective dose).

The National veterinary laboratory observes radionuclides in animal products and fodder independently.

9.3.2 Proposals for the monitoring system for the new NPP

The new NPP can start operation only after receiving permission for release of radionuclides to the environment. The permission is issued by the Ministry of Environment. According to the clause 17 of LAND 42-2007, the operating organization of the new NPP shall submit to the Ministry of Environment an application for permission, a plan on releases of radionuclides and a radiological monitoring program confirmed by the Environment Protection Agency, Lithuanian Hydrometeorological Service under the Ministry of Environment and Radiation Protection Centre. According to clause 21 of LAND 42-2007, the permission is issued indefinitely.

The monitoring system for the new NPP will be designed to fulfil all the requirements of the Lithuanian legislation and regulations, the IAEA recommendations and obligations under the United Nations Conventions. The existing INPP monitoring system will be utilized where applicable. However, all the monitoring systems and devices applied will be modernized to meet the current requirements on preciseness and periodicity. The monitoring sites and objects will be kept unaltered when possible to assure the comparability of the existing INPP monitoring data with the new system.

9.3.2.1 Monitoring of radioactive releases

Airborne releases

Accurate release measurements of radioactive substances are used to ensure that the combined releases from the NNPP to the air and water do not exceed the release limits set by the authorities. This also allows the detailed assessment of the activity of the annual airborne and waterborne releases. The releases of radioactive substances from the nuclear power plant and spent fuel repositories originate from the handling and processing systems for waters and gases containing radioactive materials. The monitoring of releases into the air and water will cover all such systems that contain or may contain radioactive materials.

Releases of radioactive materials from the nuclear power plant take place through monitored release routes. Releases into the air are emitted in a centralized manner through the vent stack of the plant and possibly, to a minor extent, through the air conditioning of the turbine building. For the assessment of the radionuclide activities of airborne releases from the new NPP the releases will be monitored by sampling and continuous measurements.

The radionuclides can be divided into three groups: radioactive noble gases, radioactive iodine and radioactive aerosols. Activity will be measured directly or from integral samples given continuously. The flow of discharged gases will be credibly measured at any condition. The radioisotopic content of airborne releases will be assessed and the activity of radionuclides will be measured. The activity of releases in the main physical-chemical forms of ^{3}H will be measured. For the assessment of short-term alternation of the releases from nuclear reactors the total activity of the releases will be measured at least daily (hourly for main flows of releases). Proposals for monitoring of the common gaseous and particle releases of the NPP and examples of the radionuclides in releases and their detectable limits are presented in Table 9.3-4.

Content of radionuclides in releases is determined on the basis of gamma specter measurement of spectrometric aerosol particles and inert gases in samples from the ventilation air stacks, and this allows evaluation of penetration of every radionuclide to the surface air. Since radionuclides may be released from the power plant to the ambient air via ventilation stacks of reactor units and via ventilation tubing of the rooms with the radioactive waste treatment equipment, calculations will be performed for three different height cases. The ventilation air stacks of the new NPP will have a set of sampling equipment through which part of the exhausted gases travel. The equipment will be based on the most effective and advanced techniques that can be practically adopted. The solid particles contained in the sample flow are caught in the sampling filter that is changed and analysed regularly. The level of radioactivity of gaseous substances is measured using a continuously operating radioactivity meter. Samples will also be taken of the gas at regular intervals for isotope-specific analysis.

The system RADIS has been used in the Ignalina NPP. It will be assessed whether the same system is also adequate for the new NPP or whether there will be a need for modernization of the system.

Table 9.3-4 Proposals for monitoring of the common gaseous and particle releases of the NNPP and examples of the radionuclides in releases and their detectable limits (*Edilex 2008*).

Release	Monitoring method	Reduplication	Radionuclide	Minimal detectable activity in release flow
Noble gases	continuous monitoring	yes	^{133}Xe	10 kBq/m^3 during monitoring < 10 min
	laboratory determination at minimum weekly	yes	^{85}Kr	10 kBq/m^3
			^{87}Kr	1 kBq/m^3
			^{133}Xe	1 kBq/m^3
Iodines	continuous monitoring		^{131}I	2 Bq/m^3 during monitoring < 1 h
	laboratory determination at minimum weekly	yes	^{131}I	4 mBq/m^3
Aerosols	continuous monitoring		all	4 Bq/m^3 during monitoring < 1 h
	laboratory determination at minimum weekly	yes	^{60}Co	1 mBq/m^3
			^{137}Cs	1 mBq/m^3
Alpha activity	laboratory determination at minimum monthly	yes	all	total activity 1 mBq/m^3
			^{241}Am	0.1 mBq/m^3
Significant single nuclides	laboratory determination at every quarter	yes	^{89}Sr and ^{90}Sr	combined activity 0,1 mBq/m^3
	laboratory determination at minimum monthly		^{3}H	0,1 kBq/m^3
	laboratory determination at minimum monthly		^{14}C	10 Bq/m^3

Waterborne releases

A similar sampling procedure as for airborne releases will also be used to monitor the radioactivity of waste waters discharged from the plant to Lake Druksiai. The radioisotopic content of waterborne discharges and the activity of radionuclides will be assessed. Stationary systems for the direct measurement or sampling of integral samples will be installed at the main pathways of permanent discharges. Automatic systems will be installed when reasonable. The total activities of the waterborne releases at the main pathways will be assessed at least daily. At less important pathways sampling will be performed regularly. The flows of waterborne discharges will be credibly measured in all pathways at any condition. Proposals for monitoring of the common liquid releases and examples of the detectable limits of the monitors are presented in Table 9.3-5.

Monitoring measurements of radioactivity in household waste water at the Ignalina NPP are performed at the waste water collection point (on the NPP site), at the waste water receiving point (at Lake Druksiai) and halfway down a stream between the waste water treatment plant and Lake Druksiai. Radioactivity is also monitored in five discharge points and six stations in Lake Druksiai (see Figure 9.3-1). It will be assessed whether the same monitoring points could be used also for the new NPP. However all waste waters from the monitored area will be treated in the liquid waste water treatment plant. From the treatment plant the waste water will be collected to specific discharge containers where the monitoring of the radioactivity releases of aqueous waste will be performed. The plant laboratory will measure the level of radioactivity in the water and clear it for pumping out if the level is acceptably low. If the radioactivity level of the water is not low enough it will be returned for further treatment. In conjunction with discharging the water into the lake, a collective sample will be taken for release measurements. There will be an automatically operating unit of measurement based on best available techniques in the discharge tube. There will also be valves which are closed automatically in cases when discharged water activity level is too high. In addition the auxiliary plants such as the repository for operating waste and the spent fuel storage will be included into the power plant's release control.

The systems designed to monitor the release of radioactive materials will have means for calibration and operability testing.

Table 9.3-5 Proposals for monitoring of the common liquid releases and examples of the detectable limits of the monitors (*Edilex 2008*).

Release	Monitoring method	Reduplication	Radionuclide	Minimal detectable activity in release flow
Gamma activity	continuous monitoring	yes or verification by sampling	significant	detection limits notably lower than the maximum limit set for the gamma activity, e.g. 400 kBq/m³
	release-specific laboratory determination		significant	1 kBq/m³
Alpha activity	laboratory determination monthly		all	total activity 1 kBq/m³
			^{241}Am	10 Bq/m³
Significant single nuclides	laboratory determination at every quarter		^{89}Sr ja ^{90}Sr	combined activity 0,2 kBq/m³
	laboratory determination monthly		^{3}H	50 kBq/m³

Additional monitoring

The activity of ^{14}C in airborne and waterborne releases will be systematically measured or assessed by calculations, which will be validated using the measurements performed under various modes of nuclear object operation. The activity of the radionuclides in airborne and waterborne releases will be credibly assessed during short-term increase of releases. If an increase of releases is foreseen (e.g. during start-up or shutdown of the NNPP), an additional observation shall be performed. Accordingly stationary observation systems or the application of laboratory methods will be used.

9.3.2.2 Monitoring of the radioactive loads to the environment and people

The purpose of environmental radiation monitoring is to determine the radiation load caused to the environment and people by the radioactive releases from the nuclear power plant. The radiation measurements of the power plant area and surroundings ensure that the radiation dose limits set by the authorities are not exceeded. Radiation monitoring also confirms the measurement results of the power plant's radioactive releases and detects any short-term and long-term changes in the normal radiation situation of the surroundings. The radiation monitoring program contains e.g. external radiation measurement and analyses of activity in inhaled air and in samples representing different phases of the food chains leading to humans.

A radiological monitoring program for the new NPP will cover monitoring of all environment radiation ways, capable of impacting people and environment. According to clause 42 of LAND 42-2007, the monitoring program of the new NPP and its amendments will be confirmed by the Ministry of Environment, Environment Protection Agency, Lithuanian Hydrometeorological Service under the Ministry of Environment and Radiation Protection Centre. According to clause 38 of LAND 42-2007, monitoring shall be performed at least one year before the start of operation of the new NPP. The first revision of the radiological monitoring program shall be performed after one year of operation of the new NPP and then after every five years.

The environmental monitoring will include the measurements of the dose rate, external absorbed dose and activities of radionuclides in various components of the environment. Continuous measurements of radiation will be performed in the sanitary protection zone of the NNPP and at some distances from it towards the nearest main settlements, taking into account the location peculiarities of the NNPP territory. All the devices for dose rate measurements and for the measurements of the external absorbed dose will represent best available techniques. Samples of environmental indicators will be taken in the sanitary protection and monitoring zones at locations where pollutants are released or discharged and where the maximal pollution (according to assessments of radionuclides dispersion and territory peculiarities) is expected.

The samples will be taken with a frequency corresponding to the alternation of components of the environment and the quantity of gathered data will be such that it allows assessment of the exposure of the members of the critical group (groups). For the assessment of the pollution of environmental indicators the radio isotopic content of samples will be estimated, and the concentrations of the gamma emitters (^{137}Cs, ^{134}Cs, ^{60}Co, ^{54}Mn, ^{95}Zr, ^{95}Nb, ^{131}I etc.) will be measured. The pollution with beta emitters (^{89}Sr, ^{90}Sr, ^{3}H and ^{14}C) and alpha emitters ($^{239,\ 240}Pu$) will be assessed using the analysis of chosen archetypal samples. Performing the measurements of the concentration of beta and alpha emitters the methods of chemical seduction of elements will be applied, if necessary. If it is known or supposed that the activities or content of airborne and waterborne releases can change, the samples will be taken more frequently, and additional measurements will be performed.

The monitoring will be performed applying measurement methods and using devices which allow measuring the activities of individual isotopes that can lead to doses higher than 0.005 mSv/y with sufficient accuracy. The monitoring systems will be doubled and operated continuously, which allows assessing the concentrations of any period and comparing with the maximum permissible concentrations. For the data quality assurance the monitoring systems will be installed, tested, calibrated, operated and renovated in accordance with the nuclear industry standards and the quality assurance program.

A proposal for a program for monitoring radionuclides of the new NPP is presented in Table 9.3-6.

External radiation

External radiation will be measured continuously. All the monitoring equipment and stations will be used and located by utilizing existing sites and devices wherever reasonable (e.g. sensors of the SkyLink System). All decisions should however be based on the best available techniques. Continuously operating environmental dose rate meters and thermoluminescent dosimeter stations located at 0–10 km from the NNPP will be used for continuous measuring and recording. Some meters will also be connected to the nationwide radiation monitoring network through which the readings will be available in real-time. In addition there will be supplementary gamma-spectrometric measurements once every two years.

Airborne radioactive particles and iodine

The radiation monitoring program will also cover samples taken in various locations and during all seasons. The samples will be taken from indicator organisms which gather or enrich the radioactive substances contained in the releases. Air and the particles contained in it will also be monitored using continuous sampling. Monitoring of airborne radioactive particles and iodine in the new NPP area will be performed by high-volume air sample collectors. Existing observation stations will be used when reasonable. Air samples will be collected continuously and simultaneously. All the devices including the filters used in collectors will represent best available techniques. The filters will be changed a few times per month, but during maintenance and refuelling outages of the power plants, filters from the sampler closest to the power plant will be changed weekly. A portable air sample collector will be used when needed for complementary monitoring, e.g. once a week during refuelling.

Deposition

Deposition will be measured continuously in rain water. Deposition collectors (rain sample collectors) for dry and wet deposition will be located at distances of 1–10 kilometers from the power plant. Electric warming will be used to prevent freezing and for melting the snow deposited in the collector in winter. The sample vessels will be changed regularly. *(STUK-A227, 2008, p. 27)*

Soil samples

Before the start of operation of the new NPP the environmental geological investigations should be carried out and possible ambient pollution should be evaluated.

During operation of the new NPP samples will be taken from the area of assumed maximum deposition to determine the accumulation of long-lived radionuclides. Samples will be drawn from 8 standard points twice a year. Possibly polluted soil will be changed mechanically to clean. Polluted soil will be treated in situ using specific physical processes (electrolysis, etc.) or materials (sorbents).

Grazing grass

Samples will also be taken of grazing grass twice per growing season at distances of 0–10 km from the new NPP. Grazing grass is taken as a collective sample representing farms producing milk.

Terrestrial wild plants, natural products and game

Samples will also be taken of terrestrial wild plants such as moss, natural products (e.g. mushrooms and berries) and game (roe deer meat) at minimum in three ecological sites.

An attempt will be to gather the samples from an area which is as small and uniform as possible. Samples are taken annually during the growth season and in the vicinity of the power plant. Samples of wild berries and mushrooms growing in the vicinities of the NPP will be taken simultaneously with the soil sampling.

Other food

Samples will be taken e.g. of milk, potatoes, cabbage, grains and meat. The sources of the samples will be chosen so that they provide comprehensive coverage of the routes through which people may receive radioactive substances in food. The samples are taken at distances ranging from 0 to 40 kilometres from the power plant. Milk samples will be taken once a week by the personnel of local dairies operating in the regions of the power plants. The samples representing the whole production of the local dairy could be taken from collection tanks in the dairy according to standard methods used in sampling of food supplies. Samples of potatoes and cabbage will be taken from a chosen garden grown at 0–10 km from the NPP as for normal household use. Grain samples of rye and oats will be taken once a year in local grain stores grown at less than 20 km from the NPP. Meat samples (pork and beef) will be taken twice a year from livestock raised at less than 40 km from the NPP. Beef samples will be taken in a central slaughterhouse from cows of varied ages in the same ratio as they are delivered for slaughter. (*STUK-A227, 2008, p. 33-35*)

Drinking water

Samples of drinking water will be taken 2–4 times a year directly from the network of water pipes or from raw water reservoirs.

Surrounding residents

The internal radioactivity measurements of the nearby residents ensure that there are no significant, unrecognised exposure pathways for the residents of the surroundings. Measurements will be taken of 8–15 residents. Radioactive emissions from the new NPP and caused annual doses to population will be summarized in the monitoring program.

Lake environment

In the lake environment samples of water are taken in the surrounding area of the new NPP 4 times a year, samples of aquatic indicator organisms and bottom sediments twice a year in six stations. The fish samples will consist of 2–4 economically important species from the discharge area and from a comparison area.

Table 9.3-6 Proposal for a program for monitoring radionuclides of the new NPP (adapting *STUK-A227, 2008, p. 14–17*).

Monitoring object	Type of measurements or samples and number of measurements or sampling stations	Measuring or sampling frequency	Analyses and frequencies
External radiation	Environmental dose rate meters at 0-10 km from the power plant	Continuous measurement and recording	Dose rate, min., max., mean, analogue plotter charts and/or digital hourly average values
	TLD dosemeter stations at 0–10 km from the power plant	Continuous measurement	Gamma dose, 4 times a year
	Supplementary gamma-spectrometric measurements	Once every two years	Gamma spectrum, once every two years
Airborne radioactive particles and iodine	Air sample collectors at 0–10 km from the power plant	Continuous collection	Gamma emitters, twice a month (once a week)
	Supplementary monitoring performed with a portable air sample collector	Once a week during refuelling	Gamma emitters, once a week during refuelling
Deposition	Deposition collectors at 0–10 km from the power plant	Continuous collection	Gamma emitters, and ^{3}H, 4–12 times a year, ^{89}Sr and ^{90}Sr, 4 times a year
Soil	Soil samples are drawn from the area of assumed maximum deposition to determine the accumulation of long-lived radionuclides	Once every four years	Gamma emitters and ^{90}Sr, vertical distribution
Terrestrial wild plants, natural products and game	Wild berries and mushrooms	Simultaneously with the soil sampling	Gamma emitters
	Roe deer meat from one sampling site close to the power plant	Once a year	Gamma emitters, once a year
	E.g. moss from one sampling site close to the power plant	Once a year after the refuelling	Gamma emitters, once a year
Grazing grass	Collective sample representing farms producing milk at 0–10 km from the power plant	Twice a growing season	Gamma emitters, twice a growing season
Milk	Sample representing farms producing milk at 0–10 km from the power plant	Once a week	^{131}I and gamma emitters, once a month
	Sample representing the whole production of the local dairy	Once a week	Gamma emitters once a month and ^{131}I if needed; ^{89}Sr, ^{90}Sr six times a year
Garden produce	Potatoes grown at 0–10 km from the power plant	Twice a growing season	Gamma emitters, twice a year
	Cabbage grown at 0–10 km from the power plant	Twice a growing season	Gamma emitters, twice a year
Grain	Samples of rye and oats grown at less than 20 km from the power plant	Once a year	Gamma emitters, once a year
Meat	Beef and pork samples from livestock raised at less than 40 km from the power plant	Twice a year	Gamma emitters, twice a year
Drinking water	Samples of drinking water or raw water from the power plant and from the nearby town	2–4 times a year	Gamma emitters, and ^{3}H, 2–4 times a year, ^{89}Sr and ^{90}Sr, twice a year
Lake water	Samples from 6 stations in the surrounding lake areas of the power plant	2–4 times a year	Gamma emitters, ^{3}H, ^{89}Sr and ^{90}Sr, 2–4 times a year
Bottom sediments	Sinking matter collected by sediment traps at stations in the surrounding lake areas	Continuous collection	Gamma emitters, 4 times a year; ^{238}Pu and ^{239,240}Pu, once a year
	Sediment samples are taken from several stations in the surrounding lake areas	Once every four years	Gamma emitters, ^{90}Sr, ^{238}Pu and ^{239,240}Pu, vertical distribution
Aquatic indicator organisms	E.g. periphyton collected by 1m^{2} sampling plates close to the cooling water outlets of the power plant	Continuous collection during the growing season	Gamma emitters, 4 times a growing season
Wild fish	E.g. pike from two sampling areas	Twice a year	Gamma emitters, twice a year, ^{89}Sr and ^{90}Sr

9.4 OTHER MONITORING

9.4.1 Current monitoring system

9.4.1.1 Seismic alarm monitoring system

The Lithuanian territory is traditionally considered as non-seismic or low seismic zone. However historical and recent data shows that seismic events of low or medium intensity have happened in territories of the Baltic States. Four seismological observation stations have been installed in the INPP region. The data gathered in the stations is processed and analysed according to the State Nuclear Power Safety Inspectorate (VATESI) regulation P-2006-01 "Requirements for Analysis of Seismic Impact on Nuclear Installations" (*State Journal, 2006, No. 87-3447*) and the IAEA Safety Standards.

The seismic alarm monitoring system comprises sensors located at distances of up to 30 km from the plant permitting alerting prior to arrival of earthquake shock waves at the site. It identifies seismic events larger than design earthquakes, does not interfere with other systems and its integration does not involve any risk for the plant supplier.

9.4.1.2 Monitoring of cooling and waste waters

Cooling water

Monitoring of thermal effects of the INNP cooling water is carried out according to the regulations "Standard Limits of Permissible Warming of Lake Druksiai Water and Methodology for Temperature Control" (*LAND 7-95/M-02*) and the Ignalina NPP Environmental Monitoring Program. A description of the content of the regulations can be found from the Section 7.1.1.5 "Water temperature monitoring of Lake Druksiai".

Waste water

The quality of waste waters is monitored according to the "Regulation on Sewage Management" (*State Journal, 2007, No. 110-4522*) and the Ignalina NPP Integrated Pollution Prevention and Control Permission (*No. TV(2)-3, issued by Utena Regional Environment Protection Department*). Household wastewater treatment is outsourced to the State Enterprise "Visagino Energija", which operates the Visaginas waste water treatment plant; hence the monitoring of household waste waters is carried out by "Visagino Energija".

In addition the waste water monitoring comprises the follow up of regeneration effluents (from process water production) and discharges from the rain water disposal system. Rain water is managed according to the requirements of "Regulation on Surface Water Management" (*State Journal, 2007, No. 42-1594*). The monitoring is carried out in the cooling water discharge channel, in the inlet channel and in the rain-industrial water release channels 1,2 (PLK-1,2), 3 (PLK-3) and in the release channel of the Spent Fuel Storage Facility (PLK-SFSF).

9.4.1.3 Monitoring of the environmental impacts

Historically the monitoring of the environmental impacts was part of the various State financed scientific programs (1978–2007) which comprised both radioecological and non-radioecological monitoring. A summary of monitoring results of the aquatic ecosystem (physico-chemical parameters, plankton, aquatic vegetation, fish stocks and fishing activity) is presented in Section 7.1.1.4. Summaries of monitoring results of the radionuclides in the water of Lake Druksiai and groundwater are presented in Section 7.1.1.5, the radioecological state of flora and fauna of Lake Druksiai in Section 7.1.1.6, the ecotoxicological state of Lake Druksiai in Section 7.1.1.7 and the radioecological state of terrestrial flora, fauna and onshore land of the region in Section 7.6 of this EIA Report.

More detailed scientific monitoring data can be found in the State Scientific Program "Atomic Energy and the Environment" (*Collection of Research Reports, 1993–1997, Vol. 1–5*) and in the report of the project recently performed by Radiation Protection Center together with various research institutitions (*Radiation Protection Centre Project Report, 2007*).

9.4.1.4 Monitoring of flue gas emissions

Total emission values are calculated based on fuel consumption. The impact of flue gases on air quality can be assessed based on data from the monitoring station in Aukstaitija (see Section 7.2 Background contamination of the ambient air and greenhouse gases).

9.4.1.5 Noise monitoring

Noise levels caused by the INPP are not monitored at regular intervals.

9.4.1.6 Monitoring of social impacts

A program for the socio-economic monitoring of the INPP region was compiled and prepared by the Division of Regional Geography of Institute of Geology and Geography in 2002 (*R. Baubinas et al., 2002*). Preparation of the program was funded by the United Nations Development Program and coordinated by the Ministry for Social Security and Labor. The monitoring has been organized in the context of preparations for the closure of the INPP. The objective has been to diminish the possible negative impacts of the closure of the INPP and to increase the effectiveness of social policy measures.

More information on the social processes taking place in the region, their interdependence and dependence on the processes outside the region is presented in Section 7.9 of this EIA Report.

9.4.2 Proposals for the monitoring system for the new NPP

The monitoring system for the new NPP will be designed to fulfil all the requirements of the Lithuanian legislation and regulations, the IAEA recommendations and obligations under the United Nations Conventions. The existing INPP monitoring system will be utilized where applicable. However, all the monitoring systems and devices applied will be modernized to meet the current requirements on preciseness and periodicity. The monitoring sites and objects will be kept unaltered when possible to assure the comparability of the existing INPP monitoring data with the new system.

9.4.2.1 Seismic alarm monitoring system

The existing seismic alarm system has been installed in 1999 in the vicinity of the INNP. The system will be utilized also for the new NPP. The new NPP, however, will be designed and constructed to prevent the risks of possible seismic activities.

All the devices used in the alarm system will be modernized if necessary to meet the current national and international requirements.

9.4.2.2 Monitoring of cooling and waste waters

Cooling water

Monitoring of the cooling water comprises the amount, temperature and quality of the discharged water.

The amount of the cooling water will be followed based on the operation data of the new NPP and the output of cooling water pumps.

Temperature monitoring will be carried out by a continuous temperature measurement system which will be installed at the new NPP. Monitoring will be performed with automatic temperature monitoring devices which send the data directly to a defined receiver. The temperature of inflow and outflow water (sample stations within the inlet and outlet channels) will be monitored continuously with real-time monitoring devices. The results will be saved to a computer system as hourly and daily averages. Also thermal and electrical usage data of the new NPP operation will be continuously saved in the computer system. The measurements are used in calculations of the temperature rise in condensers and in computing the flow rate of cooling water. Also the amount of thermal energy directed to Lake Druksiai will be calculated based on the measurements.

The thermal effects of the cooling water discharges are monitored in Lake Druksiai. Continuous temperature monitoring with automatic devices will include 2-4 sampling stations. The location of the sample stations will be defined based on representativeness. The same sample stations as in INPP monitoring will be used when applicable.

Monitoring of the quality of the cooling water is described in the following paragraph "Waste water".

Waste water

The quality of the sanitary waste waters will be monitored by the Visaginas waste water treatment plant (WWTP). The WWTP performs monitoring of waste water discharge quality and amount as it is responsible for the water quality discharged to the environment. A reconstruction project of the plant was started May 2008 and the new plant will be able to meet the current Lithuanian (Regulation on Sewage Management; *State Journal, 2007, No. 110-4522),* Regulation on Surface Water Management; *State Journal, 2007, No. 42-1594*)and EU effluent standards (*Council Directive 91/271/EEC concerning urban waste-water treatment*).

The monitoring will follow the Lithuanian legislation and regulations and protocols required by the urban waste water treatment directive. Flow-proportional or time-based 24-hour samples will be collected at the same well-defined point in the outlet and if necessary in the inlet. The minimum annual number of samples will be 12, which will be collected at regular intervals during the year. Monitoring will comprise at least the following parameters: $BOD_{5/7}$, COD, total suspended solids, total phosphorus and total nitrogen. The monitoring program may comprise also other parameters, such as pH, nitrites, nitrates or phosphates, if considered reasonable. The quality requirements (concentrations/ percentage of reduction) are presented in Section 7.1 "The state of waters".

The pH in the neutralization basin will be measured with an automatic device before discharging to the cooling water channel. The quality of cooling water discharged will be monitored every 10 days. The monitored parameters will include at least the following: pH, N_{tot}, NH_4-N, NO_2-N/NO_3-N, P_{tot}, $BOD_{5/7}$, TDS, TSS, sulphates and chlorides. In case pesticides are used, they will be included in the monitoring program. Other parameters should be considered when reasonable.

All the waters from the rain water disposal system will be collected and continuously followed in inspection wells and settling basins. Oil detector devices, which automatically alarm when oil is detected, will be installed. Detected oil will be removed in oil separators before discharging to the lake. The quality of discharged water will be monitored every 10 days. The monitored parameters will include at least the following: pH, N_{tot}, NH_4-N, NO_2-N/NO_3-N, P_{tot}, $BOD_{5/7}$, TDS and TSS.

Good sampling and laboratory practices (based on international standards) will be applied.

9.4.2.3 Monitoring of the environmental impacts

Monitoring of the environmental impacts will be included in the monitoring program. A detailed monitoring plan will be established together with the authorities but it can comprise e.g. the following indicators; physico-chemical water quality, primary production (chlorophyll-a), aquatic vegetation and fish stock. A proposal for parameters and frequencies of monitoring is presented below.

The physico-chemical water quality in Lake Druksiai will be monitored 3–12 times of year at 2–5 sampling stations. It will comprise at least monitoring of pH, O_2/l, O_2%, N_{tot}, NH_4-N, NO_2-N/NO_3-N, P_{tot}, $BOD_{5/7}$ and TDS. Also other parameters should be considered when reasonable.

Monitoring of the primary production can be based either solely on the cholorophyll-a measurements or combination of it and phytoplankton samples. It should be carried out regularly (2–6 times/ month) at several sample stations (2–5) during the growing season.

The composition and abundance of aquatic vegetation will be monitored every 3–6 year during the growing season at several sample stations (2–5).

Monitoring of the fish stock will be carried out with an interval of 1 to 4 years. The composition and abundance of fish will be monitored by gillnetting (standard gillnets) both in the pelagic and littoral zone (at 2–5 sample stations). Also other methods (such as hydroacoustics or trawling) can be applied.

The existing sample stations will be kept unaltered when possible. All the methods applied in sampling and analyzing the samples will be based on national/international standards to ensure the comparability of the results.

9.4.2.4 Monitoring of flue gas emissions

Flue gas emissions will be calculated based on fuel consumption as it has been done for the INPP. Air quality will be monitored at the integrated monitoring stations as recently.

9.4.2.5 Noise monitoring

During construction of the NNPP noise measurements will be carried out if necessary.

During operation of the new NPP noise will be measured at regular intervals in order to ensure that noise levels from the power plant complies with the levels set in the regulations.

If necessary, the noise level in open air will be measured at locations in which such noise is perceived most clearly.

9.4.2.6 Keeping records of the waste

Keeping records of different types of waste arising at the NNPP will be carried out.

9.4.2.7 Monitoring of social impacts

The methods and results of existing socio-economic monitoring of the INPP will be utilized where applicable for the new NPP.

Cooperation with interest groups is an important part of the normal operations of any modern, social responsible company. The opinions of people living in the area could be studied by queries and be used to support the assessment of the social impacts of the project. The assessment of health impacts is also part of the assessment of the project's social impacts.

Useful information on the negative impacts of the project and on the means available for mitigating or preventing them can be obtained through open exchange of information with interest groups. The connections established during the environmental impact assessment procedure can serve as channels for interaction in the future.

The operator will organise regular meetings with representatives of neighbouring areas and the existing information centre of the INPP can offer information on the new NPP (tours, the information bulletin, the news sheet, booklets, calendars, magazines etc.).

Indirect and direct impacts of the project on employment and businesses could also be studied.

9.5 MONITORING DATA REPORTING

The data concerning monthly monitoring of air and water effluents will be submitted to the Ministry of Environment, the Radiation Protection Centre and VATESI at the first week of the following month (except data on ^{3}H, which will be submitted every three months). An annual report on the results of environmental monitoring will be submitted to the Ministry of Environment, the Environment Protection Agency, VATESI, the Radiation Protection Center and the Local Authorities before first of April of the following year. In accordance with clause 68 of LAND 42-2007, the report will include information as follows:

- results of all measurements foreseen in the Monitoring Program and their analysis;
- activities of radionuclides released into ambient air and water (by months) and total annual activities of radionuclides (given in the list);
- general information concerning realized activities (amount of produced electricity, generated, conditioned, stored or disposed of radioactive waste);
- comparison of radionuclide activities with limits;
- releases and contamination changing trends and their analysis;
- evaluative doses of members of critical groups, caused by radionuclides, their comparison with dose constraint;
- reasons of extraordinary releases of radionuclides into environment and their analysis;
- any other important information.

10 RISK ANALYSIS AND ASSESSMENT

10.1 INTRODUCTION TO RISK ASSESSMENT

Potential emergency situations (risks) resulting from the proposed economic activity, which could lead to environmental impact are addressed in this chapter.

Risk assessment for environmental impact assessment (EIA) differs from risk assessment which is performed later in the Safety Analysis Report (SAR) of a NPP. Usually during the environmental impact assessment process a Technical Design of the NPP is not available yet, therefore for EIA it is important to identify potential emergency situations which are general for different types of power plants and to define emergency situations which have bounding impact on the environment. The risk assessment as presented in an EIA Report shall be considered as preliminary and does not substitute necessity for more sophisticated and detailed risk analysis which has to be based on actual design solutions. At later stages, when reactor type will be selected and Technical Design of this selected type of NPP will be available, a detailed risk analysis, resulting consequences and preventive/mitigation measures will be described in a Safety Analysis Report.

Emergency situations, which could lead to releases and cause radiological exposure of personnel and/or general public, are of primary concern for environmental impact assessment. For this proposed economical activity most of the potential emergency situations can cause radiological and non-radiological or only non-radiological consequences (i.e. emergency shutdown of reactor). Accidents with non-radiological consequences as a rule lead to considerably lower impacts. Most of the non-radiological chemical materials at the power plant are used in auxiliary processes. Design of storage tanks for chemicals and implemented procedures assure the safety usage and storage of chemicals both for the environment and for the personnel. The risk of harmful amounts of chemicals or oils being discharged into the water, atmosphere or soil is minor, therefore in the further analysis consequences of radiological accidents are considered.

The Lithuanian legal document "Regulations on Preparation of Environment Impact Assessment Program and Report" (*State Journal 2006, No. 6-225*) defines that the emergency situations of a proposed economic activity and their potential risks should be assessed according to normative document "Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity" (*Information Publications, 2002, No. 61-297*).

"Regulations on Prevention of Industrial Accidents, their Elimination and Investigation" (*State Journal, 2004, No. 130-4649*) provide requirements for how industrial accidents shall be assessed. Clause 3.1 of this document states that these regulations are not applicable to facilities which can cause radiological impact. Since radiological impact is of primary concern for EIA the industrial accidents and their investigation will be considered in the Technical Design phase.

Risk assessment performed in this EIA Report contains the following steps:

- Identification of the initiating events, design basis accidents (DBA), severe accidents;
- Screening and selection of accidents which have bounding impact to environment;
- Definition of source terms and releases into environment in case of accidents;
- Dispersion modelling of accidental releases and public exposure assessment;

- Description of protective actions of public in case of radiological or nuclear accident.

Selection of initiating events, DBA and severe accidents is based on the IAEA safety guides and reports:

- External Human Induced Events in Site Evaluation for Nuclear Power Plants *(IAEA Safety Guide No. NS-G-3.1)*;
- Meteorological Events in Site Evaluation for Nuclear Power Plants *(IAEA Safety Guide No. NS-G-3.4)*;
- Accident Analysis for Nuclear Power Plants *(IAEA Safety Reports Series No. 23)*.

Analysis of accidents, classification of consequences and selection of bounding cases is provided in Section 10.2 and is based on "Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity" (*Information Publications, 2002, No. 61-297*).

Definition of source terms and releases into environment in case of accidents is based on Design Control Documentation (DCD) of different type of reactors. DCD are freely available on the website of the US Nuclear Regulation Commission (www.nrc.gov). DCD contains information which radionuclides are released during normal operation and in case of accidents into environment from different type of reactors.

For dispersion modelling of accidental releases from the NNPP an Air Quality and Emergency Modelling System SILAM (http://silam.fmi.fi) has been used. Accidental releases, dispersion modelling and possible consequences are provided in Section 10.3.

Assessment of consequences in case of accident, protective actions of public in case of radiological or nuclear accident is based on Lithuanian Hygiene Standard HN 87:2002. "Radiation Protection in Nuclear Objects" (*State Journal, 2003, No. 15-624; 2008, No. 35-1251*) and Lithuanian Hygiene Standard HN 99:2000 "Protective Actions of Pubic in Case of Radiological or Nuclear Accident" (*State Journal, 2000, No. 57-1691*).

10.2 NNPP RISK ASSESSMENT

10.2.1 Operational states and accidental conditions at NPP

The entire set of limits and conditions for which an NPP is designed and for which damage to the fuel and release of radioactive material are kept within authorized limits, form the design basis of an NPP. Within the design basis, a number of unintended events are considered, including human errors and equipment failures, whose consequences or potential consequences are not negligible in terms of safety. According to the probability of its occurrence and potential consequences, an event may be classified as an anticipated operational occurrence (also called a transient), design basis accident, beyond design basis accident or severe accident.

Normal operation is NPP operation within specified operational limits and conditions. This includes start-up, power operation, shutting down, shutdown, maintenance, testing and refuelling. Assessment of possible radiological impacts on the environment during normal operation of the NNPP is presented in Chapter 7.

Anticipated operational occurrence (AOO) is an operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of an NPP but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions. AOO is not classified as accident; it is a part of NPP operational state which consists of Normal operation and AOO. Examples of anticipated operational occurrences are loss of normal electrical power and faults such as a turbine trip, malfunction of individual items of a normally running plant, failure to function of individual items of control equipment, and loss of power to the main coolant pump. NPPs are design to withstand such AOO, radioactive releases into the environment rarely exceed the limits that are assigned to normal operation. The dose constraint of annual population exposure during normal operation of NPP and taking into account AOO shall not exceed 0.2 mSv/year.

Design basis accident (DBA) is an accident condition against which a facility is designed according to established design criteria, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits. In case of DBA the safety systems and containment of NPP limit the amount of radioactive materials released into the environment to such a level that restrictions on land and food products are not necessary and according to HN 87:2002 (*State Journal, 2003, No. 15-624; 2008, No. 35-1251*) maximal radiation dose for the population in the case of DBA shall not exceed 10 mSv. Examples of typical DBAs are loss of reactivity control, fuel handling accidents, loss of coolant accident (LOCA), etc.

An accident occurring outside the NPP design basis is called a Beyond Design Basis Accident (BDBA). Such an accident may or may not involve degradation of the reactor core (leading to significant core damage). Examples of BDBAs are total loss of power, total loss of feedwater, LOCA combined with complete loss of an emergency core cooling system, etc.

An accident condition involving significant core degradation is called a Severe Accident (SA). The frequency of SA is less than one in 1 000 000 years of reactor operation (*IAEA Safety Reports Series No. 23*). In case of SA a large proportion of the fuel in the reactor is damaged, and a large amount of this radioactive material is released into containment which prevents a large release to the environment. The limit of release after a severe accident must not cause acute health effects to the population in the vicinity of the NPP, nor should it cause long term restrictions on the use of extensive areas of land or water. There are no regulations for releases in case of SA in Lithuanian legislation. Therefore the limit for the release of radioactive materials arising from a severe accident (100 TBq release of Cs-137) defined in Finnish legislation (*Council State decision 395/91*) is used for environmental impact estimation. According to the Council State decision (*395/91*) accidents leading to large releases of radioactive materials shall be very unlikely. The numerical design objective for this very unlikely release is specified in Finnish Radiation and Nuclear Safety Authority (STUK) Guide YVL 2.8, where it is stated that the mean value of the probability of a release exceeding the target value 100 TBq of Cs-137 must be smaller than $5 \cdot 10^{-7}$ per year. In the design stage of a NPP it is verified that the possibility of a severe accident is less often than once during the 1 000 000 years of reactor operation.

Many of the engineered provisions for radiation protection of the public in normal operation also contribute to the radiation protection in accident conditions. The special measures provided for public protection during accident situations refer to:

- ensuring containment isolation to terminate releases;
- reducing activity releases.

The first requirement for public protection is to ensure that releases are terminated. Containment isolation is provided by diverse means including isolation based on measurements of Reactor Building airborne activity.

The second requirement is to ensure that where releases take place, these are reduced by appropriate filtration and by ensuring that the volatility of radionuclides (in particular iodine) is reduced.

Table 10.2-1 presents possible subdivision of event occurrences.

Table 10.2-1. Subdivision of event occurrences, derived from (*IAEA Safety Reports Series No. 23*).

Occurrence (1/reactor year)	Characteristics		Terminology	Acceptance criteria
10^{-2} – 1 (Expected in the life of the plant)	Expected	AOO	Anticipated transients, transients, frequent faults, incidents of moderate frequency, upset conditions, abnormal conditions	No damage to fuel
10^{-4} – 10^{-2} (Chance greater than 1% over the life of the plant)	Possible	DBA	Infrequent incidents, infrequent faults, limiting faults, emergency conditions	No radiological impact at all or no radiological impact outside the exclusion area
10^{-6} – 10^{-4} (Chance less than 1% over the life of the plant)	Unlikely	BDBA	Faulted conditions	Radiological consequences outside exclusion area within limits
< 10^{-6} (Very unlikely to occur)	Remote	SA	Faulted conditions	Emergency response needed

10.2.2 External events

During the site evaluation process the hazards associated with external events that are to be considered in the design of the NPP are determined. These external events are grouped into external natural events and external human induced events. Natural events that are typically considered in NPP design are as follows:

- Earthquake;
- External flooding;
- Extremes of temperature;
- Extreme winds and whirlwinds;
- Rain, snow, ice formation;
- Drought;
- Lightning;
- Natural fires.

External human induced events that are usually considered are:

- Aircraft crash;
- Hazards from adjacent installations, transport activities (missiles, gas cloud, explosion wave, etc.);
- Electromagnetic interference;
- Sabotage, terrorist attack;
- Subsidence;
- External fire;
- Blockage or damage to cooling water intake structures.

10.2.3 International Nuclear Event Scale (INES)

Description of accidental conditions at a NPP is provided in Section 10.2.1. However, this subdivision does not give understanding about the significance of the accident. For instance both fuel handling accidents and LOCA are design basis accidents, but consequences of these accidents are very different. Therefore, the International Nuclear Events Scale (*IAEA and OECD/NEA, 2001*) was implemented to facilitate rapid communication to the media and the public regarding the safety significance of events at all nuclear installations associated with the civil nuclear industry, including events involving the use of radiation sources and the transport of radioactive materials. By putting events into proper perspective, the INES eases common understanding about incidents and accidents at NPPs (see Table 10.2-2). Events which should be communicated are those which are rated at level 2 or above, and events attracting international public interest.

Events which have nuclear or radiological significance are classified using the INES scale, which is divided into eighth levels. Industrial events which do not involve nuclear or radiological operations are termed ‘out of scale’. An example of an ‘out of scale’ event is a fire, if it did not involve any possible radiological hazard and did not affect the safety levels. Anticipated operational occurrences belong to the INES level 0.

Five levels have been selected regarding off-site impacts, the most serious of which is INES level 7. Such an incident would involve a large fraction of the core inventory of a NPP being released. The least serious, INES level 3, involves a dose to a member of the public equivalent to about one tenth of the annual dose limit. Below INES level 3, only the on-site impact and the impact on defence in depth have to be considered.

Incidents, in which civil defence actions are not required, range from INES level 1 (anomaly) to INES level 3 (serious incident). An accident without significant off-site risk is classed as INES level 4. These levels are defined by the committed dose to the critical group. Consequences of the accidents rated at INES level 5 are limited releases which would be likely to result in partial implementation of countermeasures covered by emergency plans to lessen the likelihood of health effects. INES levels 6-7 are classified as those accidents where civil defence actions are necessary, in order of increasing seriousness. These latter levels are defined in terms of the quantity of activity released, radiologically equivalent to a given number of terabequerels of the radioisotope Iodine-131.

The vast majority of reported events from operating worldwide NPPs are rated below INES level 3.

Table 10.2-2. International Nuclear Events Scale (*IAEA and OECD/NEA, 2001*).

Level / Descriptor	Nature of the events
INES 0 Deviating events	Deviations from normal operating conditions can be classed as INES 0, where operational limits and conditions are not exceeded and are properly managed in accordance with adequate procedures. Examples include: a single random failure in a redundant system discovered during periodic inspections or tests, a planned reactor trip and minor spread of containment within controlled area without wider implications for safety culture.
INES 1 Anomaly	Anomaly beyond the authorised regime, but with significant defence in depth remaining. This may be due to equipment failure, human error or procedural inadequacies and may occur in areas covered by the scale, such as plant operation, transport of radioactive materials, fuel handling and waste storage. Examples include: breached of technical specifications or transport regulations and minor defects in the pipe work beyond the expectations of the surveillance programme.
INES 2 Incident	Includes incidents with significant failure in safety provisions but with sufficient defence in depth remaining to cope with additional failures. Events resulting in a dose to a worker exceeding a statutory annual dose limit and/or an event which leads to the presence of the significant quantities of radioactive in the installations in areas not expected any design and which require corrective action.
INES 3 Serious incident	The external release of radioactivity resulting in a dose to the critical group of the order of tenths of mSv. With such a release, off-site protection measures may be needed. On-site events resulting in sufficient dose to workers to cause acute health effects and/or resulting in sever spread of contamination. Or the further failure of safety systems could lead to accident conditions. On such incident was at the Paks NPP in Hungary in 2003. During an outage, fuel assemblies were purified on the bottom of a deep water basin in separate purification equipment. Due to a design failure of the equipment, its cooling circulation system was disturbed and the fuel assemblies overheated. This cause the release of radioactive noble gases and a small amount of Iodine in to the reactor hall. Off-site release was small; levels of external radiation at the site or near its vicinity did not exceed normal background levels. No person was injured; the radiation dose to personnel was at most 10% of the annual dose limit.
INES 4 Accident without significant off-site risk	External release of radiation resulting in a dose to the critical group of the order of a few mSv. Off-site protective actions unlikely. On-site, significant damage to installations. Accident results in the irradiation of one or more workers resulting in an overexposure where a high probability of death occurs. On such event was a criticality accident that occurred in Japan at the Tokkaimure nuclear fuel factory in 1999. Three workers were over-exposed to radiation, two of which died later due to their exposure. The factory was located in an urban area, which was subsequently evacuated, and residents further away advised to protect themselves. The thin walls of the building and the Uranium container did not protect the environment from radiation. The largest dose to a person outside the staff was 16 mSv.

Level / Descriptor	Nature of the events
INES 5 Accident with off-site risk	External release of radioactive materials (in quantities radiologically equivalent to hundred to thousands of terabecquerels of Iodine-131). Such a release would be likely to result in partial implementation of countermeasures covered by emergency plans to lessen the likelihood of health effects. On-site events result in severe damage to installations. This accident may involve a large fraction of the core, a major criticality accident or a major fire or explosion releasing large quantities of radioactivity within the in installations. The Three Mile Island incident in the US in 1979 was an INES level 5 event. The accident initiated from a leak in the reactor system. The reactor emergency cooling was automatically started, and was then incorrectly interrupted by the operators. This caused the overheating and partial melting of the core. Despite the severe damage to the reactor core, the pressure vessel and containment remained intact, preventing external release. The environmental impacts were small.
INES 6 Serious accident	External release of radioactive materials (in quantities radiologically equivalent to tens of thousands of terabecquerels of Iodine-131). Such a release would be likely to result in full implementation of countermeasures covered by local emergency plans to limit serious health effects. Only one such INES level 6 accident has ever occurred. This was in Soviet Union (presently Russia) in 1957, at the reprocessing plant near the town of Kyshtym. A tank containing high-level liquid waste was exploded, causing the release of radioactive material. Health effects were limited by countermeasures, such as evacuation of the population in the environment.
INES 7 Major accident	External release of large fractions of the radioactive material in a large facility (e.g. the core of a power reactor). This would typically involve mixture of short and long lived radioactive fission products (in quantities radiologically equivalent to more than tens of thousands of terabecquerels of Iodine-131). Such a release would result in the possibility of acute health effects; delayed health effects over a wide area, possibly involving more than one country; long term environmental consequences. Only one INES level 7 event has occurred; the 1986 accident at Chernobyl nuclear power plant in the Soviet Union (in the area of the present Ukraine). A reactor was destroyed in an explosion, followed by a fire in the graphite used as a moderator in the reactor. This caused a large release of radioactive material to the environment. Several workers of the power plant and people taking part in the cleaning died of the injuries from the accident or of the immediate health effects caused by radiation. An exclusion zone area of 30 km was ordered around the reactor and about 135 000 people were evacuated.

A very high number of individual accident scenarios at a NPP can be derived from combinations of event categories, plant operational states, applicable acceptance criteria, etc. Even for Safety Analysis Report the complete analysis of all the resultant scenarios is not practicable. Therefore, only typical accidents (criticality accident, loss of coolant accident, fuel handling accidents, etc.) of NPPs are considered in the environmental impact assessment. Since anticipated operational occurrences have no significant impacts on personnel and no impact on the environment they are not considered in the EIA.

10.2.4 Risk identification and analysis

The results of risk analysis are presented in Table 10.2-3. Table structure and content follow recommendations of normative document "Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity" (*Information Publications, 2002, No. 61-297*). Requirements for classification of consequences of potential accident (for life, environment and property), accident development speed and probability of accident occurring are explained below. More detailed explanations can be found in “Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity” (*Information Publications, 2002, No. 61-297*).

Classification of consequences for life and health (L)

ID	Class	Characteristic
1	Unimportant	Temporary slight discomfort
2	Limited	A few injuries, long lasting discomfort
3	Serious	A few serious injuries, serious discomfort
4	Very serious	A few (more than 5) deaths, several or several tens of serious injuries, up to 500 evacuated
5	Catastrophic	Several deaths, hundreds of serious injuries, more than 500 evacuated

Classification of consequences for the environment (E)

ID	Class	Characteristic
1	Unimportant	No contamination, localized effects
2	Limited	Minor contamination, localized effects
3	Serious	Minor contamination, widespread effects
4	Very serious	Heavy contamination, localized effects
5	Catastrophic	Very heavy contamination, widespread effects

Classification of consequences for property (P)

ID	Class	Total cost damage, thousands Lt
1	Unimportant	Less than 100
2	Limited	100 - 200
3	Serious	200 - 1000
4	Very serious	1000 - 5000
5	Catastrophic	More than 5000

Classification of accident development speed (S)

ID	Class	Characteristic
1	Early and clear warning	Localized effects, no damage
2	Medium	Some spreading, small damage
3	No warning	Hidden until the effects are fully developed, immediate effects (explosion)

Classification of accident probability (Pb)

ID	Class	Frequency (rough estimation)
1	Improbable	Less than once every 1000 years
2	Hardly probable	Once every 100 – 1000 years
3	Quite probable	Once every 10 – 100 years
4	Probable	Once every 1 – 10 years
5	Very probable	More than once per year

Prioritization of consequences (Pr)

ID	Characteristic of consequences
A	Unimportant
B	Limited
C	Serious
D	Very serious
E	Catastrophic

L - Life S - Speed
E - Environment Pb - Probability
P - Property Pr - Priority

Table 10.2-3. Risk analysis of potential accidents resulting from proposed economic activity.

Object	Operation	Hazard	Risk	Threatened object	Consequences	Seriousness				Risk level		Preventive measures	Remarks
						L	E	P	S	Pb	Pr		
NPP	Electricity production; SNF and radwaste storage	Impact on constructions	External natural events (Design basis events)	Property	Loads and impacts on NPP operation due to earthquake, flooding; extremes of temperature; winds and whirlwinds; rain; snow; lightning; etc.	-	-	1	1	**5**	**A**	Load combinations for external natural events are considered in the NPP design and construction, safety systems are design against these external natural loads and impacts	The level of water in Lake Druksiai is regulated by a hydrotechnical construction (see Section 7.1.1). If this regulating construction is destroyed by external events, water level decreases to 139.1 m. The water level decrease process will be rather long. The bottom of the present cooling water inlet channel is at 135 m level. Therefore, cooling of NPP will not be lost completely and immediately.
NPP	Electricity production; SNF and radwaste storage	Impact on constructions	External human induced events (Design basis events)	Property	Loads and impacts on NPP operation explosion wave and missiles; external fire; electromagnetic interference; etc.	-	-	1	1	**2**	**A**	External human induced events are considered in the design of NPP. Appropriate design standards and materials are used.	
			Aircraft crash; terrorist attack (Beyond design basis events)	Operating personnel, population, property	These extreme events can cause damages of NPP construction and releases of radioactivity are possible.	3	2	2	3	**1**	**C**	It is expected that all NNPP will demonstrate a full capability to withstand the effect of aircraft crash and other terrorist threats to the integrity of the	

Object	Operation	Hazard	Risk	Threatened object	Consequences	Seriousness				Risk level		Preventive measures	Remarks
						L	E	P	S	Pb	Pr		
												structures. Appropriate physical protective measures.	
NPP	Electricity production	Radiation exposure	Loss of reactivity control (DBA)	Operating personnel, population, property	Loss of reactivity control could lead to excessive heat production in the nuclear fuel and to potential damage to the barriers against radioactive releases. High radiation fields from direct neutron and gamma radiation leading to potentially high radiation exposure to personnel; exposure of population due to releases; pause in operation	2	2	1	1	**2**	**B**	The reactivity control systems are designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of reactivity accidents can neither result in damage to the reactor coolant pressure boundary nor sufficiently disturb the core, its support structures, or other reactor pressure vessel internals to impair significantly the capability to cool the core.	
NNP	Fuel Transfer	Radiation exposure	Criticality accident (DBA)	Operating personnel, population, property	High radiation fields from direct neutron and gamma radiation leading to potentially high radiation exposure to personnel; exposure of population due to releases; pause in operation	1	2	1	2	**1**	**B**	Occurrence of accident and consequences are limited by design and operational procedures.	The main hazard is to personnel. A second consequence might be off-site release of short lived radioactive fission products and potentially contamination within the facility. In most cases off-site and on-site impact is limited to INES level 4.
NNP	Fuel Transfer	Radiation exposure	Fuel Handling Accident (DBA)	Operating personnel	Accident can occur as a result of a failure of the fuel assembly lifting mechanism, resulting in dropping a raised fuel assembly onto the	1	1	-	1	**3**	**A**	According to operating procedures in case of such accident ventilation system shall be shut down and the	Events during the handling of fresh fuel typically are rated at INES level 0 if there has been no risk of damaging spent fuel elements

Object	Operation	Hazard	Risk	Threatened object	Consequences	Seriousness				Risk level		Preventive measures	Remarks
						L	E	P	S	Pb	Pr		
					reactor core or into the SNF storage pool. Radiation exposure to personnel; pause in operation							fuel-handling area of the Reactor Building or Fuel Building isolated. Depending on the NPP configuration, containment will also provide a safety layer in most cases.	The radioactive inventory of single irradiated FA is much lower than the inventory of the spent fuel pool or the reactor core. As long as the cooling of the spent FA is assured, this provides an important safety layer since the integrity of the fuel matrix is not affected by overheating. In general there will be very long time-scales associated with fuel overheating. Events which do not affect the cooling of the spent FA element and only result in a minor release or no release typically ate be classified at INES level 0. Level 2 may be appropriate for events in which there is damage to the fuel cladding integrity as a result of substantial heat up of the fuel element.
NPP	SNF storage	Radiation exposure	Failure in SNF storage pool cooling (DBA)	Operating personnel	Decay heat removal from spent FAs can be disturbed and damages to fuel cladding are possible. Releases into storage pool water and in space of SNF storage pools hall	1	1	-	2	**3**	**A**	Because of the large water volume and the relatively low decay heat, there is usually plenty of time available for corrective actions to be taken for events involving degradation of spent fuel pool cooling. Also the leakage from the pool is limited by design.	Minor leakages from SNF pool are typically rated at INES level 0. Operation outside operating limits and conditions or a substantial increase in temperature or decrease of the spent fuel pool coolant level is rated at INES level 1. An indication of INES level 2 is the start of fuel element uncovering.
NPP	Electricity production;	Fire	Internal fire	Property	Ignition of combustible materials. Pause in operation	-	-	1	3	**4**	**A**	Appropriate fire prevention and fire	

Object	Operation	Hazard	Risk	Threatened object	Consequences	Seriousness				Risk level		Preventive measures	Remarks
						L	E	P	S	Pb	Pr		
	SNF and radwaste storage		(DBA)									suppression measures	
NPP	Mainte-nance/ Deconta-mination	Chemical hazard	Chemical accident	Operating personnel	Spread of harmful or potentially harmful chemicals.	1	-	-	2	**3**	**A**	Design, construction and operation of discharge equipment, storage and transport pipelines. Automatic alarms and supervision instructions to ensure that no uncontrolled or undetected leaks may arise.	Most of the chemicals stored at NPP are used in auxiliary processes such as the processing of water. Chemicals are also used for purposes such as the decontamination of primary circuit equipment and pipelines.
NPP	Electricity production	Radiation exposure	Loss-of-Coolant Accident Inside Containment (DBA)	Operating personnel, population, property	Piping break inside containment resulting the loss of coolant from reactor coolant system; the cooling capability for the reactor core is reduced. Significant number of fuel claddings can be damaged. Releases into containment.	2	2	1	1	**2**	**B**	The piping is of high quality, designed to nuclear construction industry codes and standards, and for seismic and environmental conditions. Also design of the containment assures integrity and design limits of releases in case of this accidents	LOCA is not expected to occur during the life of the plant, but postulated as a conservative design basis accident.
NPP	Electricity production	Radiation exposure	Main Steam line or Feedwater line Break Accident Outside Containment (DBA)	Operating personnel, population.	A large steam or feedwater line pipe breaks outside containment. Activity released from the broken line is released directly to the environment. There is no fuel damage as a result of this accident.	1	2	-	2	**2**	**A**	The piping is of high quality, designed to nuclear construction industry codes and standards, and for seismic and environmental conditions.	
NPP	Electricity	Radiation	Core damage	Operating	Large release into	3	4	4	1	**1**	**D**	Multiple safety	Core damage will require the

Object	Operation	Hazard	Risk	Threatened object	Consequences	Seriousness				Risk level		Preventive measures	Remarks
						L	E	P	S	Pb	Pr		
	production	exposure	(BDBA)	personnel, population, property	containment. Containment isolation prevents or mitigates releases.							systems to prevent the core damage. Containment assures that there is no large release into environment.	simultaneous failure of multiple safety systems and several incorrect actions from the operating personnel. Core damage frequency is less than 10^{-4} per year and the large release frequency is less than the 10^{-6} per year
NPP	Electricity production	Radiation exposure	Containment failure (Severe Accident)	Operating personnel, population, property	Large release of fission products into environment.	5	5	5	1	**1**	**E**	Multiple safety systems to prevent the containment failure. A fundamental objective is to prevent, as far as possible, all Severe Accidents which might challenge and lead to early failure of the Primary Containment.	The more likely severe accident sequences do not result in containment failure for 72 hours or more. The low frequency severe accident sequences do not result in containment failure in less than 24 hours.

10.3 ACCIDENT CONSEQUENCES ESTIMATION

10.3.1 Source Term Definition for Accident Releases

Accident releases from the new nuclear power plant (NNPP) have been considered for two cases:

- Design basis accident (DBA)
- Severe accident

Lithuanian legislation does not provide specific guidance or requirements on how impact on the environment shall be evaluated in case of DBAs or Severe Accidents. Therefore, experience of foreign countries has been used and the following documents have been considered:

- Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.183, 2000;
- Accident Source Terms for Light-Water Nuclear Power Plants, NUREG-1465, 1995;
- Decision 395/91 of the Council of State on the general regulations for the safety of nuclear power plants, Finland 1991;
- Accident analysis for nuclear power plants. IAEA Safety Reports Series No. 23, 2002.
- The International Nuclear Event Scale (INES). Jointly prepared by IAEA and OECD/NEA. 2001.

There are different DBAs (criticality accident, fuel handling accident, fire, etc.) at NPPs, however for EIA it is important to identify the typical accident which envelopes consequences of all DBAs. According to RG 1.183, such enveloping design basis accident is loss-of-coolant accident LOCA with intact containment (i.e. containment leakage limited to design basis leakage).

Regulations of Finnish Decision 395/91 have been used for estimation of the source term to represent severe accident releases.

Different technological alternatives (reactor types) are considered as options for the new NPP in Lithuania. The activity of released radionuclides depends on reactor type, therefore based on freely available information comparison of activity released from different reactor types in case of accidents was done. The technological alternatives (reactor types) which are considered as options for new NPP in Lithuania are described in Chapter 5.

Two freely available information sources were used for estimation of accident releases:

- Website of U.S. Nuclear Regulation Commission (ABWR; AP1000; ESBWR; U.S. EPR; US-APWR)
- Website of Health and Safety Executive (HSE) (ACR-1000; UK EPR; ESBWR; AP1000).

Information about some reactors (V-392, V-448, SWR-1000, etc.) is not freely available. However, analysis of freely available information on accident releases from different power reactors has showed that activity of released radionuclides depends on reactor power. Therefore, the impact to environment from the most powerful reactors such as ESBWR, EPR and APWR should be considered as the basis of a bounding estimate of source term and potential consequences.

Also it should be noted, that freely available information for some reactors is very comprehensive (all assumptions, initial data, intermediate results and final results are provided) and for some only initial data and resulting radiological consequences are presented.

The set of isotopes, which have been taken into account for estimation of releases in case of DBA and Severe accident, is based on International Nuclear Event Scale (*IAEA and OECD/NEA, 2001*).

Loss of Coolant Accident (LOCA)

ABWR (*DCD US-ABWR, 2008*), APWR (*DCD US-APWR, 2007*) and ESBWR (*DCD US-ESBWR, 2007*) data was examined as basis for source term, since characteristics (power densities, fuel discharge irradiation, enrichment) for these reactors are provided in detail and this will tend to maximise the build up of short and long lived fission products important in the determination of consequences. Analysis of the activities of released isotopes presented in (*DCD US-ABWR, 2008*), (*DCD US-APWR, 2007*), (*DCD US-ESBWR, 2007*) has led to the conclusion that the releases to the environment from APWR in case of LOCA should be considered as bounding case.

Time dependent releases into environment in case of LOCA at APWR are summarized in Table 10.3-1. As it was mentioned above, the list of isotopes is based on INES manual (*IAEA and OECD/NEA, 2001*). According to RG 1.183 in case of LOCA radioactivity release duration 30 days (720 hours) shall be assumed.

This release in case of LOCA can be rated as INES Level 5 event.

Table 10.3-1. Time Dependent Released Activity into Environment during LOCA (Bq) (*DCD US-APWR, 2007*).

Nuclide	0-8hr	8-24hr	24-96hr	96-720hr	TOTAL
Kr-85 (eq for NG)	3.44E+16	1.71E+16	1.13E+16	2.04E+16	8.32E+16
I-131	5.25E+13	2.08E+13	6.85E+13	2.07E+14	3.49E+14
Cs-134	5.33E+12	5.99E+10	0.00E+00	0.00E+00	5.40E+12
Cs-137	3.03E+12	3.41E+10	3.70E+07	0.00E+00	3.06E+12
Te-132	5.22E+12	6.33E+10	3.70E+06	0.00E+00	5.29E+12
Sr-90	1.45E+11	1.89E+09	0.00E+00	0.00E+00	1.47E+11
Co-60	5.88E+08	7.40E+06	3.74E+04	0.00E+00	5.96E+08
Ru-106	9.88E+10	1.28E+09	0.00E+00	0.00E+00	9.99E+10
Am-241	2.78E+06	3.61E+04	0.00E+00	0.00E+00	2.81E+06
Pu-239	1.48E+07	1.92E+05	0.00E+00	0.00E+00	1.50E+07

Severe Accident

As it was mentioned in Section 10.2.1 there are no regulations for releases in case of severe accident in Lithuanian legislation. Therefore the limit for the release of radioactive materials arising from a severe accident (100 TBq release of Cs-137) defined in Finnish legislation (*Council State decision 395/91*) is used to represent a typical large release scenario to indicate the potential scale of consequences for such events, and inform the extent of emergency planning provisions that might be implemented should construction and operation of a new NPP proceed.

Since the APWR reactor is used for LOCA accident, this type of reactor is also selected for severe accident impact estimation.

Only a limitation for Cs-137 is defined in (*Council State decision 395/91*); however the release of other isotopes must be taken into account also. The source term for release into the environment is estimated based on a 100 TBq release of Cs-137. The releases of other isotopes are scaled according to APWR core inventory at time of the release. Core inventory of APWR is provided in (*DCD US-APWR, 2007*).

According to probabilistic risk assessment and severe accident evaluation of APWR (such assessment has been done by the reactor supplier and is presented in DCD for US-APWR) containment integrity is maintained more than 24 hours after onset of core damage. The time period of 24 hours is a goal for containment performance defined in US NRC regulations and also in European Utility Requirements (*EUR 2001*), which includes a deterministic goal that containment integrity shall be maintained for approximately 24 hours following the onset of core damage and a probabilistic goal that the conditional containment failure probability shall be less than approximately 0.1 for the composite of core damage sequences assessed in the probabilistic risk assessment. Therefore, 24 hours delay before the release into the environment is assumed for source term calculations.

Releases into the environment in case of severe accident are summarized in Table 10.3-2. The source term for the release is normalized for Cs-137 100 TBq release. The activities of other released isotopes are scaled according to core inventory after 24 h and "Accident Source Terms for Light-Water Nuclear Power Plants" (*NUREG-1465, 1995*). The core inventory is used for definition of ratios between the different nuclides. Release fractions into containment for various radionuclides are basically in accordance with (*NUREG-1465, 1995*). An exception is the release fraction for Cs, which is assumed to be 0.50 (0.75 is provided in (*NUREG-1465, 1995*)). Since the release is normalized to 100 TBq Cs-137, a higher release fraction of Cs-137 into containment will underestimate activities of other isotopes. Also different countries assume different release fractions into containment. "A Comparison of World-Wide Uses of Severe Reactor Accident Source Terms" (*SAND94, 1994*) gives an overview on how source term for severe accident is defined in various counties.

A release height of 100 m is assumed. Such height is conservative for the nearby range, as there is no population living in the sanitary protection zone (1-3 km). For the assessment of consequences the maximum should fall within a populated area. Release duration is 6 hours.

This severe accident release can be rated as INES Level 6 event.

Table 10.3-2. Releases into the environment in case of Severe Accident (Bq).

	Core Inventory		Release fraction into containment	Releases into Environment after	Eq. I-131
	0 h	24 h		24 h	
Kr-85m	1.79E+18	4.41E+16	1.00	1.24E+13	0.00E+00
Kr-85	6.40E+16	6.40E+16	1.00	1.79E+13	0.00E+00
Kr-87	3.55E+18	7.49E+12	1.00	2.10E+09	0.00E+00
Kr-88	5.00E+18	1.43E+16	1.00	4.00E+12	0.00E+00
Xe-133	1.11E+19	1.07E+19	1.00	2.99E+15	0.00E+00
Xe-135	3.38E+18	4.23E+18	1.00	1.19E+15	0.00E+00
I-131	5.33E+18	4.97E+18	0.75	1.04E+15	1.04E+15
Te-132	7.59E+18	6.13E+18	0.50	8.59E+14	2.58E+14
Sr-90	5.14E+17	5.14E+17	0.05	7.20E+12	7.20E+13
Cs-134	1.25E+18	1.25E+18	0.50	1.76E+14	3.51E+15
Cs-137	7.14E+17	7.14E+17	0.50	1.00E+14	3.00E+15
Pu-239	2.09E+15	2.09E+15	0.001	5.84E+08	5.84E+12
Co-60	1.61E+16	1.61E+16	0.05	2.25E+11	1.35E+13
Ru-106	2.79E+18	2.78E+18	0.05	3.89E+13	2.73E+14
Am-241	9.77E+14	9.81E+14	0.003	8.24E+08	7.42E+12
					8.18E+15

10.3.2 Dispersion and uptake of radionuclides

10.3.2.1 Methodology

The dispersion simulations for the two accident scenarios were made with Air Quality and Emergency Modelling System SILAM of the Finnish Meteorological Institute (FMI) (http://silam.fmi.fi). The SILAM system is a dual-core Lagrangian-Eulerian modelling framework, which was developed by FMI in co-operation with several other institutes from different countries for solving a wide range of emergency, air quality and regulatory problems. Following the standards of the emergency modelling, SILAM evaluates concentrations and depositions of each released nuclide and its derivatives along the decay chain.

The dispersion model was run with meteorological data obtained from the European Center for Medium Range Weather Forecasts (ECMWF) Operational Data Archives. The data covers two consecutive years 2001 and 2002, which were chosen because meteorologically these years represent typical years in Europe.

The assessment of doses from an accidental radioactive release from the NNPP is based on the results of dispersion simulations and it utilizes empirical coefficients and methodologies for converting the modelled concentrations in air and depositions to doses. The specific formulations and all numerical constants used for the dose assessment computations are defined in a separate report (*FMI 2008*).

Comparison with other methodologies

An approach widely used in past similar assessments of dispersion is based on simulations with simple Gaussian plume model using artificial conditions seen as the “worst-case dispersion scenario”. The outcome of the Gaussian simulations is equilibrium concentrations and deposition fluxes considered as the upper-limit estimates of the accident impact. Providing reasonable results in the nearest vicinity of the plant, Gaussian models ignore the real pattern of dispersion – with wind meandering, actual developments of vertical and horizontal mixing along the day etc. They do not indicate the probability of observation of the simulated pattern in reality. The results are obtained without information on how realistic they are and how often such dispersion conditions take place in the specific geographical region.

The approach applied in this current work is based on brute-force multi-scale computations of dispersion using actual meteorological data from weather archives. The 3-D modelling system used in this assessment is built to solve the turbulent dispersion equation taking into account the variability of the meteorological conditions and the inhomogeneity of the turbulent diffusion coefficient in space or time. This approach allows replacing the artificial "worst case" with physically and statistically grounded characteristics. Having the simulations made over a sufficiently long period, the percentiles of concentrations and depositions can be calculated in a straightforward way. This methodology is very expensive computationally but it is also the most universal: it is applicable at any scale and for any type of source.

10.3.2.2 Results of the dispersion modelling and dose estimates

The exposure of the environment and people depends on the specific meteorological conditions during the accident and the geographical location of the receiving point. To cover all realistic meteorological conditions several cases in different meteorological conditions during the years 2001 and 2002 have been simulated. 2-dimensional maps have been created of the exposure levels, which are not exceeded with a certain probability for any realistic meteorological conditions.

The dispersion has been simulated for an area of about 1200 km wide (computation domain), which is extensive enough for the purpose of the assessment. For the loss of coolant accident (LOCA) and severe accident (SA) release scenarios, the simulation of a particular case lasts until the pollutants released during the accident leave the computation domain. An estimate of the time needed is: $t = X_s / 30$, where X_s is the domain size in km, and 30 km/h is a typical wind speed at the top of the boundary layer. Hence, for a domain of about 1200 km in horizontal size the transport time of nuclides outside the area is about 40 hours.

Using the above screening formula, simulation duration for a single case was taken as 32 days for LOCA scenario and 2 days for SA. The model starts computations of a case at the beginning of each day during the whole period selected for the assessment (2 years 2001 and 2002). Due to the short duration of the release for SA, two sets of cases had to be analysed: day-time release and night-time release. Daytime and night-time releases appear under strongly different atmospheric conditions and this is why it is reasonable to assess these two sets of cases independently.

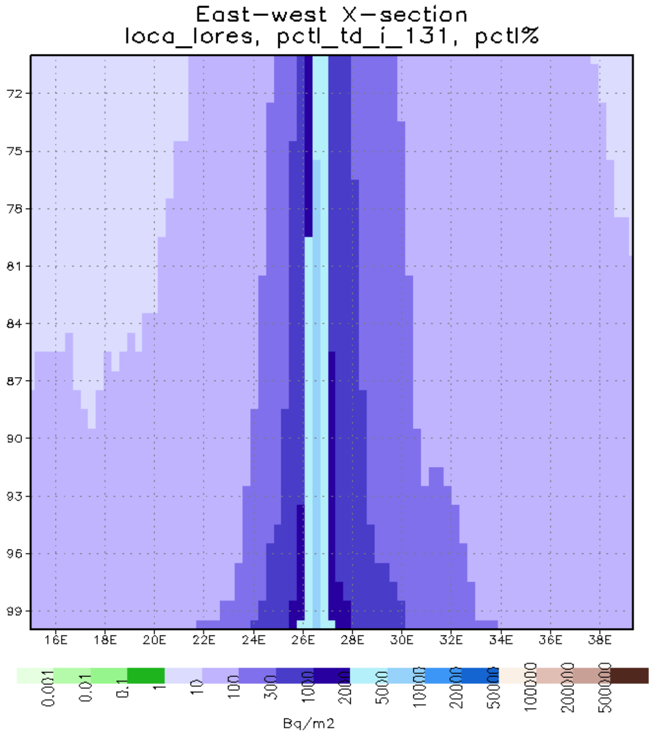
Each of the 3 cases (LOCA, SA-day, SA-night) have been analysed with two spatial resolutions to account for both regional and local effects. A resolution of 20 km is used for long-range transport and a resolution of 2 km for near-range transport.

The assessment was performed on the basis of 98 % of depositions and doses. This means that, in case of an accident, the presented values can be exceeded in some places only with the probability of 2 %. Thus, if 98-th percentile of deposition at some place for the LOCA scenario is equal to 100 Bq/m^2, it means that if a LOCA accident happens, the probability for this place to be affected by concentrations higher than 100 Bq/m^2 is 2 %. Importantly, the information is place-specific, i.e. the assessment results in geographical maps of the percentiles.

The following figures (Figure 10.3-1) illustrate the dependence of the deposition values on distance from the NNPP and on percentile. The X-axis represents the longitude for

East-West cross-section and latitude for North-South cross-section. The Y-axis represents the percentile – the range shown is from 70 % to 100 % (max value), with 100 % at the bottom. Because of the anisotropy of wind directions both latitudinal and longitudinal cross-sections are provided. For example, directly to the east from the NNPP on the meridian of 20^0E, the deposition in case of a LOCA accident is maximum 10 Bq/m^2 with the probability of about 83 %. The results of this study for the deposition of I-131 in case of LOCA accident are the geographical regions corresponding to the 98-th percentiles in these cross-sections. Similarly, the dose values also depend on the distance from the NNPP and the percentile.

As expected, the area with higher concentrations is larger for the higher percentile. This increase is observed (but not necessarily uniformly) over the whole grid: at every point the concentration for 99 % is higher than for 98 %. The cross-section figures show significant and irregular jumps from 99 % to 100 %. The maximum values are the most sensitive among all parameters to model limitations and inaccuracies in the meteorological data – and thus the most uncertain. This is why it is reasonable not to use the maximum percentiles as the basis for the assessment.



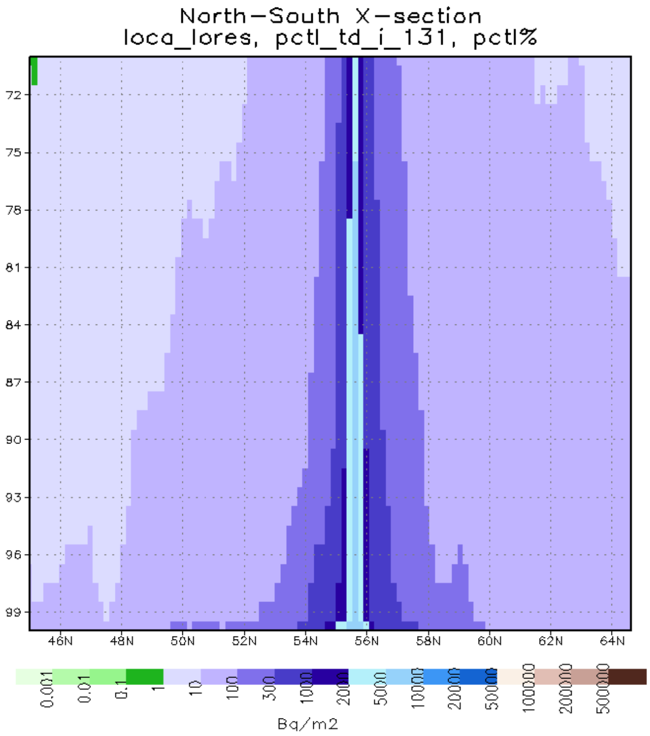


Figure 10.3-1. Loss of coolant accident (LOCA), deposition of Iodine-131 in Bq/m^2 in the large domain with 20 km resolution; upper map: east-west cross-section, lower map: north-south cross section.

The maps presented to describe the results have the scale in latitudinal and longitudinal degrees. The geographical location of the NNPP itself is 26.56^{0}E, 55.6044^{0}N. At this latitude one degree of distance along parallel (west-east cross-section) is equivalent to 62.8 km while one degree distance along meridian (south-north cross-section) is equivalent to 111 km.

Deposition

Cesium-137 (Cs-137) and Iodine-131 (I-131) are essential nuclides when assessing the radioactive deposition and dose after a postulated NPP accident, since they are biologically the most significant of the radionuclides released in an NPP accident. Cs-137 has a radiological half-life of 30 years. Thus once it is released into the environment, it remains present for many years. This is why it is especially important in the assessment of the long-term impacts. Compared to Cs-137, I-131 has a short radiological half-life of 8 days. I-131 can accumulate in the thyroid and harm it as it decays. The risk relates especially to children, but it can be mitigated by taking iodine supplements. In this report the deposition maps are presented for Cs-137 and I-131. The unit of radioactivity used in these maps is Becquerel [Bq].

Doses

Radioactive releases to the atmosphere may contribute to radiation exposure through several pathways either externally or internally. External exposure is due to the direct radiation from a radioactive plume or from radionuclides deposited on the ground. External dose thus includes the dose from cloud shine and the dose from ground shine. Internal exposure is due to inhalation or ingestion of radioactive material. The ingestion dose includes the intake of radioactive substances taking into account the migration of the radioactive nuclides along the food chains finally reaching the human body.

The total effective dose includes both external and internal dose. The short-term effective dose is determined by the dose from cloud and ground shine as well as inhalation dose. Long-term effective dose is mainly due to ground shine and ingestion. The unit of dose is Sievert [Sv]. In this chapter dose maps are presented for total external dose. The calculation period for the doses is 50 years.

LOSS OF COOLANT ACCIDENT

This section contains the 98-percentile maps for the depositions of I-131 and Cs-137 as well as cloud-shine and external doses resulting from the LOCA release scenario. Also the rates for ground-shine dose and external dose are presented to be compared with the criteria for protective actions (section 10.4). In the maps one degree of distance along parallel (west-east cross-section) is equivalent to 62.8 km while one degree distance along meridian (south-north cross-section) is equivalent to 111 km.

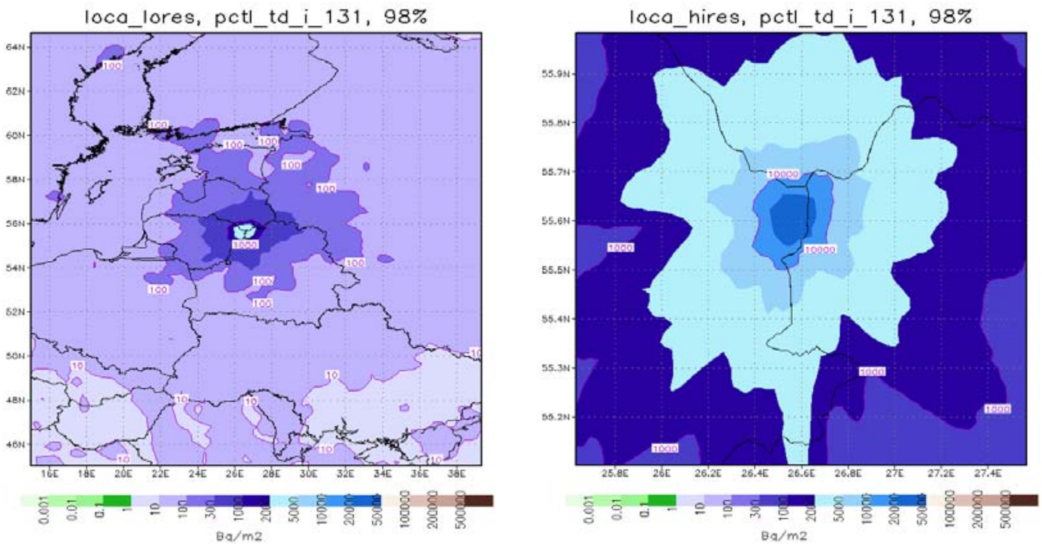


Figure 10.3-2. Loss of coolant accident (LOCA), total deposition of I-131 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

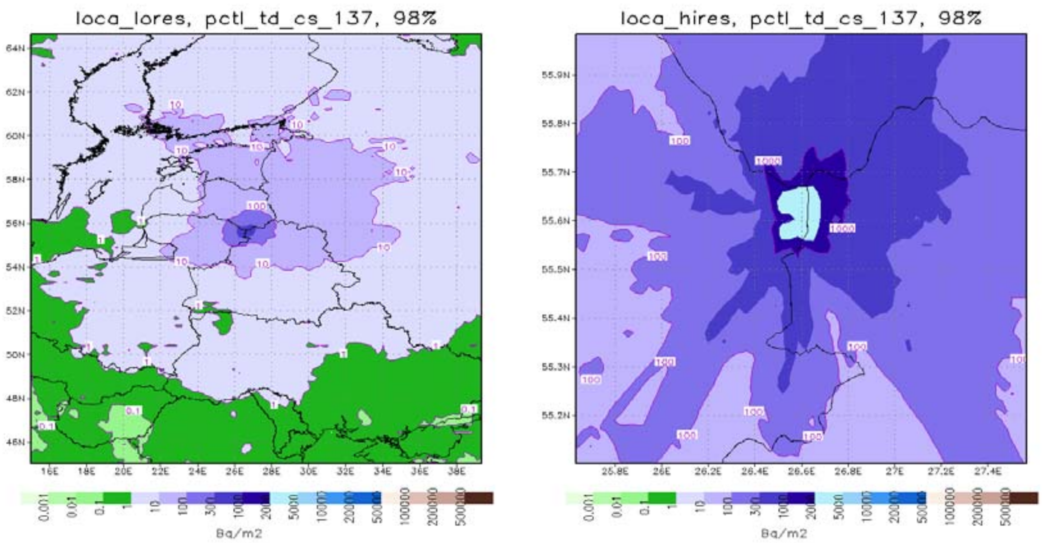


Figure 10.3-3. Loss of coolant accident (LOCA), total deposition of Cs-137 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

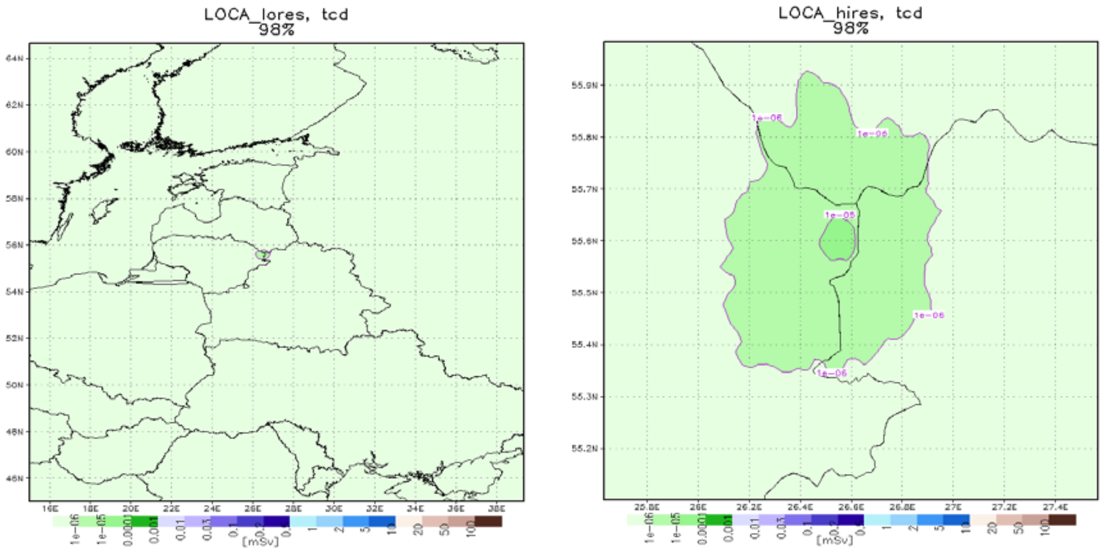


Figure 10.3-4. Loss of coolant accident (LOCA), cloud-shine dose [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

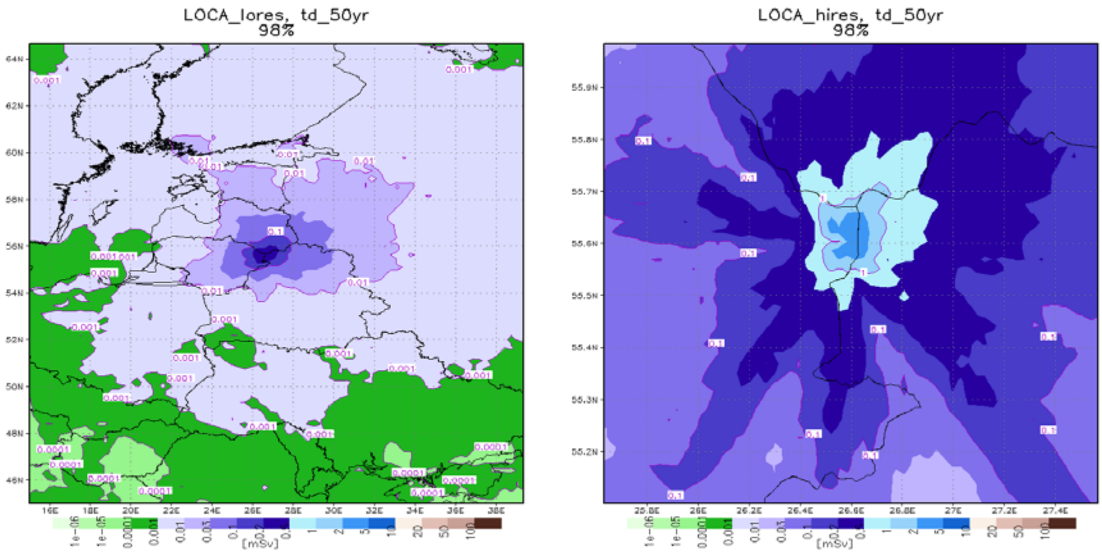


Figure 10.3-5. Loss of coolant accident (LOCA), total external dose over 50 years [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

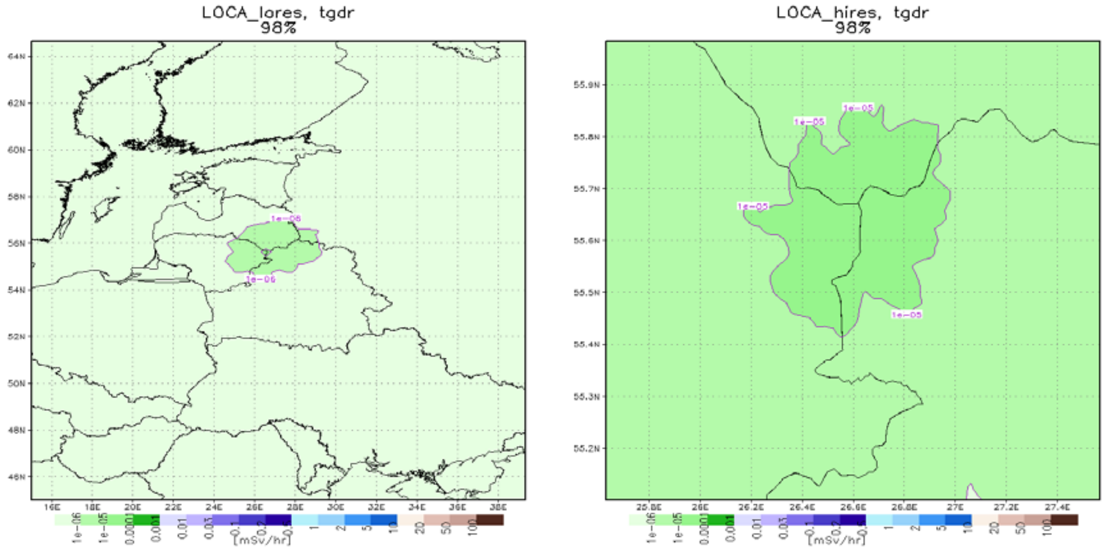


Figure 10.3-6. Loss of coolant accident (LOCA), ground-shine dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

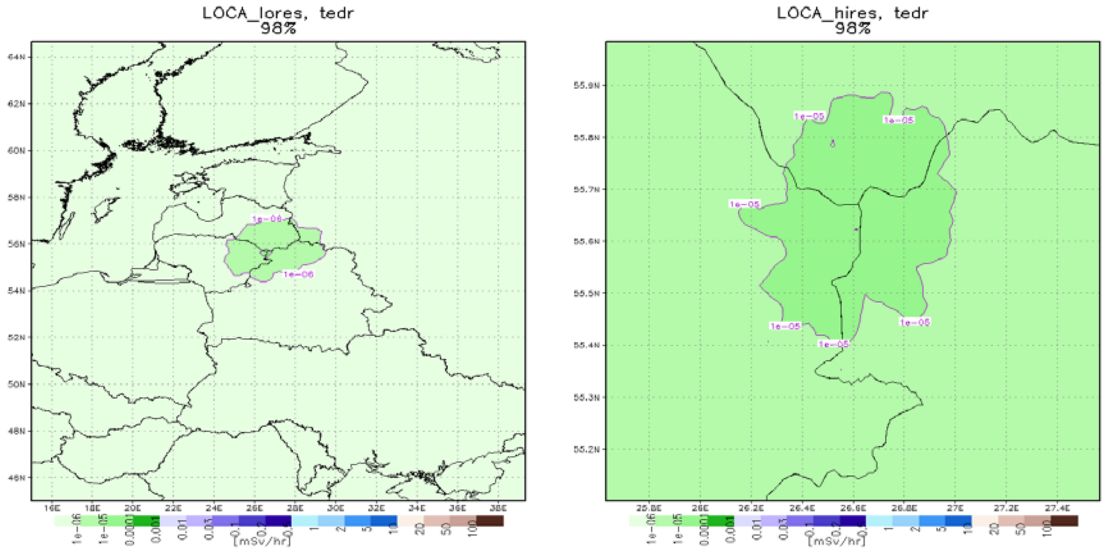


Figure 10.3-7. Loss of coolant accident (LOCA), external dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

SEVERE ACCIDENT

Severe accident, daytime release

This section contains the 98-percentile maps for the depositions of I-131 and Cs-137 as well as cloud-shine and external doses resulting from the SA, daytime release scenario. Also the rates for ground-shine dose and external dose are presented to be compared with the criteria for protective actions (section 10.4). As before, in the maps one degree of distance along parallel (west-east cross-section) is equivalent to 62.8 km while one degree distance along meridian (south-north cross-section) is equivalent to 111 km.

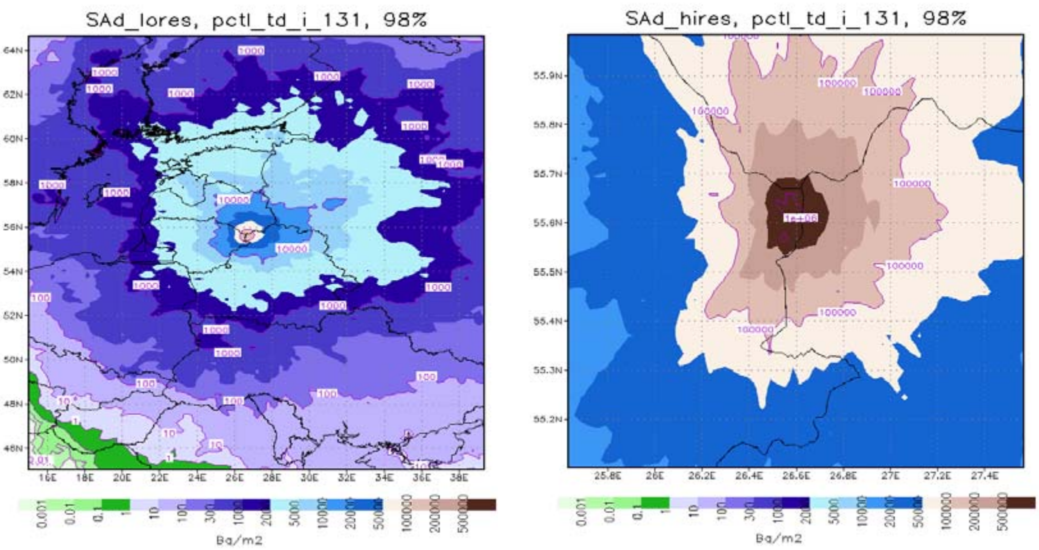


Figure 10.3-8. Severe accident, daytime release (SAd); total deposition of I-131 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

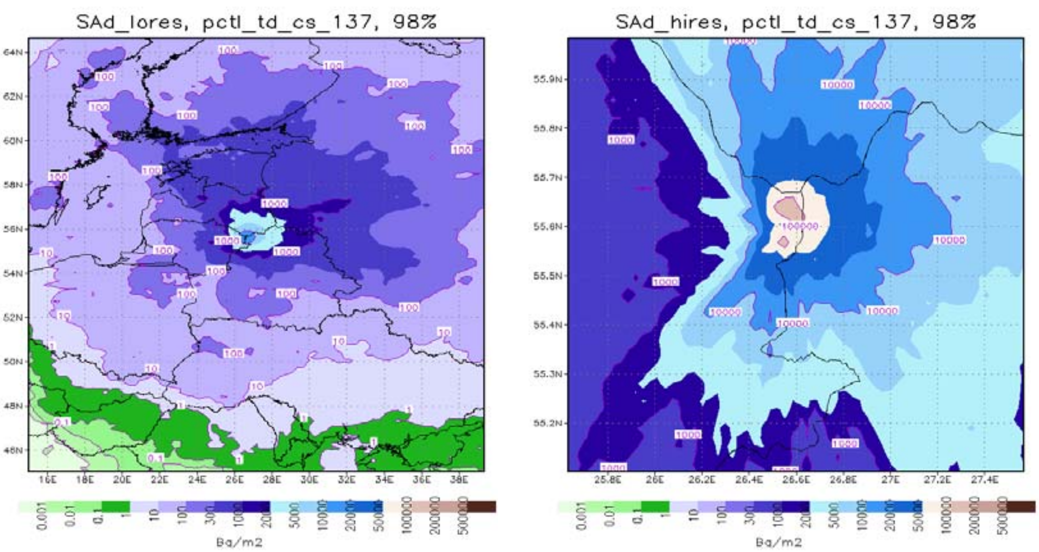


Figure 10.3-9. Severe accident, daytime release (SAd); total deposition of Cs-137 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

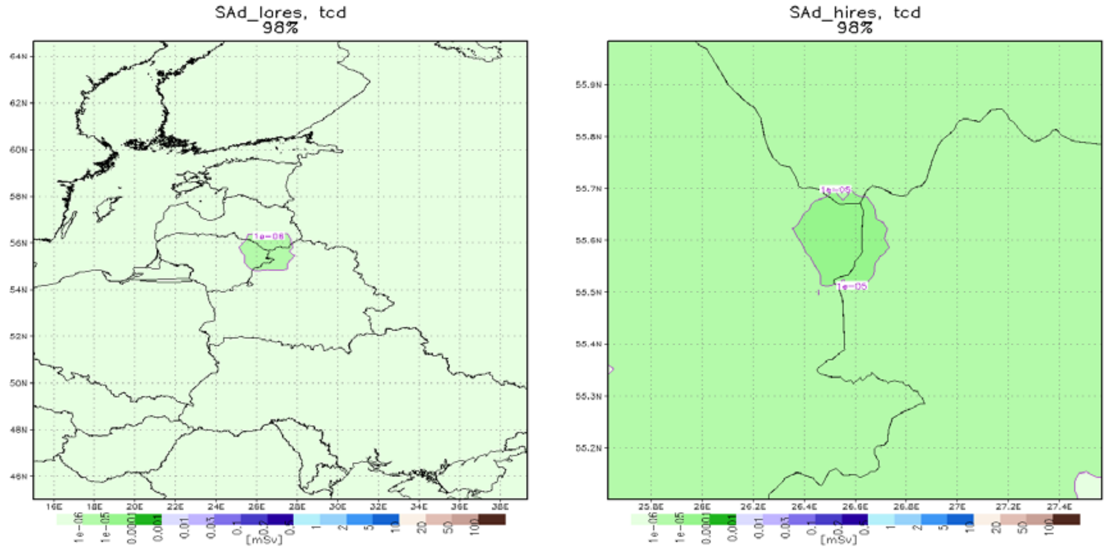


Figure 10.3-10. Severe accident, daytime release (SAd); cloud-shine dose [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

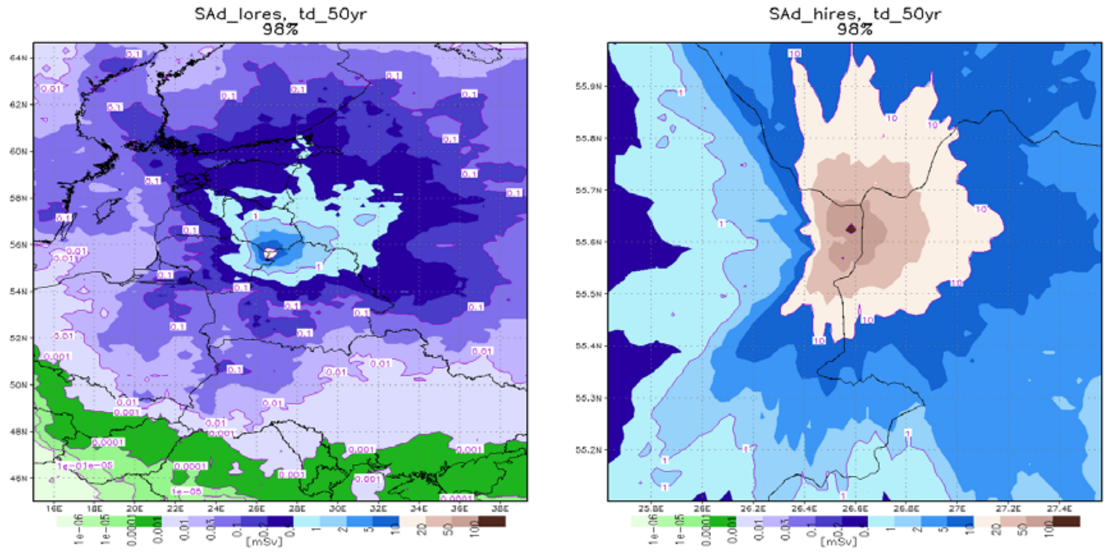


Figure 10.3-11. Severe accident, daytime release (SAd), total external dose over 50 years [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

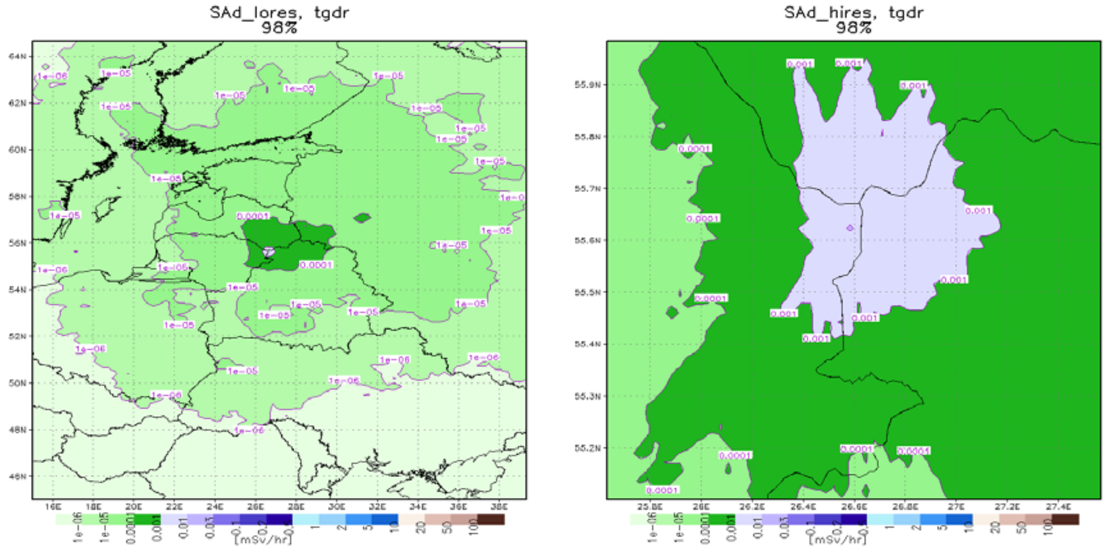


Figure 10.3-12. Severe accident, daytime release (SAd), ground-shine dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

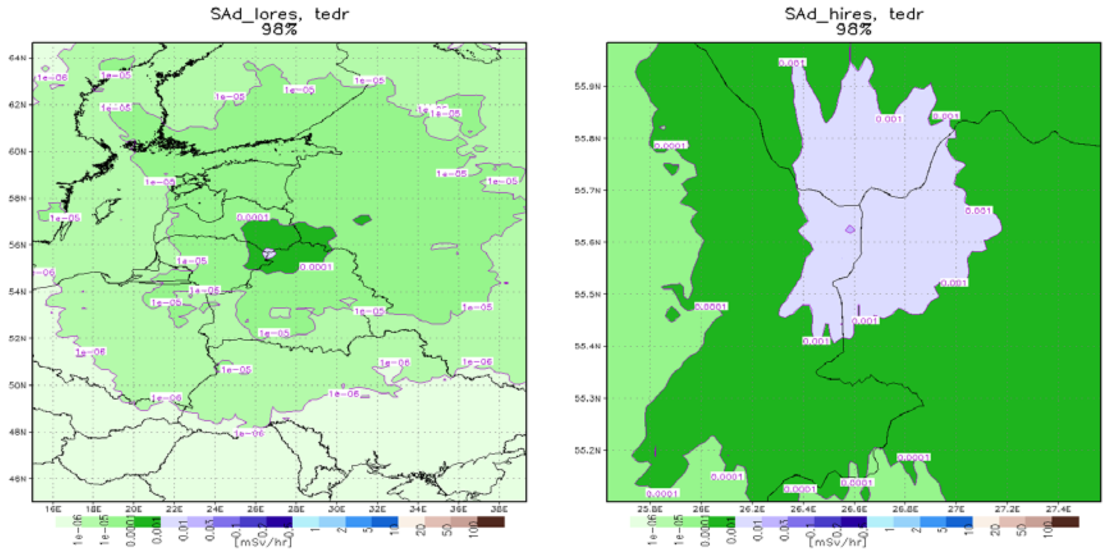


Figure 10.3-13. Severe accident, daytime release (SAd), external dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

Severe accident, night-time release

This section contains the 98-percentile maps for the depositions of I-131 and Cs-137 as well as cloud-shine and external doses resulting from the SA, night-time release scenario. Also the rates for ground-shine dose and external dose are presented to be compared with the criteria for protective actions (section 10.4). As before, in the maps one degree of distance along parallel (west-east cross-section) is equivalent to 62.8 km while one degree distance along meridian (south-north cross-section) is equivalent to 111 km.

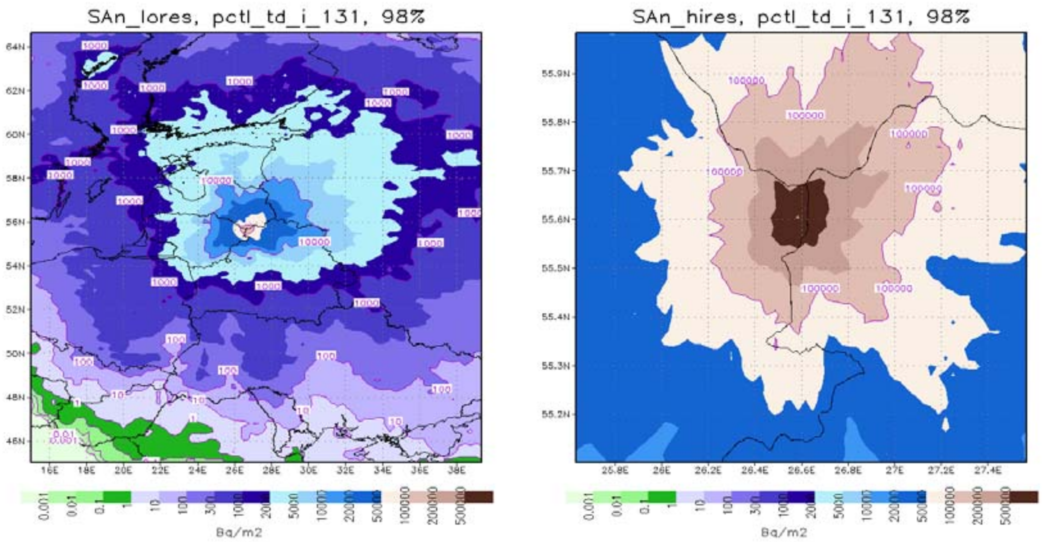


Figure 10.3-14. Severe accident, night-time release (SAn); total deposition of I-131 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

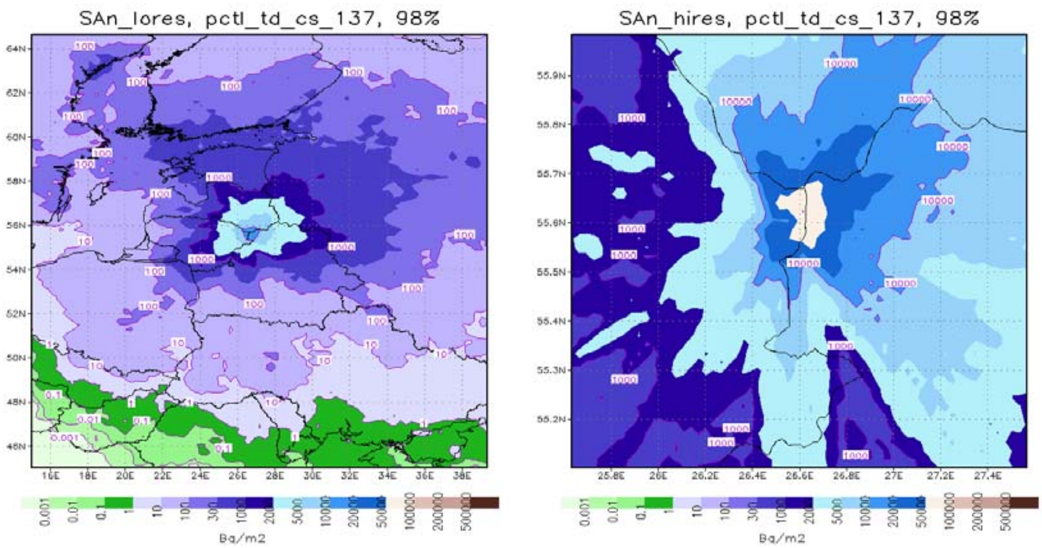


Figure 10.3-15. Severe accident, night-time release (SAn); total deposition of Cs-137 in Bq/m^2 (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

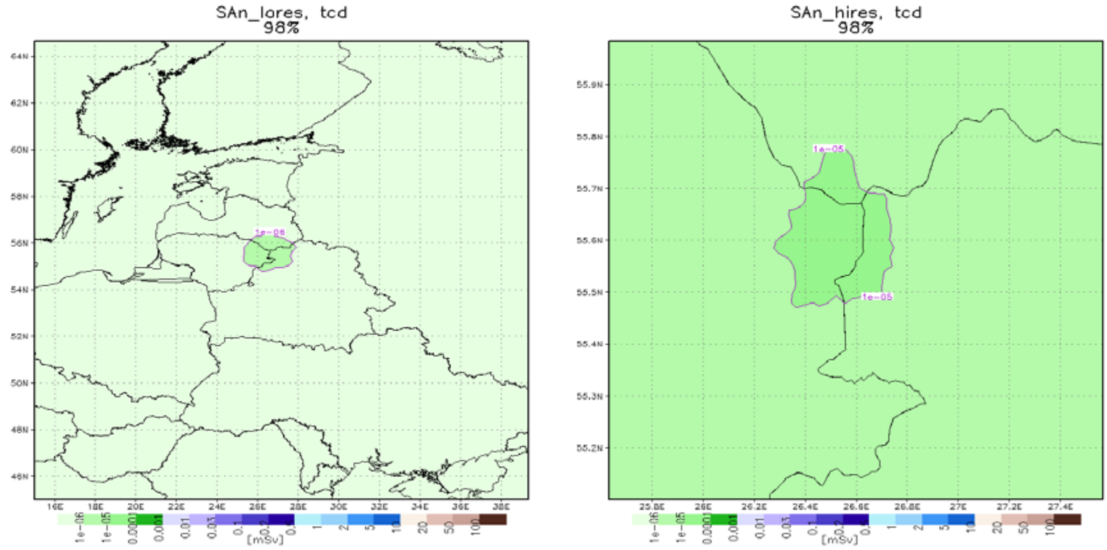


Figure 10.3-16. Severe accident, night-time release; cloud-shine dose [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

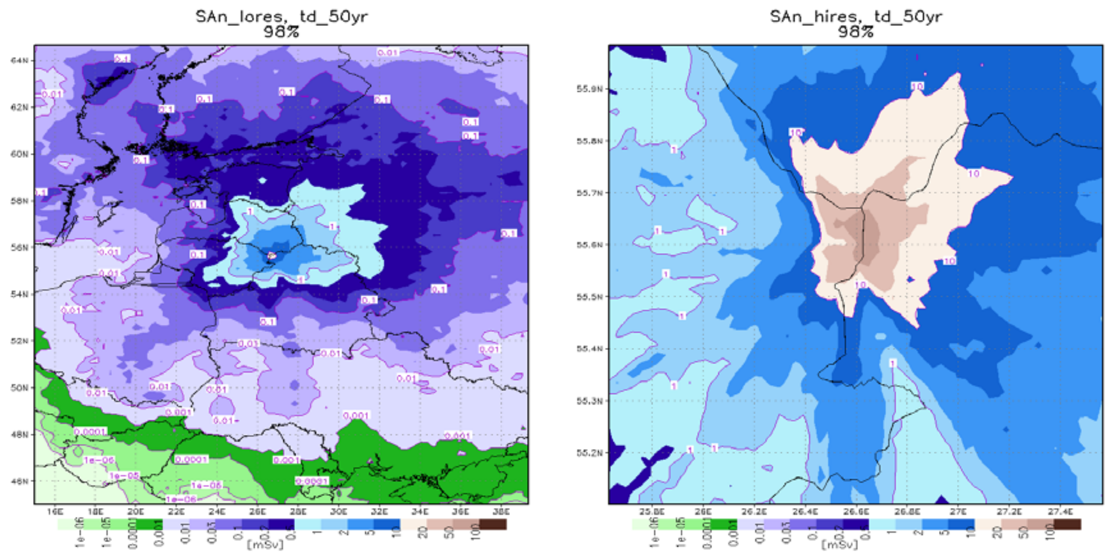


Figure 10.3-17. Severe accident, night-time release (SAn); total external dose over 50 years [mSv] (left panel: large domain with 20 km resolution; right panel: fine-grid domain, 2 km resolution).

From Figure 10.3-14, Figure 10.3-15 and Figure 10.3-17 we can see that compared with the SA daytime release the areas of depositions of I-131 and Cs-137 and total external dose due to the SA night-time release would be slightly smaller.

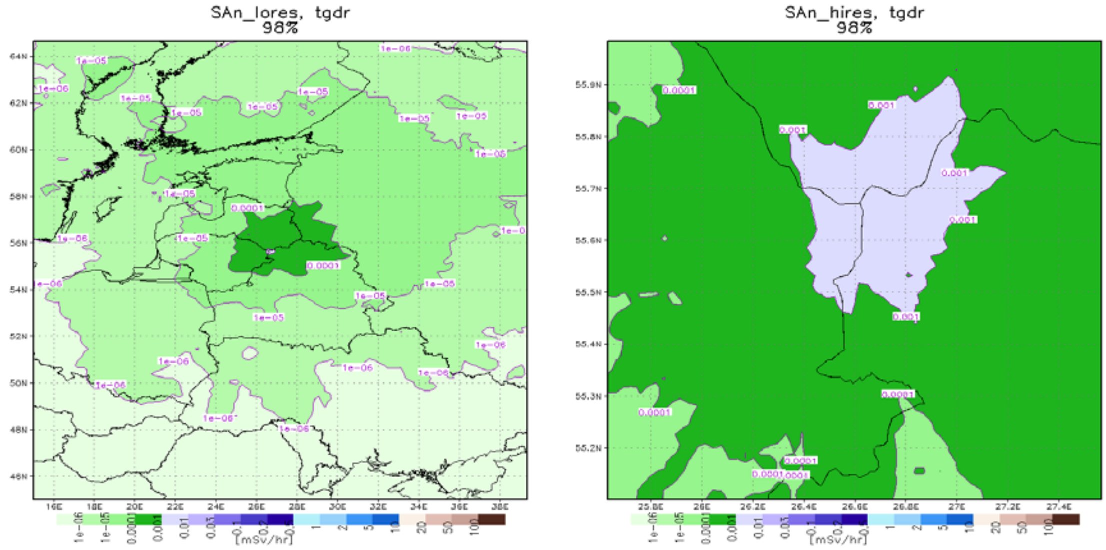


Figure 10.3-18. Severe accident, night-time release (SAn), ground-shine dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

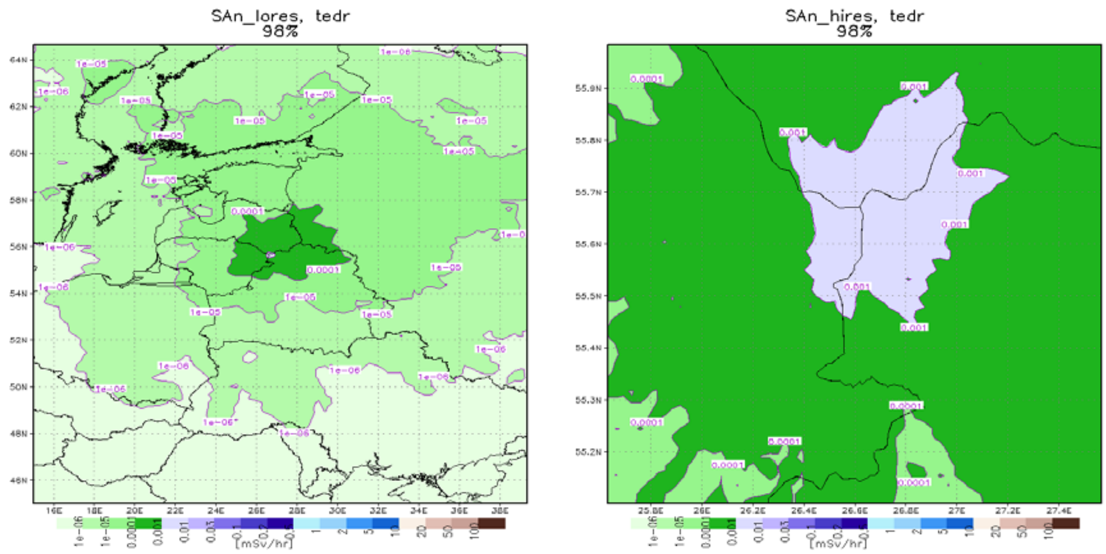


Figure 10.3-19. Severe accident, night-time release (SAn), external dose rate [mSv/hr] (left panel: large domain with 20 km resolution; right panel: fine-grid domain 2 km resolution).

10.4 ASSESSMENT OF ACCIDENT CONSEQUENCES

The accident consequence analyses for the DBA and reference SA illustrated in Section 10.3 provide a basis for accident consequence assessment in the EIA and for the description of the emergency planning. Specifically, estimates of radiation doses can be made at different distances and for individual pathways of exposure. This information can be used to determine protective actions that might need to be undertaken and the spatial scales over which those actions might need to be implemented. In particular, examination of the variability in spatial patterns of doses from realisation to realisation yields information on the extent to which responses would be affected by the meteorological conditions at the time of the accident, and scaling the results to releases of different magnitude yields information on the extent to which responses would be affected by the source-term characteristics of the accident. These issues are not addressed in detail here, as this is a matter for comprehensive safety assessment studies. Rather information is provided related to the assessment of accident consequences and the emergency actions that would be taken in response to a wide range of actions. However, indications are given in Table 10.4-3 of the protective actions that could be needed in the case of DBA and SA.

According to HN 87:2002 (*State Journal, 2003, No. 15-624; 2008, No. 35-1251*), safety of the new designed and constructed nuclear power plant shall assure that during operation or decommissioning the dose for the members of public caused by one design basis accident shall be less than the intervention level applied for protective action – sheltering, i.e. 10 mSv. As it was mentioned before, bounding design basis accident for the NNPP is LOCA. Dispersion modelling and dose estimation for the members of public have showed that total radiation dose even accumulated over 50 years is less than 10 mSv.

Requirements for protective actions of the public in case of a radiological or nuclear accident are provided in HN 99:2000 (*State Journal, 2000, No. 57-1691*). Protective actions are divided into urgent and longer term protective measures.

Urgent protective actions shall be applied in pre-release (time between the start of accident sequence having the potential for off-site consequences and the emission of radioactive material into the atmosphere; the duration may vary from about half an hour to one day or more) and in early (time of release; the release phase may last from a fraction of an hour to several days) phase of emergency. Urgent protective actions are summarized in Table 10.4-1.

Table 10.4-1. Urgent protective actions.

Protective action	Description
Sheltering	Sheltering protects population from external exposure from plume, from inhalation of radioactive aerosols (internal exposure) and from deposits of radionuclides on skin and clothes. The level of avertable dose when the sheltering should be taken is ≥ 10 mSv no longer than 2 days. Regulatory authority may wish to recommend sheltering at lower intervention levels for shorter periods or so as to facilitate further protective actions, e.g. evacuation. Sheltering is recommended in any case when general emergency is classified (before the release of radionuclides into environment), projections indicate that urgent protective actions should be taken and operational intervention levels are as follow: – ambient dose rate in the plume – (0.1 – 1) mSv/h; – ambient dose rate from deposition - ≥ 1 mSv/h;
Iodine prophylaxis	The purpose of iodine prophylaxis is to prevent exceeding of threshold dose for deterministic effects of thyroid gland (acute radiation thyroiditis, chronic lymphocytic thyroiditis and hypothyroidism) and to decrease thyroid doses as much as possible to reduce risk of thyroid cancer and benign thyroid nodules. Iodine prophylaxis is recommended in any case when one of the following Operational Intervention Level is exceeded: – ambient dose rate in the plume ≥ 0.1 mSv/h; – ambient dose rate from deposition ≥ 1 μSv/h; – ground deposition level of I-131 – ≥ 10 kBq/m^2 (restricted consumption of potentially contaminated general food); – ground deposition level of I-131 – ≥ 2 kBq/m^2 (restricted consumption of milk and drinking water); – specific concentration of I-131 of general food ≥ 1 kBq/kg (restricted consumption of potentially contaminated foods); – volumetric concentration of I-131 of milk ad drinking water ≥ 0.1 kBq/kg (restricted consumption of potentially contaminated milk and drinking water).
Evacuation	Evacuation is an urgent protective action that should be pre-planned in advance and implemented before the radioactive release into the environment has occurred. Evacuation of population from contaminated area can also be implemented in early phase of emergency after the release occurs. Evacuation is implemented with respect of these Operational Intervention Levels: – ambient dose rate in the plume ≥ 1 mSv/h; – ambient dose rate from ground deposition ≥ 1 mSv/h. Evacuation is recommended in any case even though one of Operational Intervention Level is exceeded.
Improvised respiratory protection	In early phase of emergency, for population being in the open area at the time of passing of radioactive cloud, improvised respiratory protection is recommended. It decreases the internal exposure from intake of inhaled radioactive aerosols and radioactive iodine. Special respirators are used for respiratory protection. If they are not available, simple materials for protection can be used

Protective action	Description
Restriction of foodstuffs, drinking water and feeding stuffs	Restriction or banning of consumption of contaminated foodstuffs and drinking water are important protective actions in early and late phase of emergency. Considering the projections and scale of general emergency, movement direction of radioactive plume, people are warned against consumption of fresh vegetables, berries, fruits from the open area, unprotected well water, from drinking milk within 100 km radius in grazing time for 2-3 weeks period. In case the value of ambient dose rate from deposition is ≥ 1 μSv/h, consumption of potentially contaminated foodstuffs should be restricted. This operational intervention level shows, that ambient dose rate from deposition during the first days after the accident exceeds natural background and the values of maximum permitted activity concentration of foodstuffs could be exceeded. Due to soil contamination by I-131 2-7 days after general emergency consumption of surface contaminated foods and milk in case the animals were grazing contaminate grass is banned. Due to contamination of soil by I-131 more than ≥ 10 kBq/m^2 consumption of potentially contaminated foods or ≥ 2 kBq/m^2 – milk and drinking water shall be banned. Restrictions are valid while the volumetric or specific concentration measurements of foodstuff, milk, drinking water will be performed. Due to soil contamination by Cs-137 2-7 days after general emergency consumption of foods which potentially could be contaminated is banned. Due to contamination of soil by Cs-137 more than ≥ 2 kBq/m^2 consumption of potentially contaminated foods or Cs-137 ≥ 10 kBq/m^2 – milk and drinking water shall be banned. Restrictions are valid while the volumetric or specific concentration measurements of foodstuff, milk, drinking water will be performed. First 1 – 2 weeks after general emergency consumption of contaminated foods shall be restricted or banned if the value of specific concentration of I-131 exceeds ≥ 1 kBq/kg and volumetric concentration of milk and drinking water exceeds ≥ 0.1 kBq/l. First 1 – 2 weeks after general emergency consumption of contaminated foods shall be restricted or banned if the value of specific concentration of Cs-137 exceeds ≥ 0.2 kBq/kg or volumetric concentration of milk and drinking water exceeds ≥ 0.3 kBq/l.
Decontamin-ation of persons and clothing	Decontamination is complete or partial removal of radionuclides from a human body, clothing, other objects and the surface of the ground. Decontamination of contaminated persons affected by radioactive plume, by radioactive substances on skin and clothing, from ground deposition should be organised in decontamination points. Decontamination points can be a part of intermediate evacuation points or separate mobile decontamination points. Tasks of decontamination point: – take in and register people from contamination territory; – to measure a radioactive contamination of people, clothes and personal belongings; – decontamination of people and control of its effectiveness; – to evaluate whole body, organ, tissue exposures and incorporated radionuclides; – to collect separately contaminated clothes, other things in order to prevent the possible spread of contamination; – first medical aid or medical examination shall be performed if necessary.

The long term protective actions are applied in the late phase (late phase lasts until the time when any protection measures are not necessary; depending on emergency scale it may last several and more years) of emergency. The purpose of long term protective actions is generally to reduce the risk of stochastic health effects (cancer and genetic effects) and to prevent serious deterministic effects of protracted exposures. Long term protective actions are summarized in Table 10.4-2.

Table 10.4-2. Long term protective actions.

Protective action	Description
Temporary relocation	Temporary relocation is organized and concerted measure of relocation of population from affected area for longer but limited time (for several months to a year). The purpose is to protect population from external irradiation from the radioactive material deposited on the ground and surfaces, to prevent internal exposure from inhalation of re-suspended particulate radioactivity. Temporary relocation from contaminated territory shall be initiated, when generic intervention level is 30 mSv per month. Recommendations for temporary relocation are based on ambient dose rate from deposition. When ambient dose rate from deposition exceeds ≥ 0.2 mSv/h and 50% reduction in dose due to partial occupancy is taken into account, population is averted 30 mSv dose in 30 days. If the dose that can be averted by the relocation is less than 10 mSv in the subsequent month relocation is terminated. In the time of temporary relocation of population recovery operations in contaminated area are initiated: decontamination of soil, buildings, roads, etc.
Permanent resettlement	Permanent resettlement should be considered if the lifetime dose is projected to exceed 1 Sv.
Decontami-nation of environment	In late phase of emergency the following measures are recommended: – To decontaminate the soil by using different depth of ploughing; – To remove a shallow surface layer of the contaminated soil (5 – 10 cm).
Recovery measures in agriculture	The main principle of the recovery actions is application of materials (sapropell, potassium fertilizers, aluminosilicates, farmyard manure, phosphate fertilizers, etc.) that reduce radiocaesium and radiostrontium uptake into plants. Also it is recommended to apply changes in land use, select suitable varieties of a crop that accumulate lower levels of the caesium and strontium radionuclides; to alter animal species, replace sheep or goats with cattle (sheep and goats accumulate caesium in milk and meat 2-5 times more than cows); and other recovery measures.

Based on modelling results (see Section 10.3), protective actions that might be needed in case of LOCA and Severe Accident at new NPP are described in Table 10.4-3. It should be noted that the modelling was performed on the basis of 98% probability of depositions and doses. This means that the results presented in Section 10.3 can be exceeded only with the probability of 2 %. Thus the depositions and doses resulting from an accident can also be less than the presented values. It should also be noted that the modelling results are site specific, as can be seen from the maps included in Section 10.3. Because of the reasons explained, the protective actions do not necessarily extend up to the distance given in Table 10.4-3. It is also likely that the areas where the protective actions are implemented are not uniform around the NNPP, since they depend on how the radioactive plume will disperse. The dispersion of the plume depends on the prevailing weather conditions.

It should be emphasized that the doses accumulated during the accident episode (cloud-shine dose, skin dose, etc) should be clearly distinguished from the dose rates, such as the ground dose rate, total external dose rate, etc. The primary difference between these parameters is that e.g. the cloud dose is collected only during the accident episode itself – i.e. during 2 days or 32 days for SA and LOCA cases, respectively. After the main episode is over the accumulation stops because the contaminated cloud has gone or has been deposited. To the opposite, the doses originating from the deposited radioactivity –

ground-shine dose, ingestion dose, etc – are essentially long-term and by the end of the episode only the rate of their accumulation is established. With this rate (minus radioactive decay and environmental self- and forced cleaning) the accumulation continues for a long period of time.

Table 10.4-3. Protective actions in case of LOCA and Severe Accident at NNPP.

Protective action	Criteria	LOCA	Severe Accident
Sheltering	Ambient dose rate in the plume: (0.1–1) mSv/h. Ambient dose rate from deposition: ≥ 1 mSv/h.	Maximum calculated total dose from the cloud (plume) during the whole LOCA episode (32 days) is 3.1E-05 mSv. Maximum calculated dose rate from deposition is 9.2E-05 mSv/h. Maximum calculated values are in the vicinity of NPP (up to 10 km). Sheltering is not necessary in case of LOCA.	Maximum calculated total dose from the cloud (plume) during the whole SA episode (2 days) is 6.2E-05 mSv. Maximum calculated dose rate from deposition is 0.01 mSv/h. Maximum calculated values are in the vicinity of NPP (up to 10 km). Sheltering is not necessary in case of Severe Accident.
Iodine prophylaxis	Ambient dose rate in the plume: ≥ 0.1 mSv/h; Ambient dose rate from deposition: ≥ 1 μSv/h; I-131 deposition: ≥ 2 kBq/m^2.	Maximum calculated total dose from the cloud (plume) during the whole LOCA episode (32 days) is 3.1E-05 mSv. Maximum calculated dose rate from deposition is 9.2E-02 μSv/h. Maximum calculated (at the distance 10-15 km from NPP) deposition of I-131 is 41.2 kBq/m^2. Based on criteria of I-131 deposition, in case of LOCA iodine prophylaxis will be needed for population living within 10-15 km distance from NPP.	Maximum calculated total dose from the cloud (plume) during the whole SA episode (2 days) is 6.2E-05 mSv. Maximum calculated dose rate from deposition is 10 μSv/h. Maximum calculated deposition of I-131 is 1272.0 kBq/m^2. Based on criteria for I-131 deposition, iodine prophylaxis will be needed for population living within 250-600 km distance from NPP.
Evacuation	Avertable dose ≥ 50 mSv; Ambient dose rate in the plume: ≥ 1 mSv/h; Ambient dose rate from deposition: ≥ 1 mSv/h.	Avertable dose is less than 50 mSv. Maximum calculated total dose from the cloud (plume) during the whole LOCA episode (32 days) is 3.1E-05 mSv. Maximum calculated dose rate from deposition is 9.2E-05 mSv/h. Evacuation is not necessary in case of LOCA.	Avertable dose is less than 50 mSv. Maximum calculated total dose from the cloud (plume) during the whole SA episode (2 days) is 6.2E-05 mSv. Maximum calculated dose rate from deposition is 0.01 mSv/h. Evacuation is not necessary in case of Severe Accident.

Protective action	Criteria	LOCA	Severe Accident
Restriction of foodstuffs, drinking water and feeding stuffs	Ambient dose rate from deposition: ≥ 1 μSv/h; I-131 deposition: ≥ 10 kBq/m^2 (food ban); I-131 deposition: ≥ 2 kBq/m^2 (milk and drinking water ban); Cs-137 deposition: ≥ 2 kBq/m^2 (food ban); Cs-137 deposition: ≥ 10 kBq/m^2 (milk and drinking water ban).	Maximum calculated dose rate from deposition is 9.2E-02 μSv/h. Maximum calculated deposition of I-131 and Cs-137 is 41.2 and 4.3 kBq/m^2 respectively. According to criteria of I-131 deposition food should be banned at the distance of 10-15 km; milk and drinking water should be banned at the distance of 30-35 km. According to criteria of Cs-137 deposition food should be banned at the distance of about 5 km.	Maximum calculated dose rate from deposition is 10 μSv/h. Maximum calculated deposition of I-131 and Cs-137 is 1272.0 and 143.8 kBq/m^2 respectively. According to criteria of I-131 deposition food should be banned at the distance of 100-250 km; milk and drinking water should be banned at the distance of 200-600 km. According to criteria of Cs-137 deposition food should be banned at the distance of 50-100 km; milk and drinking water should be banned at the distance of 20-50 km.
Temporary relocation	30 mSv per month; Ambient dose rate from deposition exceeds ≥ 0.2 mSv/h (2-30 days after emergency)	External dose rate is 1.0E-04 mSv/h. Dose received per month will be 0.074 mSv. Maximum calculated dose rate from deposition is 9.2E-05 mSv/h. Temporary relocation is not necessary in case of LOCA.	External dose rate is 0.018 mSv/h. Dose received per month will be 13.4 mSv. Maximum calculated dose rate from deposition is 0.01 mSv/h. Temporary relocation is not necessary in case of Severe Accident.
Permanent resettle-ment	Lifetime dose: > 1 Sv.	Maximum calculated lifetime dose is 3.44 mSv. Permanent resettlement is not needed in case of LOCA.	Maximum calculated lifetime dose is 117 mSv. Permanent resettlement is not needed in case of Severe Accident.

The main protective actions in case of LOCA and Severe Accident are iodine prophylaxis and restriction on the use of foodstuffs, milk and drinking water. In case of LOCA the territory where these protective actions might be needed is much smaller (up to 35 km from NPP) in comparison with Severe Accident (up to 600 km). It should be noted that the highest distances for protective actions is caused due to deposition of I-131. However the iodine prophylaxis and restrictions on the use of foodstuffs, milk and drinking water are temporary, since the radiological half-life of I-131 is 8 days and activity of I-131 deposition reduces rapidly. Activity of Cs-137 deposition is lower than I-131, however Cs-137 has radiological half-life of 30 years, therefore based on criteria defined for Cs-137 distances for restriction on the use of foodstuffs, milk and drinking water will be lower (up to 5 km in case of LOCA and up to 100 km in case of SA), but restriction will be long-lasting.

10.5 EMERGENCY PREPAREDNESS AND RESPONSE

Emergency response arrangements at nuclear power stations means adequate provision is made for responding to an emergency situation. To mitigate the consequence of an accident to the public, the power plant and rescue service authorities maintain emergency preparedness. This is aimed at civil defence actions in a radiation hazard situation. Nuclear energy legislation sets requirements for civil defence, rescue and emergency response actions.

Emergency preparedness encompasses a wide range of emergency response arrangements for different incidents and accidents. The power station will have its own emergency organisation formed from the power plant's personnel. They will be trained for duties defined in advance by the emergency plan, as informed by the safety analysis for the power plant. The objectives of this taskforce include the organisation and implementation of rescue and other urgent activities, as part of coping with the consequences of an accident, providing support for the development and implementation of measures to enhance plant safety in emergencies, and providing emergency training to emergency response authorities and forces. Engineered equipment includes a sheltered on-site emergency centre, computerised radiation monitoring system and local notification system.

The organisation should have the appropriate rooms, channels of communication and equipment to deal with any type of incident or accident. Equipment provided includes the appropriate radiation measuring devices to allow monitoring of the site and within the exclusion zone (presently 3 km in radius for the Ignalina NPP; to be confirmed for a new plant once a design is selected).

A simplified diagram of the current emergency notification and communication system for the Ignalina NPP is represented in Figure 10.5-1. A similar system is likely to be implemented for the new NPP.

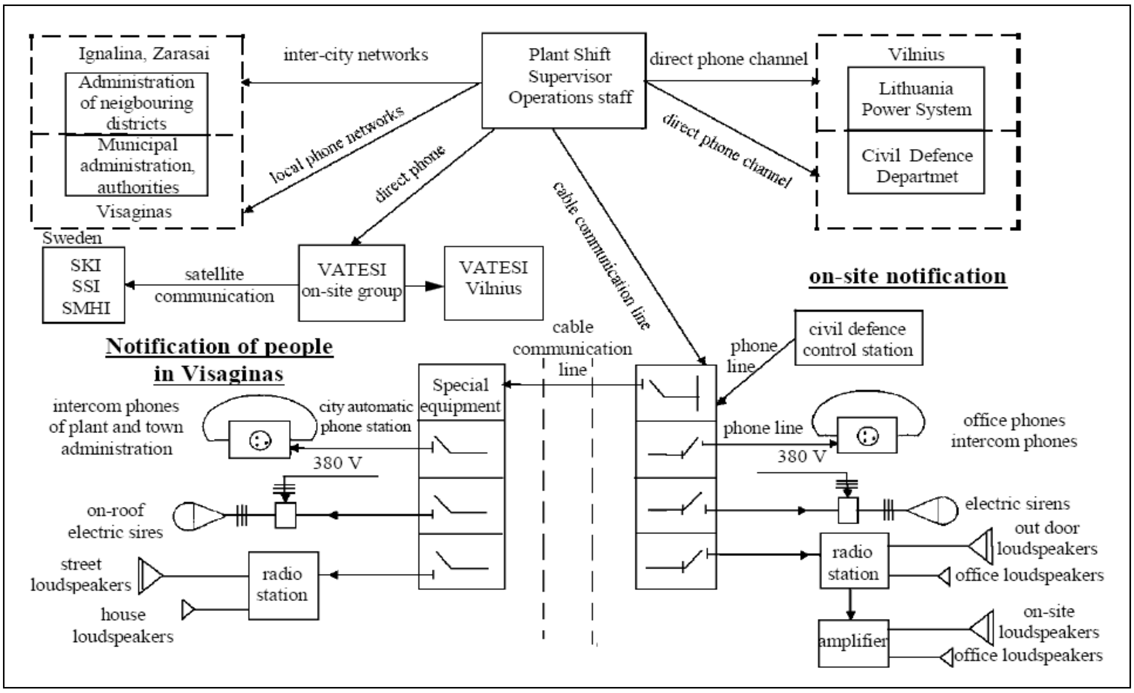


Figure 10.5-1 Block diagram of the Ignalina NPP notification system for personnel and population ***(Handbook about the Ignalina Nuclear Power Plant, for the emergency preparedness organizations around the Baltic sea. Kaunas, Lithuanian Energy Institute. 1997.*****)**

It is the role of the emergency organisations to make necessary announcements and alarms and take actions for managing situations in the event of an emergency. The present emergency notification system at Ignalina includes (*INPP Handbook, 1997*):

– Notification of plant personnel.

- Notification of Visaginas residents and administration authorities of the nearby regions.
- Direct phone connection with the Department of Civil Defence in Vilnius and Dispatcher of the Lithuania Power System.
- INMARSAT satellite communications system, installed in VATESI office in the plant administrative building, for notification of Swedish authorities: Radiation Protection Institute, Swedish Nuclear Power Inspectorate and Swedish Meteorological Institute.

Personnel notification systems include (*INPP Handbook, 1997*):

- One-way loudspeaker communications network, consisting of loud speakers installed in reactor buildings and around the site.
- Wire transmission network consisting of radio centre and office radio receivers.
- Conference hall cabinet where telephones of the plant administration of linked.
- Emergency warning sirens installed inside the power plant units and on site.

The emergency response plan would be implemented during an emergency or recognition that a serious problem may be evolving at the plant. The measures needed in an accident and the civil defence actions will be described in the emergency plan. The plan is designed for the protection of personnel as well as confinement and mitigation in the case of a radiation accident at the nuclear power plant. This basic document provides instructions for the organisation of engineering, medical, evacuation and other actions which may be required. This plan is valid for all on-site personnel, the fire protection staff, the security guards and the attached persons.

The emergency situations are classified into three types according to severity and controllability: emergency standby, site emergency and general emergency. Each has their own actions, according to the nature and scope of the situation.

During emergency standby, the safety level of the power plant is intact but the operators may consider or recognise the potential for the situation to deteriorate and therefore take pre-emptive, precautionary local actions. The preparedness is raised by the manning of the emergency operator centre. The situation is also reported to VATESI and the local rescue authority.

During a site emergency, safety has deteriorated or is in imminent danger of deteriorating, such that a radiation threat is considered a possibility. The emergency organisation is alerted in full, should the event escalate to a general emergency (core damage, release of radioactive material, or excessive radiation hazard). VATESI is alerted and the local rescue authority informed.

During a general emergency, there is a realistic or actual risk of radioactive releases which require civil defence actions. The emergency organisation is alerted in full, and is ready to immediately implement protective actions. VATESI and the local rescue authority are alerted immediately.

The Ignalina nuclear power plant, and site of the new power plant, is situated 6 km from the town of Visaginas, which has a population of about 32 600. The emergency plan currently in force enables notification of an accident to the residents through remote control communication. This includes loudspeaker communication network and alarm warning sirens. The emergency plan does not provide a shelter. It does however provide for action to be taken including: communication to the population of the town advising them to stay indoors and to close all windows and doors, the administration of Iodine tablets, evacuation to an area out of the path of radioactivity being blown by the wind and the control of food and water supplies.

During the first stages of an accident, it is important to be protected against the radiation from the release plume and avoid radiation dose by inhalation. Evacuation is the most efficient form of protection, but in most accidents the radiation dose is reduced adequately enough by the protection of a building (i.e. sheltering).

Taking Iodine tablets can protect the thyroid against radioactive Iodine. This ensures the thyroid is filled with stable Iodine, and as a result little radioactive Iodine is absorbed into the body.

The radiation dose caused directly by the fallout and dust can be decreased significantly by temporarily transferring the population away from the contaminated area, followed, if required or possible, by local cleaning (decontamination) of the ground and buildings. A restriction on movement may be implemented to control access to contaminated area, except during necessary emergency actions. If required, and if possible, evacuation is implemented before the radioactive plume reaches the area. Taking into account wind direction a number of evacuation routes are prepared. Inhabitants would be evacuated by public or personnel transport, to intermediate evacuation points controlled by the municipal emergency situation commissions. These points are set up to control departure from and arrival to contaminated territory, fulfil radiometric control of people, animals and transporting means, ensure necessary medical aid, perform sanitary treatment of people and decontamination of engineering.

The use of Iodine pills, evacuation of the population and restrictions on movement can efficiently decrease the largest radiation dose caused by the accident. Such restrictions are only required in the immediate vicinity of the nuclear power plant, and only cover a small area. Further away from the contaminated area, the dose will be so small that no long-term restrictions on movement will be expected.

Protecting domestic and production animals can reduce the radiation dose to foodstuffs, by moving animals indoors and protecting their feed. In fallout situations, instructions will be given for producing as clean feed as possible and reserving clean water. The control of food and water supplies is essential, after a large accidental release of radioactivity into the environment. Some foodstuffs may be restricted. The maximum permitted levels of radioactive contamination in foodstuffs are given in Lithuanian Hygiene Standard HN 99:2000.

Large-scale civil defences are only required during a severe accident, during an INES level six accident or greater. Civil defence structures of neighbouring countries, such as Latvia, Belarus and the Kaliningrad region of Russia, would be informed about an accident by the department of Civil Defence using inter-state means of communication, and civil defence structures of Latvia and Belarus also via the local warning zone of the nuclear power plant (serving a 30 km radius for Ignalina, to be confirmed for a new nuclear plant, but may be reduced with agreement of the appropriate Regulatory authorities)

Should an off-site release of radioactivity occur, the Ministry of Environment shall first of all present information regarding the nuclear accident to VATESI. VATESI then provides information regarding the accident to the IAEA and neighbouring countries, including; time, exact place and nature of accident, possible or determined causes of the accident, general characteristics of environmental release and the quality, composition and height of the radioactive release. In case of a nuclear accident the Department of Civil Defence will provide information to the municipal civil defence subdivisions about the accident via an automatic management and notification system.

The Visaginas population including plant personnel would be evacuated by the decision of the Government in accordance with the plan of the Department of Civil Defence. The new power plant unit will not bring any changes to the existing civil defence actions of the area.

The Department of Civil Defence organises radiation monitoring. A permanent radiation level monitoring system is currently employed at the Ignalina site and its vicinity. Variations of radiation levels in Lithuania, caused by the transfer of radioactive substances from other countries or released into the atmosphere by an accident at the Ignalina site can be monitored and tracked.

11 DIFFICULTIES AND UNCERTAINTIES OF THE ENVIRONMENTAL IMPACT ASSESSMENT

The potential uncertainty factors or practical difficulties encountered during the EIA work have been identified as comprehensively as possible during the assessment work, and their implications on the reliability of the impact assessment results have been taken into consideration. Identified uncertainties and difficulties and their implications are mainly described in the relevant sections of Chapters 7 and 10.

The available environmental data and the assessment of impacts always involve generalisations and assumptions. At this stage of the NNPP project for instance the technical data is still preliminary and incomplete, thus causing the need for above mentioned generalisations and assumptions.

The limited amount of data regarding the Belarus region has caused difficulties in parts of the assessment work. Only information on performed radiological monitoring was received from Belarus despite official requests through the Lithuanian Ministry of Environment for other information as well.

Some difficulties were encountered when trying to compile sufficiently reliable up to date data on Lake Druksiai hydrology and the hydrology of River Prorva and other rivers in Belarus. For instance actual data of the present outflow from the lake does not exist. Extrapolations from available measurement data had to be made in order to acquire sufficient hydrological data. Lack of sufficient data may cause uncertainties and inaccuracy in the assessment work. Therefore the represented assessment of water balance should be considered preliminary.

There are no regulations for releases in case of a severe nuclear accident in Lithuanian legislation. Therefore the limit for the release of radioactive materials arising from a severe accident (100 TBq release of Cs-137) defined in Finnish legislation had to be used for environmental impact estimation.

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