FENNOVOIMA

PÖYRY

# Environmental Impact Assessment Program for Spent Nuclear Fuel Encapsulation Plant and Final Disposal Facility

June 2016

Supplement to the Construction License Application for the Hanhikivi 1 Nuclear Power Plant

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The original language of the Environmental Impact Assessment is Finnish. Versions in other languages are translations of the original document which is the document Fennovoima is committed to.

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**Topographic base maps**

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# SUMMARY


### *Organization responsible for the project and background of the project*

The organization responsible for the project as laid down in the EIA Act is Fennovoima Oy (hereinafter referred to as "Fennovoima"), a Finnish nuclear power company established in 2007. Fennovoima is building a nuclear power plant with a generating capacity of around 1,200 MW on Hanhikivi headland in Pyhäjoki. Fennovoima submitted a construction license application for a nuclear power plant pursuant to the Nuclear Energy Act to the Government in the end of June 2015.

In accordance with the Decision-in-Principle granted to Fennovoima in 2010, Fennovoima must, by the end of June 2016, present to the Ministry of Economic Affairs and Employment either a final disposal cooperation agreement made with the parties currently under the nuclear waste management obligation, or an environmental impact assessment (EIA) program for its own encapsulation plant and final disposal facility.

With this EIA program, Fennovoima supplements the nuclear power plant construction license application and launches the environmental impact assessment procedure required by the prerequisite included in the 2010 Decision-in-Principle for its own spent nuclear fuel encapsulation plant and final disposal facility.

Fennovoima has also started cooperation with the Finnish nuclear waste management company Posiva Oy by signing a service contract with its subsidiary Posiva Solutions Oy. This service contract ensures that Posiva Oy's expertise gained over the course of almost 40 years can be utilized in the final disposal of spent nuclear fuel by Fennovoima. Furthermore, Fennovoima continues its negotiations with the parties currently under the nuclear waste management obligation on long-term cooperation in the final disposal of spent nuclear fuel.

### *Environmental Impact Assessment for the project*

According to the Act on Environmental Impact Assessment Procedure (468/1994) and the Decree on Environmental Impact Assessment Procedure (713/2006), an environmental impact assessment procedure is mandatory for facilities that are designed for the processing and final disposal of irradiated nuclear fuel. The EIA procedure does not make any decisions concerning the project or the final disposal location of spent nuclear fuel; instead, the objective is to produce information to serve as a basis for decision-making. The objective of the EIA procedure is to contribute the environmental impact assessment and to ensure that environmental impacts are always taken into account in planning and decision-making. Another objective is to increase the availability of information to citizens and the possibility for them to participate in the planning of projects.

The EIA procedure consists of the program phase and the report phase (Figure 0-1). The EIA program is a plan for arranging the environmental impact assessment procedure and the required additional studies. The submission of the program will initiate a research phase of several years, during which the environmental impact of the spent nuclear fuel final disposal project, the geological characteristics of the alternative locations, and their suitability for final disposal will be studied. The EIA report to be prepared later will describe the project's characteristics and technical solutions, and offer an assessment of its environmental impacts based on the EIA procedure.

The EIA procedure officially starts when the EIA program is submitted to the coordinating authority. The coordinating authority of this EIA procedure is the Ministry of Economic Affairs and Employment. The coordinating authority will announce the public display of the EIA program. During the display period, citizens may express their opin-

ions about the EIA program to the coordinating authority. The coordinating authority also requests statements on the program from various authorities. An announcement to be published by the coordinating authority will determine how and when opinions can be given.

The coordinating authority compiles the opinions and statements on the EIA program, and it issues its own statement based on these to the organization responsible for the project. The EIA report will also be placed on public view for the issuance of statements and opinions.

Public information events will be arranged at the program and report phase of the environmental impact assessment procedure. More specific information about the public events will be given in the coordinating authority's announcement. Other interaction opportunities during the EIA procedure include resident surveys, small group interviews, and meetings of the advisory group to be established. More information about the project and the participation opportunities is available on the project website at www.fennovoima.com.

The Ministry of the Environment will act as the competent authority in the international hearing pursuant to the Espoo Convention.

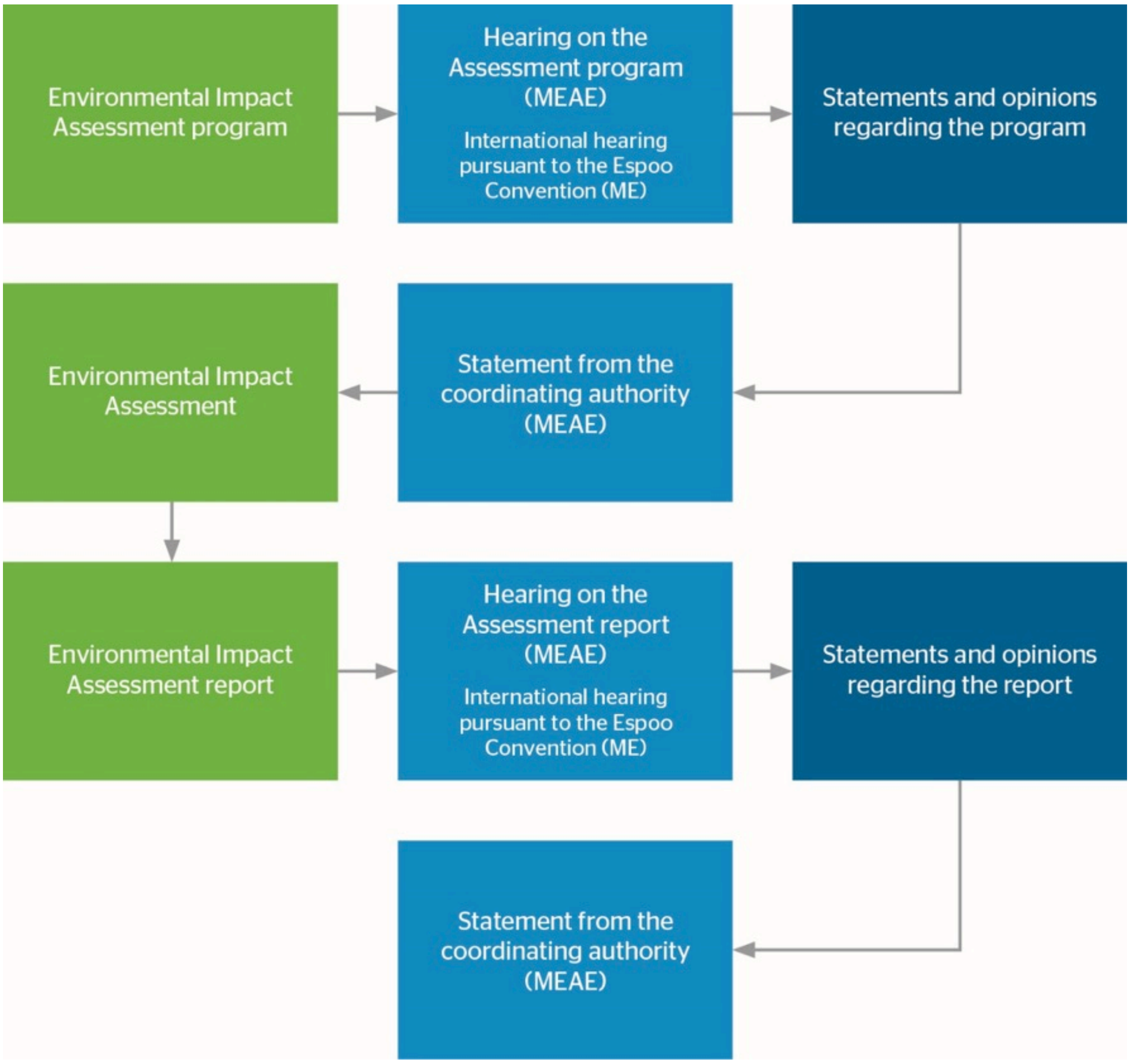


**Figure 0-1. Phases of the EIA procedure (MEAE = Ministry of Economic Affairs and Employment, ME = Ministry of the Environment).**

### *Project description*

This EIA procedure is a study of Fennovoima's spent nuclear fuel final disposal project, which consists of an encapsulation plant above ground level and a final disposal facility located several hundred meters deep in the bedrock. The term 'encapsulation plant' refers to a nuclear facility where spent nuclear fuel is packed into final disposal canisters. The term 'final disposal facility' refers to tunnels for the final disposal of spent nuclear fuel hundreds of meters deep in the bedrock. An illustration (Figure 0-2) shows the underground and aboveground parts of the encapsulation plant and the final disposal facility.

The final disposal project aims to permanently dispose the spent nuclear fuel, generated by Fennovoima's Hanhikivi 1 nuclear power plant, into the Finnish bedrock. During the operation of the nuclear power plant, around 1,200–1,800 tons of spent uranium nuclear fuel will be generated. This corresponds to around 700–900 disposal canisters.

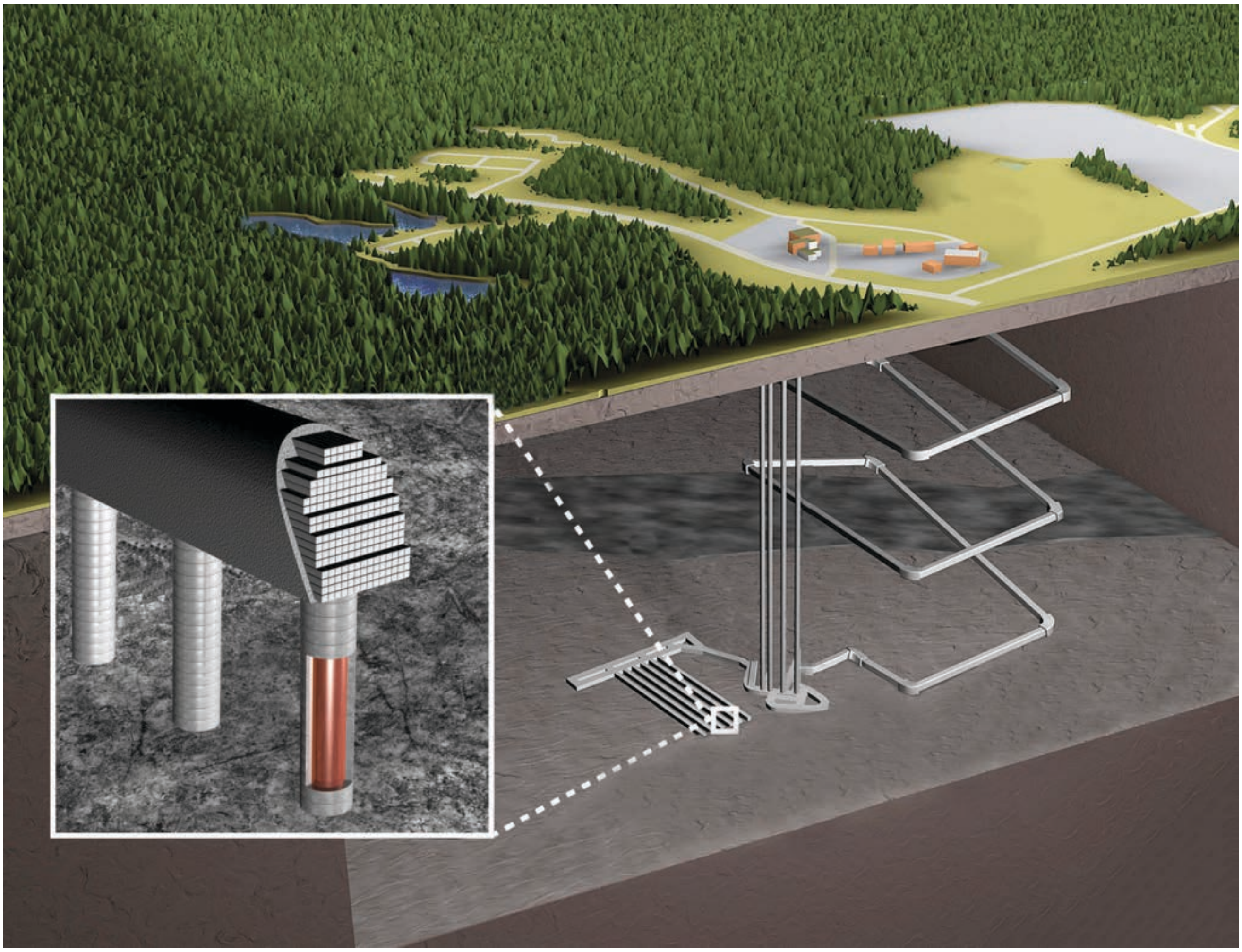

**Figure 0-2. Illustration of the encapsulation plant and the final disposal facility. Figure by Posiva Oy (edited).**

The project consists of the following phases:

- Preliminary investigation phase. Determining potential research areas which may be suitable for final disposal.
- Research and planning phase. Conducting geological surveys before selection of the final disposal site, interpreting the results, modeling, and preparation of preliminary site-specific facility plans. The research, design, and development work of the encapsulation plant and final disposal facility will continue throughout the project period.
- Construction phase. Building a research facility, building the encapsulation plant and facilities for processing the low and intermediate level waste generated by the encapsulation plant, building an underground final disposal facility, and other construction activities (incl. any roads and power lines to be built).
- Operational phase. Transporting spent nuclear fuel to the encapsulation plant and final disposal facility, encapsulation, and final disposal in the bedrock.
- Decommissioning phase. Shutting down the operations of the encapsulation plant and final disposal facility, closing the final disposal facility, decommissioning and demolishing the buildings above ground level (incl. final disposal of demolition waste), and releasing the site from surveillance.
- Some of the project phases can be implemented partially simultaneously.

Fennovoima's spent nuclear fuel final disposal plan is based on the KBS-3 concept, which was originally developed in Sweden and Finland. The KBS-3 concept is based on the multibarrier principle, where radioactive substances in the spent nuclear fuel are isolated with several redundant protective structures (barriers). The barriers ensure that the radioactive substances in the spent nuclear fuel do not come into contact with the living environment or people. In a final disposal solution according to the KBS-3 concept, the spent nuclear fuel is inserted into a copper disposal canister with a cast iron insert, surrounded with bentonite clay, and placed in final disposal holes drilled deep into the bedrock (Figure 0-3). The disposal can take place in vertical (the KBS-3V concept) or horizontal (the KBS-H concept) drilled holes.

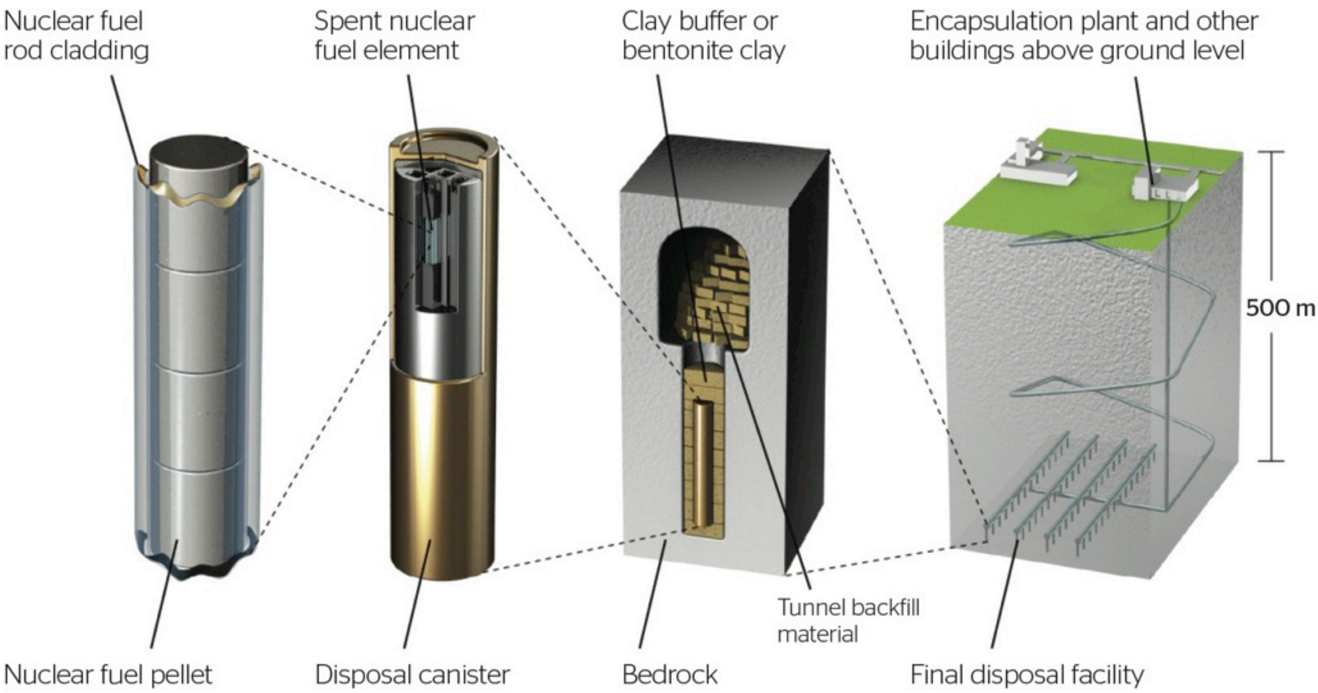


**Figure 0-3. Structure of the nuclear fuel and radioactive substance release barriers used in the KBS-3 method. The release barriers include the final disposal canister, bentonite clay, tunnel backfill material, and bedrock.**

### *Alternatives to be studied in the EIA program*

The research, construction, operational, and decommissioning phases of Fennovoima's own encapsulation plant and final disposal facility will be studied during the EIA procedure. Capacity of the encapsulation plant and final disposal facility will be 1,200–1,800 tons of uranium. The chosen technical implementation alternative is the KBS-3 method where the final disposal of nuclear fuel can take place either in vertical holes (KBS-3V) or in horizontal holes (KBS-3H) drilled in final disposal tunnels. The EIA procedure will also include a study of the transport of spent nuclear fuel. Other issues covered by the impact assessment include the impacts of ancillary projects, such as the construction of roads and power lines.

The alternative locations are (Figure 0-4):

- Option 1: Eurajoki
- Option 2: Pyhäjoki (Sydänneva)

Applicability of the alternative locations for final disposal will be assessed during the EIA procedure. New locations can be added or one of the locations, Pyhäjoki or Eurajoki, can be left out at a later point in time if necessary.

Of the alternative locations listed in this EIA program, the preliminary research phase has been completed at Pyhäjoki. One research area that may be suitable for final disposal (Sydänneva) was identified. The preliminary research phase at Eurajoki will start after the filing of the EIA program. The research area will be determined before the EIA report phase.

Another studied alternative is the zero-option, i.e. not constructing the spent nuclear fuel encapsulation plant and final disposal facility.

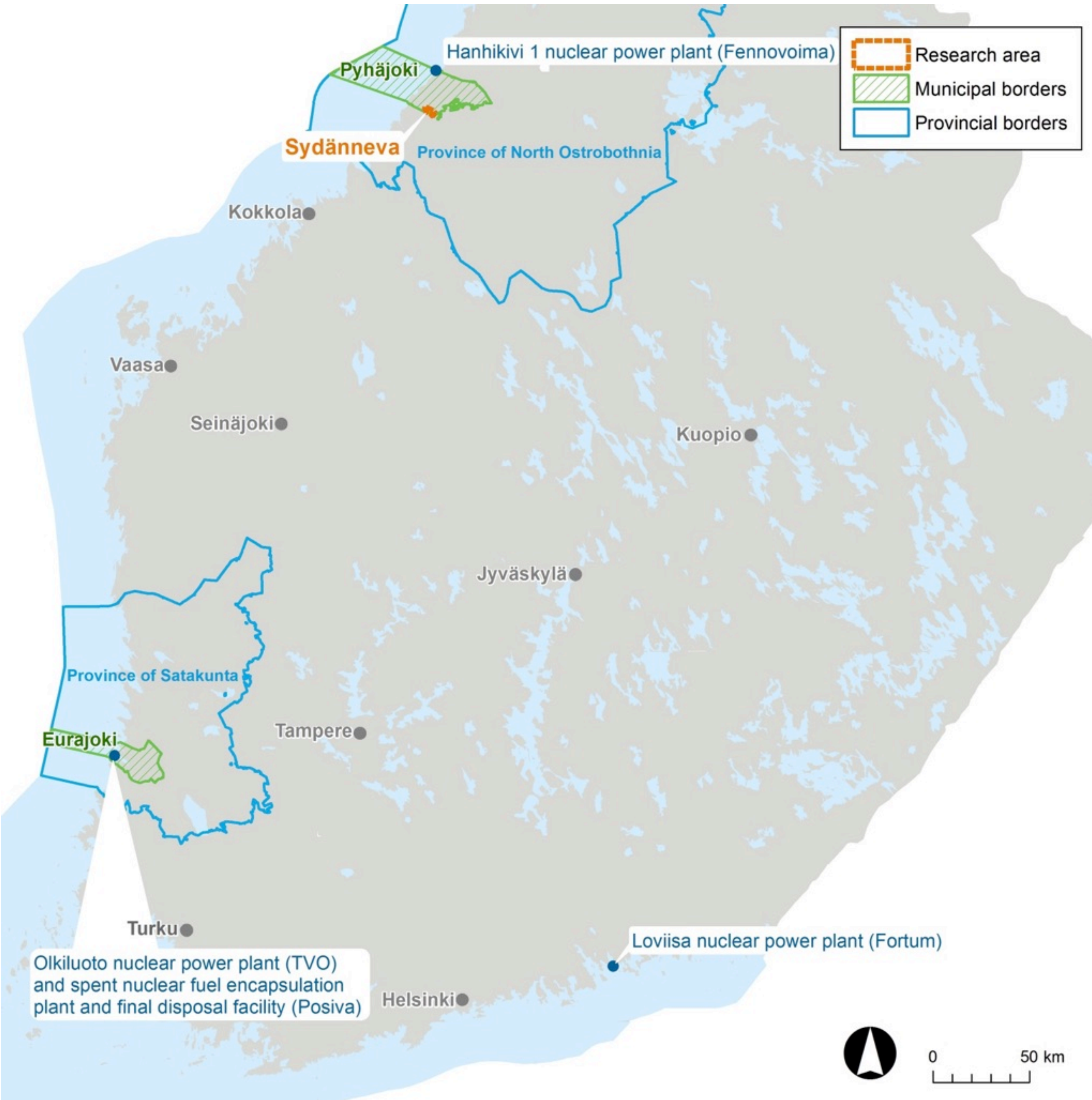


**Figure 0-4. The alternative locations.**

## *Project schedule*

The submission of the program will initiate a research phase of several years, during which the geological characteristics of the alternative research areas, and their suitability for final disposal will be studied. The suitability of the final disposal site is subject to numerous safety-related criteria. In particular, investigating the suitability of the bedrock conditions will require a dedicated research program lasting several years or even decades. The schedule for the research phase will be further specified based on the research program. The research program will be drafted separately for each research area.

The environmental impact assessment for the final disposal project and the preparation of the EIA report will start towards the end of the research activities. The EIA report will be completed in time to allow for the selection of the spent nuclear fuel final disposal site in the 2040s. According to the current plans, the final disposal of Fennovoima's nuclear fuel is expected to begin at the earliest in the 2090s, in accordance with the nuclear power plant construction license application.

The estimated total project period is more than 100 years (Figure 0-5). The schedule is approximate and will be specified further as the project progresses.

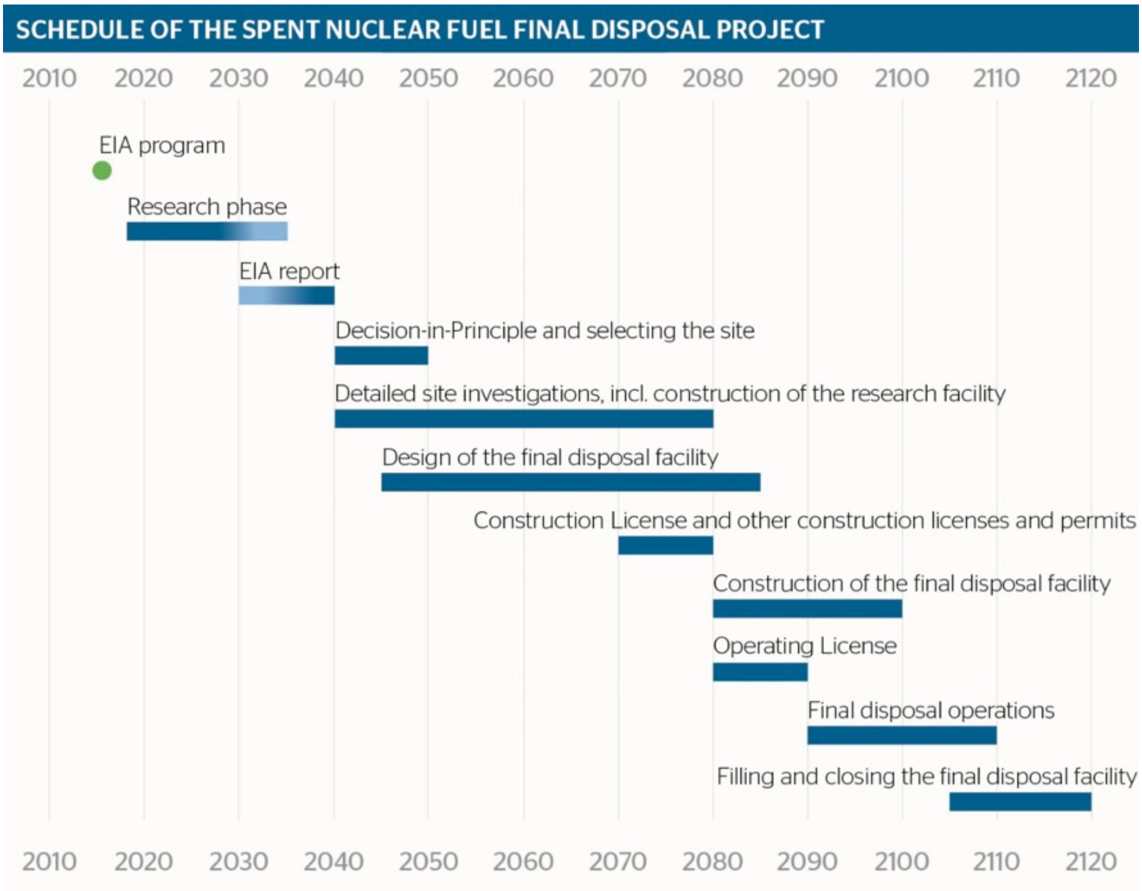


**Figure 0-5. Preliminary overall project schedule.**

### *Final disposal safety principles*

According to the general safety principles applied to nuclear waste management, final disposal may not result in any health hazards or any other damage to the environment (people, flora, or fauna), or property. This principle applies far into the future: the final disposal operations may not cause any health hazards or environmental damage even in the future.

In Finland, nuclear waste management is governed by the Nuclear Energy Act (990/1987) and the Nuclear Energy Decree (161/1988), which both entered into force in 1988. They determine the obligations of nuclear energy producers, the permit procedures, and the regulatory role of the authorities, for example.

The Finnish Radiation and Nuclear Safety Authority (STUK) oversees the safety of the processing, storage, and final disposal of nuclear waste. Several obligations for producers of spent nuclear fuel have been specified to ensure proper planning of the final disposal of spent nuclear fuel. STUK reviews all plans for safe final disposal, starting from the research and planning phase. STUK's YVL Guides provide more detailed regulations on nuclear waste management.

Safety of the KBS-3 final disposal concept is based on the multibarrier principle (several redundant barriers). According to section 30 of regulation Y/4/2016 of the Radiation and Nuclear Safety Authority, *"long-term safety of final disposal shall be based on redundant, long-term safety functions achieved with supplementary barriers in such a manner that deterioration of one or several of the long-term safety functions or an anticipated change in the bedrock or climate will not compromise long-term safety."*

The safety of final disposal up to a million years from now must be proven with sufficient confidence. This is why the term 'long-term safety' is used when referring to final disposal. It covers environmental radiation safety also after closing of the final disposal facility.

### *Licenses and permits required by the project*

The EIA report to be prepared at a later date will be enclosed with the Decision-in-Principle application for the spent nuclear fuel encapsulation plant and final disposal facility. According to the Finnish Nuclear Energy Act, the construction of a nuclear facility with a noticeable general significance requires a Decision-in-Principle issued by the Finnish Government and ratified by the Parliament concerning the fact that the construction of the nuclear facility will be in accordance with the total benefit of the society. Construction of the final disposal facility at the selected location will also require an approval by the location municipality. In addition to the Decision-in-Principle, a construction license and an operating license pursuant to the Nuclear Energy Act will be required.

The permits, notifications and decisions related to the construction and operation of the spent nuclear fuel encapsulation plant and final disposal facility are illustrated in the image below (Figure 0-6).

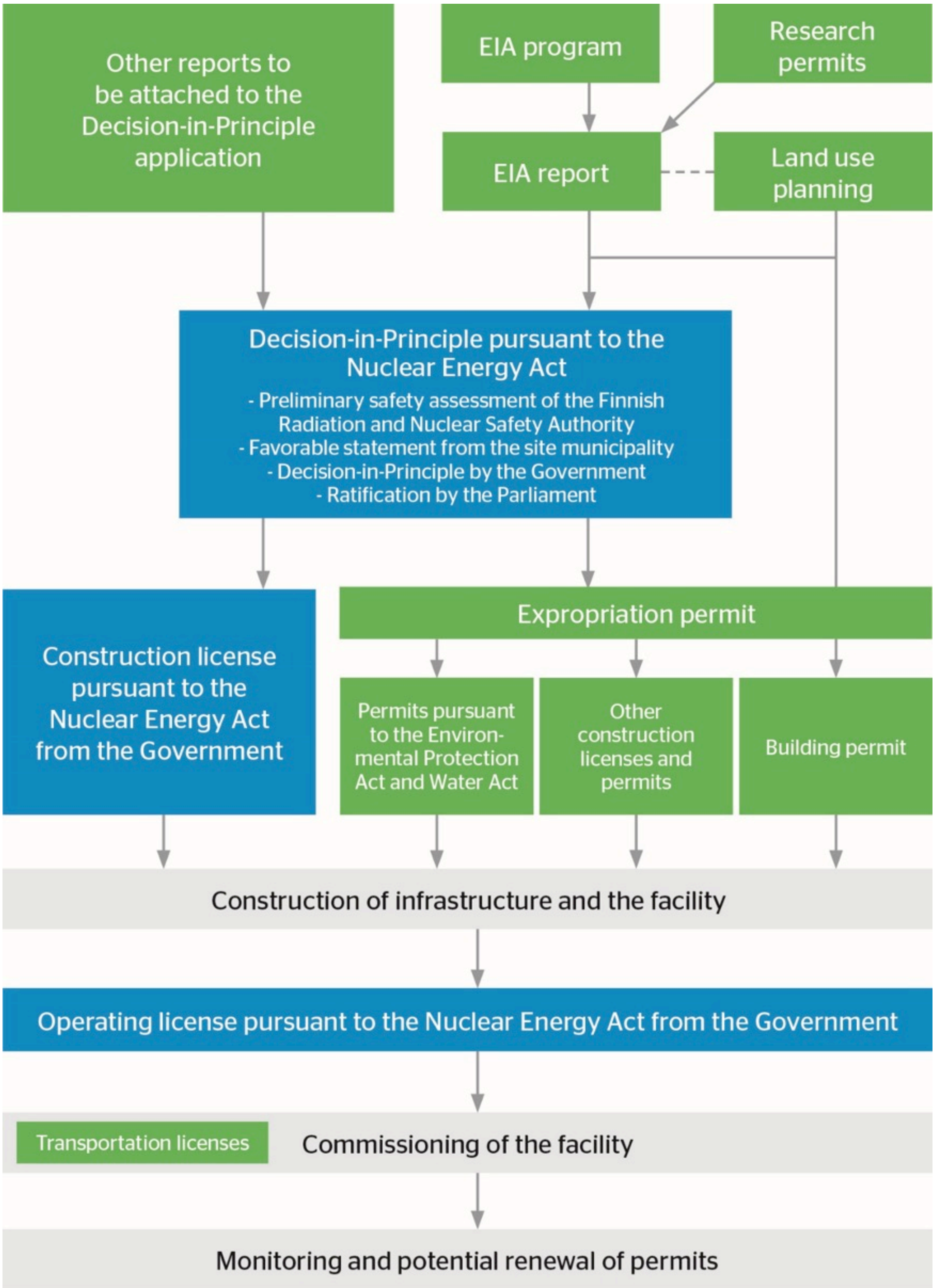


**Figure 0-6. License procedure in the construction and operation of the encapsulation plant and final disposal facility.**

### *Environmental impacts to be assessed*

Pursuant to the EIA Act, an environmental impact assessment must cover the project's environmental impact on the following:

- Human health, living conditions, and well-being
- Soil, water systems, air, climate, flora, fauna, and biodiversity
- Infrastructure, buildings, landscape, cityscape, and cultural heritage
- Utilization of natural resources
- Mutual interaction between the above-mentioned factors

Currently, the most important identified environmental impacts of the project are impacts on the soil, bedrock, and groundwater due to the underground construction activities and long duration of the project. Furthermore, impacts on humans, particularly those that can be experienced in different ways by different people, may become important during the project period. In the EIA report, the significance of environmental impacts will be assessed by, for instance, comparing the tolerance of the environment with regard to each environmental burden, taking into account the current environmental load of the area.

The environmental impact assessment will focus on impacts in the immediate vicinity of the research area, but the impact assessment scope will cover the entire affected area. The goal is to determine an assessment area so large that significant environmental impacts cannot be expected to occur outside the area. The actual definition of affected areas will be carried out in the environmental impact assessment report as a result of the assessment work.

# 1 INTRODUCTION

In accordance with the Decision-in-Principle granted to Fennovoima in 2010, Fennovoima must, by the end of June 2016, present to the Ministry of Economic Affairs and Employment either a final disposal cooperation agreement made with the parties currently under the nuclear waste management obligation, or an environmental impact assessment (EIA) program for its own encapsulation plant and final disposal facility. With this EIA program, Fennovoima meets the obligation laid down in the 2010 Decision-in-Principle.

Fennovoima has also started cooperation with the Finnish nuclear waste management company Posiva Oy by signing a service contract with its subsidiary Posiva Solutions Oy. This service contract ensures that Posiva Oy's expertise gained over the course of almost 40 years can be utilized in the final disposal of spent nuclear fuel by Fennovoima. Furthermore, Fennovoima continues its negotiations with the parties currently under the nuclear waste management obligation on long-term cooperation in the final disposal of spent nuclear fuel.

According to the Act on Environmental Impact Assessment Procedure (468/1994) and the Decree on Environmental Impact Assessment Procedure (713/2006), an environmental impact assessment procedure is mandatory for facilities that are designed for the processing and disposal of irradiated nuclear fuel. The purpose of the EIA procedure is to produce information to serve as a basis for future decision making instead of making any concluding decisions about the project or the final disposal location of the spent nuclear fuel.

The EIA procedure consists of the program phase and the report phase. The EIA program is a plan for arranging the project's EIA procedure and the required additional studies. The submission of the program will initiate a research phase of several years, during which the environmental impacts of the spent nuclear fuel final disposal project, the geological characteristics of the alternative locations, and their suitability for final disposal will be studied. The environmental impact assessment report, which will provide a comprehensive assessment of the project's environmental impacts based on the EIA procedure, will be completed in such a manner that the spent nuclear fuel final disposal site can be selected in the 2040s.

According to the current plans, Fennovoima's final disposal of spent nuclear fuel is expected to begin at the earliest in the 2090s, in accordance with the nuclear power plant construction license application. Construction of the encapsulation plant and final disposal facility at the selected location will require a positive Decision-in-Principle and an approval from the location municipality. In addition to the Decision-in-Principle, a construction license and an operating license pursuant to the Nuclear Energy Act and a host of other permits and licenses will be required.

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# 2 PROJECT

## 2.1 Organization responsible for the project

The organization responsible for the project as laid down in the EIA Act is Fennovoima Oy, a Finnish nuclear power company established in 2007. Fennovoima's owners are Voimaosakeyhtiö SF, a consortium of Finnish companies, and RAOS Voima Oy, a subsidiary of Rusatom Energy International. The largest owners of Voimaosakeyhtiö SF are Outokumpu Oyj, Suomen Voima Oy, and Fortum Oyj. Other owners include municipal energy companies and other industrial companies. Voimaosakeyhtiö SF owns 66% and RAOS Voima Oy 34% of Fennovoima. According to the 2014 Decision-in-Principle, Fennovoima's domestic ownership share (including Finland, other EU Member States, and EEA countries) will always be a minimum of 60%.

## 2.2 Background and purpose of the project

Fennovoima is building a nuclear power plant with a generating capacity of around 1,200 MW on the Hanhikivi headland in Pyhäjoki. Parties to the Hanhikivi 1 nuclear power plant's plant supply contract are Fennovoima and RAOS Project Oy, which is a company included in the Rosatom Group. According to the agreed schedule, the nuclear power plant will produce electricity in 2024.

Fennovoima submitted a construction license application for a nuclear power plant pursuant to the Nuclear Energy Act to the Government in the end of June 2015. By the summer of 2016, the nuclear power plant project will have proceeded from the planning phase to work on the infrastructure and construction of auxiliary buildings.

In its application dated January 14, 2009, Fennovoima applied for a Decision-in-Principle pursuant to section 11 of the Nuclear Energy Act regarding the construction of a nuclear power plant and the nuclear facilities required for its operation. The Government issued a Decision-in-Principle for the Fennovoima project on May 6, 2010 (M 4/2010 vp). In this Decision-in-Principle, the project was found to be in line with the overall benefit of the society. On July 1, 2010, the Finnish Parliament decided that the Decision-in-Principle shall remain in force. The Decision-in-Principle included a prerequisite on determining a spent nuclear fuel final disposal solution. According to the Decision-in-Principle, Fennovoima must by the end of June 2016 present to the Ministry of Economic Affairs and Employment either a final disposal cooperation agreement made with the parties currently under the nuclear waste management obligation, or an environmental impact assessment program for its own encapsulation plant and final disposal facility. The Fennovoima Decision-in-Principle was supplemented in 2014. The prerequisite in the Decision-in-Principle on the final disposal of spent nuclear fuel remained in force in the format presented in 2010.

With this EIA program, Fennovoima supplements the nuclear power plant construction license application and launches the environmental impact assessment procedure required by the prerequisite included in the 2010 Decision-in-Principle for its own spent nuclear fuel encapsulation plant and final disposal facility.

## 2.3 General description of the project

This EIA procedure is a study of Fennovoima's spent nuclear fuel final disposal project, which consists of an encapsulation plant above ground level and a final disposal facility located several hundred meters deep in the bedrock. The term 'encapsulation plant' refers to a nuclear facility where spent nuclear fuel is packed into disposal canisters. The term ‘final disposal facility’ refers to tunnels for the final disposal of spent nuclear fuel hundreds of meters deep in the bedrock.

According to a regulation by the Radiation and Nuclear Safety Authority that entered into force on January 1, 2016 (Y/4/2016) the above-mentioned facilities, i.e. the final disposal facility and the encapsulation plant, are separate nuclear waste facilities, and the requirements laid down in said regulation must be taken into account in their design and construction.

The final disposal project aims at permanent disposal of the spent nuclear fuel in the Finnish bedrock generated by Fennovoima’s Hanhikivi 1 nuclear power plant. During the operation of the nuclear power plant, around 1,200–1,800 tons of spent uranium nuclear fuel will be generated. This corresponds to around 700–900 disposal canisters.

The project consists of the phases listed below.

- Preliminary research phase. Determining potential research areas which may be suitable for final disposal.
- Research and planning phase. Geological surveys before selection of the final disposal site, interpreting the results, modeling, and preparation of preliminary site-specific facility plans. The research, design, and development work of the encapsulation plant and final disposal facility will continue throughout the project period.
- Construction phase. Building a research facility, building the encapsulation plant and facilities for processing the low and intermediate level waste generated by the encapsulation plant, building an underground final disposal facility, and other construction activities (incl. any roads and power lines to be built).
- Operational phase. Transporting spent nuclear fuel to the encapsulation plant and disposal facility, encapsulation, and final disposal in the bedrock.
- Decommissioning phase. Closing the operations of the encapsulation plant and final disposal facility, closing the final disposal facility, decommissioning and demolishing the buildings above ground level (incl. disposal of demolition waste), and releasing the site from control.

Some of the project phases can be partially implemented simultaneously. Chapter 3 includes a more detailed description of final disposal, the final disposal phases and operating principles, and the encapsulation plant and disposal facility.

## 2.4 Alternatives to be studied in the EIA program

### 2.4.1 Implementation alternatives

The research, construction, operational, and decommissioning phases of Fennovoima’s own encapsulation plant and final disposal facility will be studied during the EIA procedure. Capacity of the encapsulation plant and final disposal facility will be 1,200–1,800 tons of uranium. The chosen technical implementation alternative is the KBS-3 method where the final disposal of nuclear fuel can take place either in vertical holes (KBS-3V) or in horizontal holes (KBS-3H) drilled in disposal tunnels. The EIA procedure will also include a study of the transport of spent nuclear fuel. Other issues covered by the impact assessment include the impacts of ancillary projects, such as the construction of roads and power lines.

The alternative locations are (Figure 2-1):

– Option 1: Eurajoki
– Option 2: Pyhäjoki (Sydänneva)

Applicability of the alternative locations for final disposal will be assessed during the EIA procedure. New locations can be added or one of the locations, Pyhäjoki or Eurajoki, can be left out at a later point in time, if necessary.

### *Eurajoki*

Teollisuuden Voima Oyj's nuclear power plants and research facility ONKALO of the planned encapsulation plant and disposal facility of Posiva Oy are located in Olkiluoto, Eurajoki (Figure 2-1). In 2015, Posiva Oy received a construction license for the encapsulation plant and final disposal facility in Olkiluoto in Eurajoki. According to the construction license, a maximum of 6,500 tons of spent uranium nuclear fuel may be placed in the final disposal facility at Olkiluoto.

Since Eurajoki has already been selected as the final disposal location of spent nuclear fuel originating in Finland in the Posiva Oy selection process, Fennovoima has decided to study the applicability of Eurajoki as an alternative location in the Fennovoima spent nuclear fuel final disposal project. Fennovoima plans to determine the research area suitable for final disposal together with Posiva before the EIA report phase. This procedure enables the utilization of the latest geological information available to Posiva when limiting and determining the research area.

As the organization responsible for the project, Fennovoima has decided to start the EIA procedure with this EIA program by studying the entire municipality of Eurajoki. The organization responsible for the project is aware of the fact that a targeted research area within the municipality of Eurajoki must be specified, further studies in the research area must be completed, and current status of the area must be described in the extent required by the EIA report before the preparation of the EIA report to ensure proper comparison of the alternative locations.

### *Pyhäjoki*

Fennovoima Oy's nuclear power plant will be built on the Hanhikivi headland in Pyhäjoki. Applicability of the Finnish bedrock for final disposal of highly radioactive spent nuclear fuel has been studied since the late 1970s *(e.g. Niini et al 1982, Vuorela & Hakkarainen 1982)*, and an area that may be suitable for final disposal in the Pyhäjoki region was determined based on national selection studies *(Salmi et al 1985)*. In 2015, the Geological Survey of Finland studied the geological properties of the Pyhäjoki region in more detail. It was able to identify a target area delimited by lineaments (fracture zones) that may be suitable for final disposal and a smaller research area (Sydänneva) within this target area (Figure 2-1).

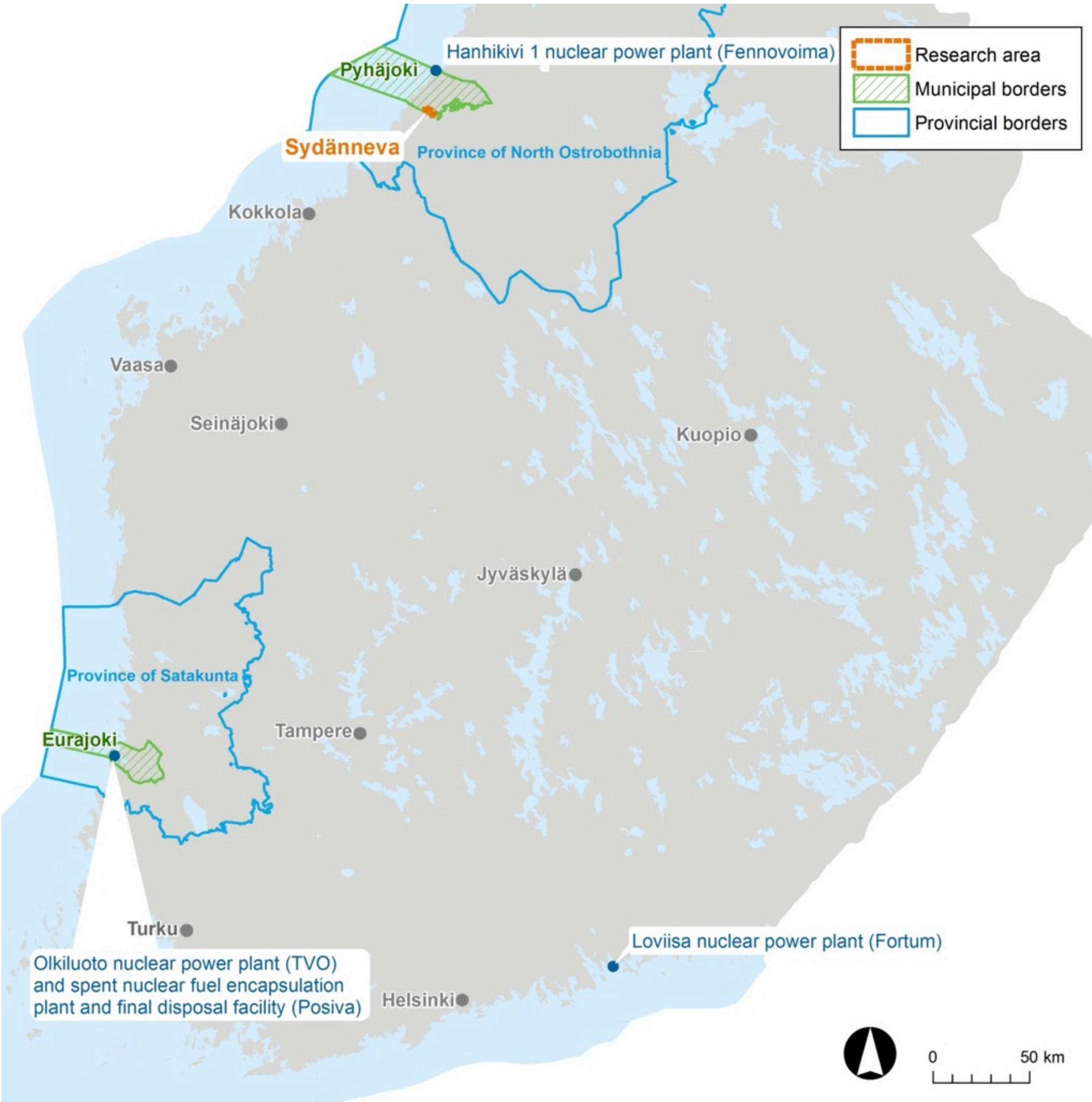


**Figure 2-1. The alternative locations.**

## 2.4.2 Zero option

Another alternative being studied is the zero-option, i.e. not constructing the spent nuclear fuel encapsulation plant and final disposal facility. In this option, the spent nuclear fuel would be stored in an interim storage for spent nuclear fuel at the nuclear power plant site on the Hanhikivi headland in Pyhäjoki for several decades. However, Finnish nuclear legislation requires that spent nuclear fuel is permanently disposed of, which is why prolonged storage cannot be the final solution for the disposal of spent nuclear fuel.

## 2.5 Project schedule

The submission of the EIA program will initiate a research phase of several years, during which the geological characteristics of the alternative research areas and their suitability for final disposal will be studied. The suitability of the final disposal site is subject to numerous safety-related criteria pertaining, particularly to the bedrock conditions which it will take several years or even decades to investigate with a dedicated research program. The schedule for the research phase will be further specified based on the research program. A separate research program for each research area will be prepared.

The environmental impact assessment for the final disposal project and the preparation of the EIA report will start towards the end of the research activities. The EIA report will be completed in time to allow for the selection of the spent nuclear fuel final disposal site in the 2040s. According to the current plans, the final disposal of Fennovoima's spent nuclear fuel is expected to begin at the earliest in the 2090s, in accordance with the nuclear power plant construction license application.

The estimated total project period is more than 100 years (Figure 2-2). The schedule is approximate and will be further specified as the project progresses.

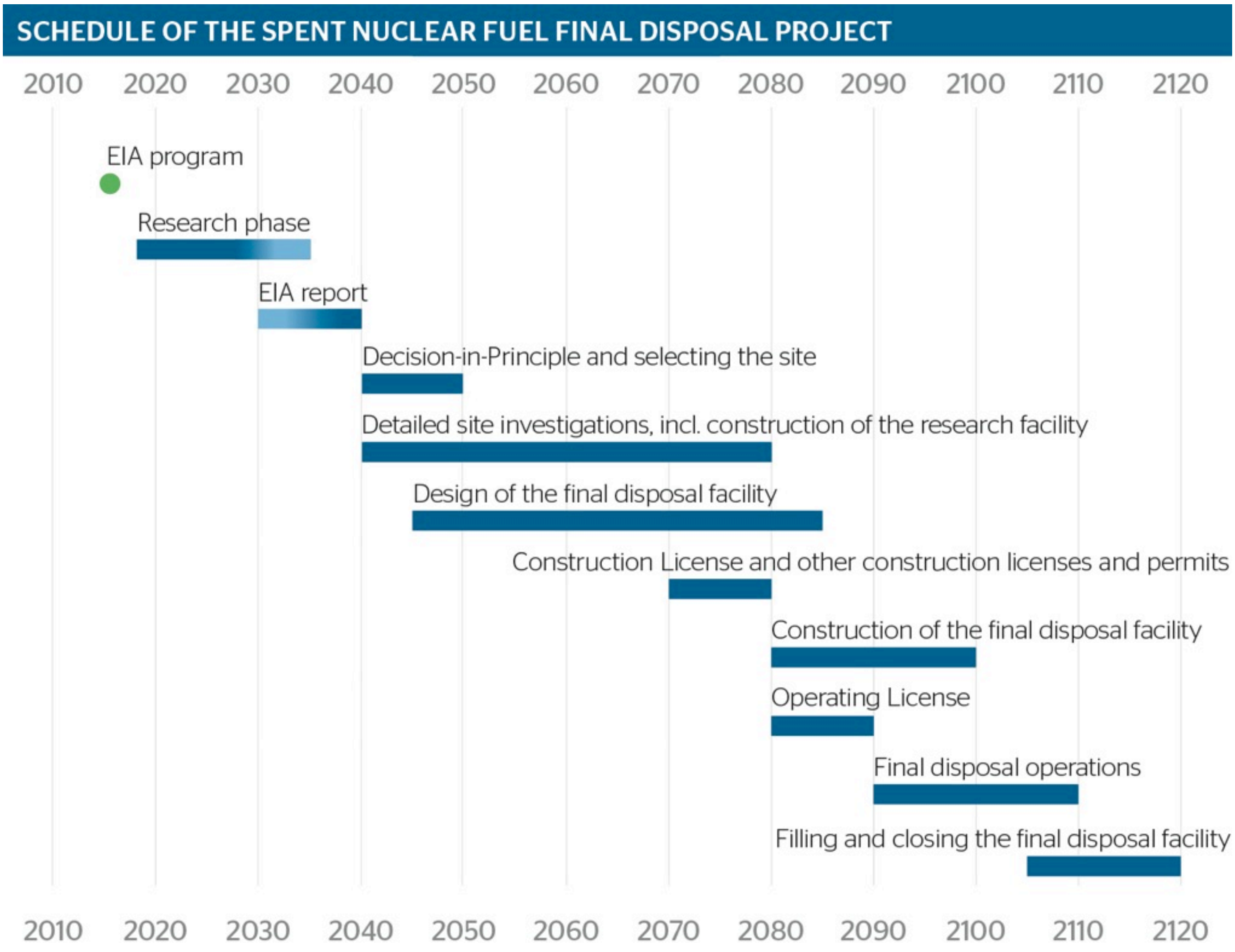


**Figure 2-2. Preliminary overall project schedule.**

## 2.6 Links to other projects

The spent nuclear fuel final disposal project is linked to Fennovoima's Hanhikivi 1 nuclear power plant project. Pursuant to the Nuclear Energy Act (990/1987) a licensee whose operations generate, or have generated, nuclear waste (licensee under a waste management obligation) is responsible for all nuclear waste management measures and their appropriate preparation, as well as for their costs (waste management obligation). By the summer of 2016, the Hanhikivi 1 nuclear power plant project will have proceeded from the planning phase to work on the infrastructure and construction of auxiliary buildings.

The Fennovoima final disposal project presented in this EIA program is similar to the spent nuclear fuel final disposal projects of Svensk Kärnbränslehantering AB (SKB) and Posiva Oy. All of the above-mentioned projects will partially overlap. Publicly available materials regarding the KBS-3 final disposal concept developed in Sweden and Finland (Chapter 3) will be applied to this project

# 3 DESCRIPTION OF THE FINAL DISPOSAL PROJECT

## 3.1 Justification for geological final disposal

Geological final disposal refers to a solution for the final disposal of spent nuclear fuel where the spent fuel is isolated deep underground so that its impacts on the environment are equal to or less than those of naturally occurring radioactivity. According to the Nuclear Energy Agency (NEA), an OECD organization, geological final disposal is the most highly recommended nuclear waste management strategy (*Picot et al. 2011*). The Finnish Nuclear Energy Act (990/1987, section 6a) requires that spent nuclear fuel must be handled, stored, and permanently disposed of in Finland. The spent nuclear fuel management solution selected by Finland and Sweden is the geological final disposal. Development of the final disposal technology started in the 1970s.

Alternative solutions for spent nuclear fuel management have also been proposed, such as long-term storage of the nuclear fuel (hundreds of years) at ground level or reprocessing of the fuel to separate uranium and plutonium from it. However, these solutions do not completely eradicate the need for a geological final disposal solution.

Storing spent nuclear fuel for hundreds of years at ground level is not a viable alternative in Finland, because the Nuclear Energy Act states that spent nuclear fuel must be permanently disposed of in Finland.

The spent nuclear fuel may be reprocessed, i.e. turned into recycled or reprocessed nuclear fuel in a reprocessing facility built for this purpose. Finland does not have any reprocessing facilities for spent nuclear fuel, nor is building one in Finland considered technically or financially viable. The spent nuclear fuel cannot be exported to be reprocessed abroad either, because section 6a of the Finnish Nuclear Energy Act states that spent nuclear fuel generated in Finland must be handled, stored, and permanently disposed of in Finland.

Thus, the only possible spent nuclear fuel management alternative is geological final disposal in the Finnish bedrock. The technical solution selected for the Fennovoima's final disposal project is a solution based on the KBS-3 concept, where the spent nuclear fuel is packed in canisters and placed deep into the bedrock. Other potential final disposal solutions based on the bedrock (such as deep borehole or a hydraulic cage) were deemed, already in the 1990s, not to be as well adapted to Finnish conditions (*Posiva 1999*). The KBS-3 concept has been found to be a suitable final disposal solution for Finland and selecting this concept enables cooperation with other Nordic nuclear waste management companies utilizing the same concept.

## 3.2 Properties and quantity of spent nuclear fuel

Around 20–30 tons of uranium is annually removed as spent nuclear fuel from the reactor of Fennovoima's Hanhikivi 1 nuclear power plant. During the sixty-year lifespan of the nuclear power plant, around 1,200–1,800 tons of spent nuclear fuel (uranium) will be generated. The definite quantity will depend on the enrichment degree of the nuclear fuel used, the discharge burnup, and the length of the fuel cycle. When nuclear fuel is used, it becomes highly radioactive.

Around 95 % of spent nuclear fuel still consists of uranium isotope U-238. The fuel is placed in the reactor as ceramic pellets in hermetically sealed tubes, called fuel rods, which are compiled into fuel assemblies (Figure 3-1). The spent nuclear fuel contains new elements generated through the uranium decay process and neutron capture reactions. Most of the new elements are fission products. The rest are elements heavier than uranium, known as transuranic elements. The fission products and transuranic elements are radioactive. The term radioactivity refers to the instability of the atomic nucleus, i.e. its tendency to transform into another type of nucleus. The transformation event is often called radioactive decay. Several such radioactive decay events may occur one after the other, but the final result is always a stable, non-radioactive substance. Some of the radioactive substances quickly decay into other substances, whereas others are very long-lived. The radiation emitted by a radioactive substance reduces over time as the shorter-lived substances decay into stable, non-radioactive substances. At first, the level of radioactivity decreases quickly, but this rate of decrease slows down over time. Immediately after removal from the reactor, spent uranium fuel is highly radioactive, but its radioactivity reduces to one hundredth of the original level after only one year. At the time of final disposal, only one-thousandth of the nuclear fuel's radioactivity remains. A couple of meters of rock will completely attenuate the radiation emitted by disposed fuel assemblies. *(Finnish Energy Industries 2006)*

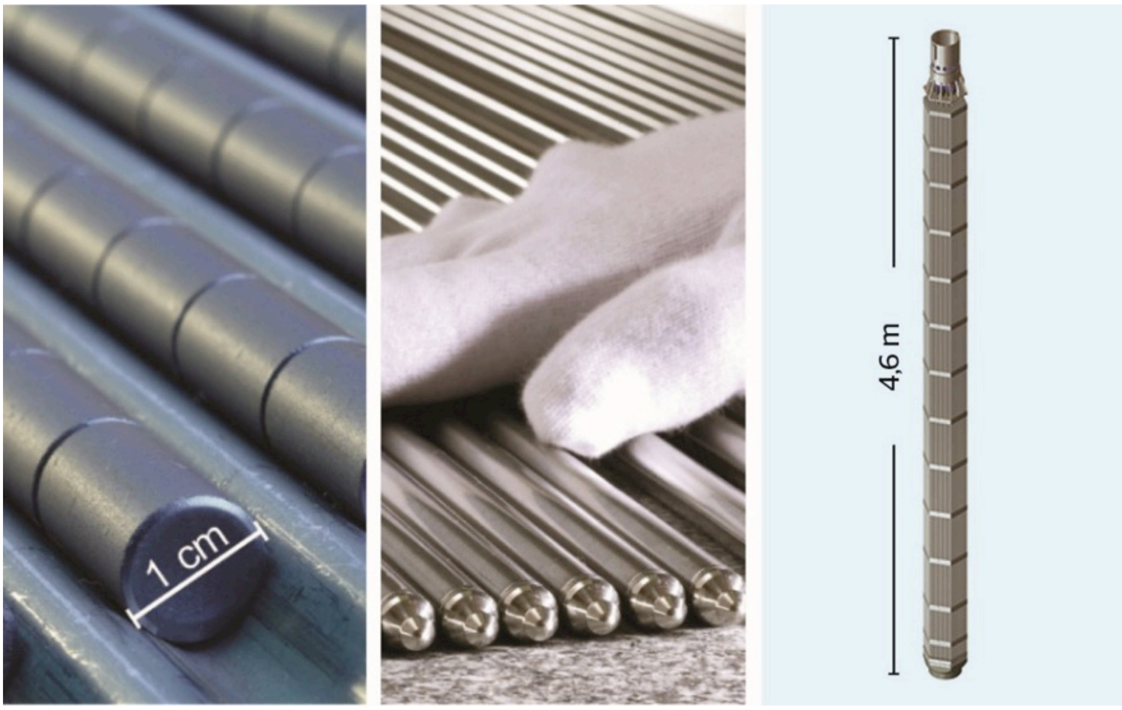


**Figure 3-1. Example image of the fuel pellets, fuel rods, and fuel assembly.**

Once removed from the reactor of a nuclear power plant, the spent fuel assemblies are transferred to pools of water in the reactor hall, where they are allowed to cool down for 3–10 years. The fuel assemblies are immersed under several meters of water, which effectively attenuates the radiation coming from the assemblies. Furthermore, water effectively cools the spent nuclear fuel. As the radioactive substances in the assemblies decay, plenty of heat is still generated, which is why the spent fuel assemblies must be cooled. The radioactivity and, simultaneously, the heat generated by the fuel decreases rapidly during the first year after removal from the reactor. *(Finnish Energy Industries 2006)*

The spent nuclear fuel will be transferred from the reactor building to an interim storage facility on the Hanhikivi headland. The fuel will remain there for several decades, waiting for final disposal. The interim storage period is necessary to reduce the decay heat and radiation level of the spent nuclear fuel to the level required for final disposal. The interim storage of spent nuclear fuel will take place in pools of water or as dry storage. The interim storage options and the environmental impact of interim storage are presented in Fennovoima's nuclear power plant environmental impact assessment report *(Fennovoima 2014)*. The nuclear fuel procurement procedure is also presented in Fennovoima's nuclear power plant environmental impact assessment report *(Fennovoima 2014)*.

## 3.3 General description and state of the design of the final disposal concept

Fennovoima's spent nuclear fuel final disposal plan is based on the KBS-3 concept, which was originally developed in Sweden and Finland. Development of the final disposal concept started in Sweden in 1976, and further development of the geological final disposal concept in Finland has been ongoing for more than 30 years. The development work in both countries still continues. The company in charge of nuclear waste management in Sweden, Svensk Kärnbränslehantering AB (SKB), applied for a construction license for an encapsulation plant and final disposal facility based on the KBS-3 concept in Sweden in 2011. In Finland, Posiva Oy received, in November 2015, a construction license for an encapsulation plant and final disposal facility based on the KBS-3 concept to be built at Olkiluoto.

Fennovoima can utilize the experience and expertise on final disposal from Finland and Sweden in the detailed planning of its final disposal concept. This means that the various final disposal operations can be fully optimized in terms of both safety and finances. Detailed planning of the Fennovoima final disposal project will be further developed during the project's research and development phase before the EIA report phase. Principles of the final disposal concept are described in Chapter 3.5.

The KBS-3 concept is based on the multibarrier principle, where radioactive substances are isolated with several redundant protective structures (barriers). The barriers ensure that the radioactive substances in the spent nuclear fuel do not come into contact with the biosphere or people. In a final disposal solution according to the KBS-3 concept, the spent nuclear fuel is inserted into a copper disposal canister with a cast iron insert, surrounded with bentonite clay, and placed in final disposal holes drilled deep into the bedrock (Figure 3-2).

The disposal depth in the final disposal facility will be determined by the geological properties of the selected final disposal site. In any case, the final disposal will take place at a depth of several hundred meters. While the selection of the final disposal site depends on several factors, the most significant ones of them in terms of the safety of final disposal are related to the geological properties of the bedrock. Guaranteeing the performance of the copper canister and the buffer material requires that the bedrock is geologically stable, the groundwater flow is low, and the chemical properties of the groundwater are favorable.

The final disposal can take place in vertical (the KBS-3V concept) or horizontal (the KBS-H concept) drilled holes. In their construction license application, Posiva Oy proposed the KBS-3V concept as the basic solution. Posiva Oy has also continued research in cooperation with SKB on the horizontal alternative (the KBS-3H concept; *Palomäki & Ristimäki 2012*).

Once the final disposal operations are concluded, the entire underground final disposal facility will be backfilled and permanently sealed so that the bedrock will return to as close as possible to the natural state in which it was before the excavation of the final disposal facility. The buildings above ground level will be dismantled, unless they can be used for another purpose, and the area will be landscaped. The phases of the final disposal project are described in Chapter 3.5.

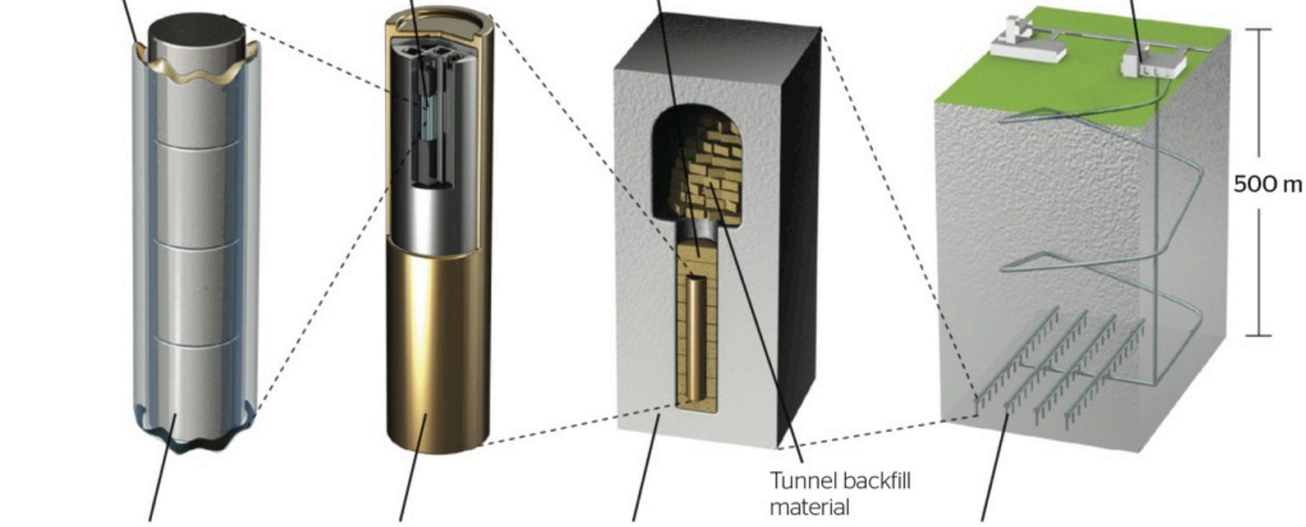


**Figure 3-2. Structure of the nuclear fuel and radioactive substance release barriers used in the KBS 3 method. The release barriers include the disposal canister, bentonite clay, tunnel backfill material, and bedrock.**

## 3.4 Safety principles of final disposal

### 3.4.1 General principles

According to the general safety principles applied to nuclear waste management, final disposal may not result in any health hazards or any other detriment to the environment (people, flora, or fauna), or property. This principle applies far into the future: the final disposal operations may not cause any health hazards or environmental damage even in the future.

In Finland, nuclear waste management is governed by the Nuclear Energy Act (990/1987) and the Nuclear Energy Decree (161/1988), which both entered into force in 1988. They determine the obligations of nuclear energy producers, the permit procedures, and the regulatory role of the authorities, for example.

The Finnish Radiation and Nuclear Safety Authority (STUK) oversees the safety of the processing, storage, and final disposal of nuclear waste. Several obligations for producers of spent nuclear fuel have been specified to ensure proper planning of the final disposal of spent nuclear fuel. STUK reviews all plans for safe final disposal, starting from the research and planning phase.

A regulation from the Radiation and Nuclear Safety Authority on safety of the final disposal of nuclear waste (Y/4/2016), which entered into force in the beginning of 2016, applies to the final disposal of spent nuclear fuel and other types of nuclear waste, originating from nuclear facilities, built into the bedrock or near the surface disposal. The regulation also applies to separate nuclear facilities for the processing and storage of spent nuclear fuel and other types of nuclear waste, i.e. facilities which are not part of a nuclear power plant. This means that in the case of this project, the regulation applies to both the encapsulation plant and the underground final disposal facility.

There are more detailed guidelines on the planning and realization of the encapsulation plant and final disposal facility in STUK's regulatory guides (the YVL Guides). YVL Guide D.3 (Handling and storage of nuclear fuel) applies particularly to the encapsulation plant and YVL Guide D.5 (Disposal of nuclear waste) to the final disposal of spent nuclear fuel. Regulations on the transport of spent nuclear fuel are given in YVL Guide D.2 (Transport of nuclear materials and nuclear waste). Applicable parts of the other YVL Guides must also be taken into account during the design and operation of the facility.

### 3.4.2 Multibarrier principle

Safety of the KBS-3 final disposal concept is based on the multibarrier principle (i.e. the use of several redundant barriers). According to section 30 of regulation Y/4/2016 of the Radiation and Nuclear Safety Authority, *"long-term safety of final disposal shall be based on redundant, long-term safety functions achieved with supplementary barriers in such a manner that deterioration of one or several of the long-term safety functions or an anticipated change in the bedrock or climate will not compromise long-term safety."*

The safety of final disposal up to a million years from the present must be proven with sufficient confidence. This is why the term 'long-term safety' is used when referring to final disposal. It covers environmental radiation safety also after the closure of the final disposal facility. As the studied time periods are very long, the long-term safety is based on experimental research activities and computer modeling.

The first safety prerequisite of the final disposal of spent nuclear fuel depends on the properties of the spent nuclear fuel. Inside the hermetically sealed metal tubes, the spent nuclear fuel is in its ceramic state, meaning that it is solid and dissolves poorly in water, which would slow down the release of radioactive substances if the spent nuclear fuel came into contact with groundwater in the bedrock. *(Posiva 2012a)*

In the KBS-3 concept spent nuclear fuel is placed inside several barriers that are independent from each other in order to prevent interaction with the environment. The barriers must be based on carefully studied, well-tested, and empirically proven high-quality technology. The barriers must effectively prevent the release of radioactive materials in the disposed spent nuclear fuel into the bedrock for at least several thousand years. One failed barrier does not compromise the isolation. There are both engineered and natural barriers. Engineered barriers include the copper and cast iron canister, clay (bentonite) buffer, and tunnel backfill material. The bedrock is a natural barrier: it will limit and slow down the migration of radioactive substances in case one of the canisters is damaged despite all the precautions taken. Furthermore, the bedrock effectively limits direct radiation emitted by the disposal canisters: two meters of rock is enough to attenuate the radiation to the level of natural background radiation (*Posiva 2012a*). The barriers are described in the table below (Table 3-1) and illustrated in the figure (Figure 3-2).

**Table 3-1. Barriers of the final disposal concept and their tasks.**

| | BARRIER | TASK OF THE BARRIER |
|---|---|---|
| Engineered barriers | Copper-cast iron canister | The canister consists of a cast iron insert and a copper shell. The cast iron insert retains the canister's mechanical strength and the copper shell prevents corrosion of the shell. (Raiko et al. 2012) |
| | Clay buffer | The clay buffer is made from bentonite clay, which expands when it comes into contact with water, thus slowing down the corrosion of the canisters. Another task of the clay buffer is to conform to the movements of the rock. (Juvankoski et al. 2012) |
| | Tunnel backfill material | The deposition tunnels will be filled with a material containing bentonite clay to limit the movement of water in the tunnel. (Keto et al. 2012) |
| Natural barriers | Bedrock | One of the tasks of the bedrock is to limit and slow down the migration of radioactive materials. To complete this task, the bedrock must be intact and The deposition tunnels may not run across any major fracture zones. (Posiva 2012b) |

### 3.4.3 Suitability requirements for the final disposal site

According to a regulation (Y/4/2016, section 31) by the Radiation and Nuclear Safety Authority (STUK), the bedrock properties of the selected final disposal site must, as a whole, be favorable for the isolation of radioactive substances from the biosphere. The selected site may not have any evident unfavorable properties in relation to long-term safety.

According to the regulation (Y/4/2016, section 31), the potential final disposal site must contain adequately large and intact bedrock volumes, in which the final disposal facility can be constructed. There may not be any significant or exceptional amounts of exploitable natural resources at or in the vicinity of the final disposal site. Positioning, excavation, construction, and closing of the underground facility must be implemented in such a manner that the bedrock properties important for the long-term safety will be conserved as well as possible. The depth of the repository must be appropriate for the waste type and the local geological conditions. Events, activities, and changed conditions at the ground level may only have a minor impact on long-term safety, and entry of humans into the final disposal facility must be made difficult. (Y/4/2016, section 31)

Properties favorable for the bedrock hosting a final disposal facility are described in more detail in the STUK regulatory guide for disposal of nuclear waste (YVL D.5):

- Stability and water tightness of the bedrock
- Low groundwater flow
- Favorable groundwater chemistry

- Retention of radioactive substances in the bedrock
- Protection against natural phenomena and human activities.

The bedrock properties must be favorable for long-term performance of the engineered barriers. All bedrock properties influencing long-term safety must be stable. Location of the final disposal facility must be beneficial in terms of observed groundwater flow. According to STUK's YVL Guide D.5, the depth of final disposal must be chosen so that it is favorable for long-term safety and considers the geological structures, as well as changes caused by the final disposal depth in hydraulic conductivity, hydrogeochemistry, and mechanical stability of the bedrock. The final disposal facility must be placed at a depth of several hundred meters, so that the impacts of natural phenomena at ground level, such as glaciation and human actions, will be adequately attenuated.

STUK's YVL Guide D.5 also determines a number of properties indicating unsuitability of a potential final disposal site:

- Proximity of exploitable natural resources
- Unacceptably high stress fields when compared to the strength of the bedrock
- Exceptionally high seismic or tectonic activity
- Exceptionally disadvantageous groundwater properties, such as the lack of redox capacity and high concentrations of substances that may impair the performance of safety factors

Geological criteria used in previous site selection studies in Finland are as follows (*Salmi et al. 1985, Anttila 1995*):

- <u>Topography</u>, which is an indication of the variability in elevation and hydraulic pressures controlling groundwater movements. In most parts of Finland, the topography is flat. Steep topography may be an indication of fragmented bedrock, which in turn influences the stability of the bedrock and groundwater flow.
- <u>Bedrock stability</u>, which determines whether the disposal canisters will stay in place deep in the bedrock. The Fennoscandian Shield is seismically stable at present and no significant changes in the prevailing conditions are expected. Bedrock movements in the future, such as after the next ice age, can be expected to focus on the existing deformation zones. The stresses in the Earth's crust will be released along these deformation zones and thus the final disposal facility will be positioned in between the pre-existing deformation zones.
- <u>Type of the rock</u>, which has an effect on bedrock strength, thermal properties, integrity, water content, and radionuclide retention capacity. Granitic rock types typically occur as large homogeneous formations that normally have a rather regular fracturing geometry. On the other hand, basic rocks, such as gabbros, composed of iron and magnesium minerals, have a better sorption capacity than predominantly quartz- and feldspar-bearing granitic rocks. However, clay- and mica-bearing fracture infillings in granitic rocks improve their retardation properties.
- <u>Bedrock fracturing</u> (quality of bedrock), which affects hydraulic conductivity, rate of groundwater flow, and flow routes. Bedrock fracturing also influences the constructability of the final disposal facility. The purpose of the studies is to locate fractured bedrock sections (fracture zones) so that they can be avoided when placing the final disposal facility, if necessary. Groundwater flow along fracture zones is the most important natural mechanism that may cause migration of radionuclides from the final disposal facility to the ground level.
- <u>Size of the research area</u>: the area must be large enough to allow the construction of the final disposal facility at a safe distance from the fracture zones.

– Exposure of the bedrock (number and distribution of outcrops), which affects the general investigability of the site. An area that does not include any exposed bedrock is difficult to study. A low number of outcrops make the studies laborious as more measuring and deep drilling is needed.
– Natural resources, which may have significance for the future use of the site. Some rock types in Finland, such as basic rocks, have a higher ore potential, which makes them more attractive targets for future research and mining activities. However, there are also geological units with ore potential that are partly independent of rock types in the Finnish bedrock, and these should be avoided as well. In addition, groundwater reserves potential for public water supply are also considered important natural resources.

In addition to the safety criteria described above, the operator can set more detailed criteria for the final disposal site concerning bedrock and groundwater quality, as well as requirements on technical and economic factors. Furthermore, the site selection must respect the demands of public acceptance.

## 3.5 Phases of the final disposal project

The final disposal project consists of several phases: the preliminary investigation phase, the research and planning phase, the construction phase, the operational phase, and the decommissioning phase. These phases for the KBS-3V concept (vertical canisters) are described in more detail in the following chapters. The differences between the KBS-3V concept and the KBS-3H concept (horizontal canisters) are minor in terms of the environmental impact assessment. Publicly available materials have been used when preparing the description. The plans for the facility will be further specified as the project progresses.

An illustration (Figure 3-3) shows the underground and aboveground parts of the encapsulation plant and final disposal facility.

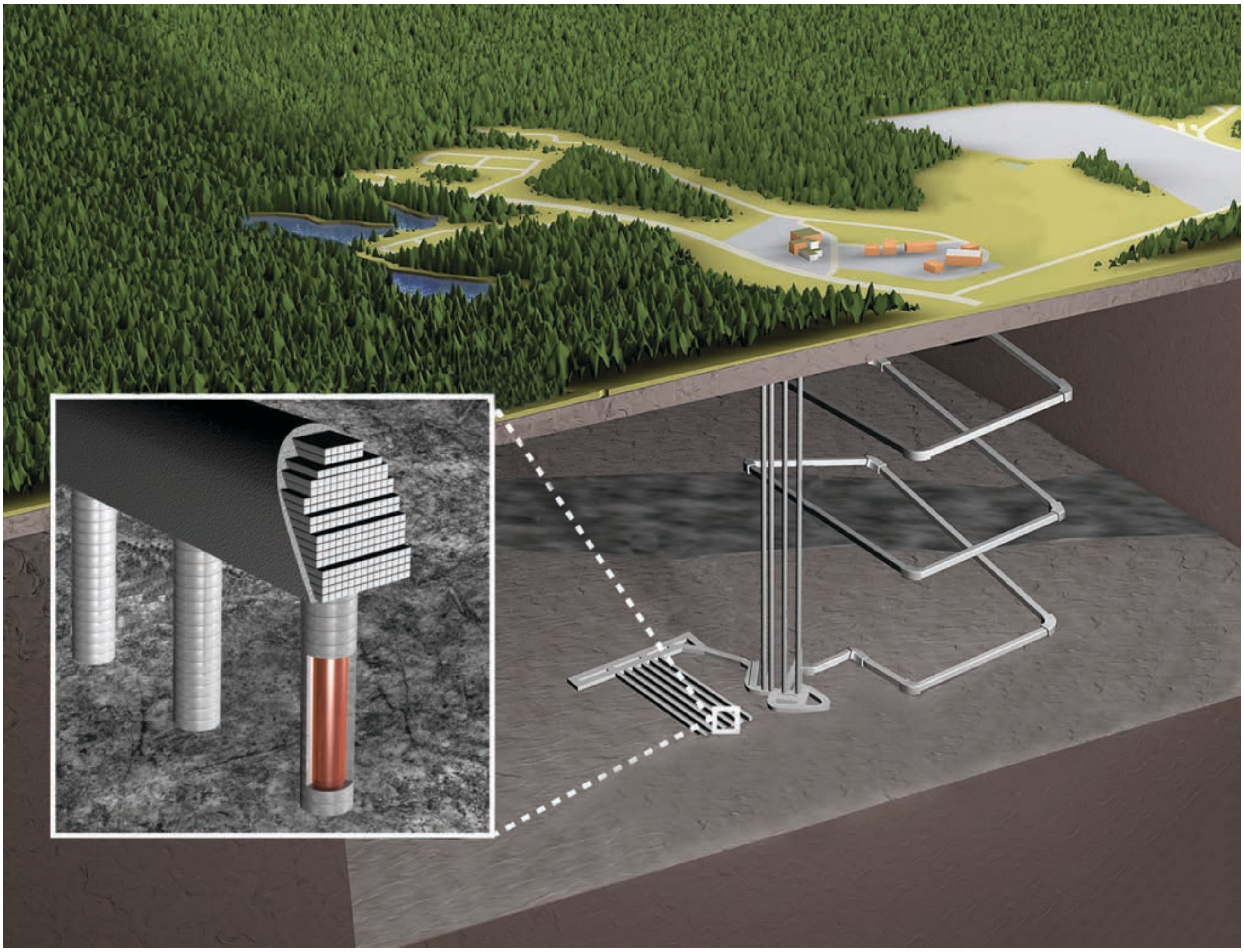

**Figure 3-3. Illustration of the encapsulation plant and final disposal facility. Figure by Posiva Oy (edited).**

### 3.5.1 Preliminary investigation phase

The suitability of the Finnish bedrock for the final disposal of spent highly radioactive nuclear fuel has been studied since the late 1970s. The first investigations were general in nature, focusing on, for instance, geological factors important for final disposal (*Niini et al. 1982*) and on major structures of the Finnish bedrock (*Vuorela & Hakkarainen 1982*). Based on these studies it was concluded that it is possible to find a site for final disposal that meets the geological safety criteria.

In 1983–1985, the Geological Survey of Finland (GTK) carried out a nation-wide site selection study (*Salmi et al. 1985*). The starting point for the study was a hypothesis of mosaic structure of the bedrock, where intact bedrock blocks are limited by deformation zones of different sizes. Smaller research areas were defined within these major blocks, called target areas. They are limited by smaller deformation zones. These research areas were considered to have potential for further investigations and be possibly suitable for final disposal in terms of their size and general properties (Figure 3-4). A target area may consist of one or several research areas. During the latter phases, various geological investigations will be carried out in each of the research areas and the location of the final disposal facility will be determined based on the results.

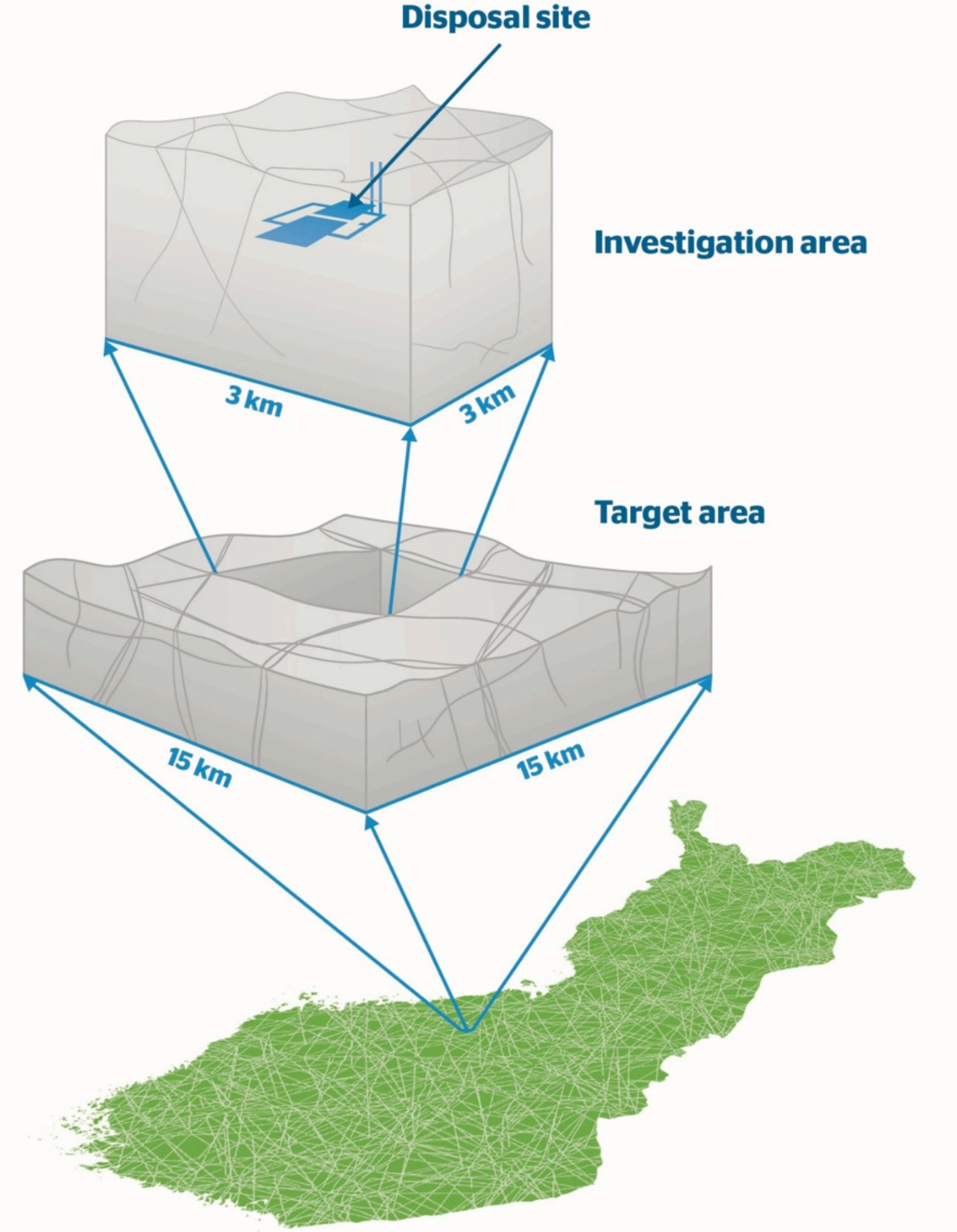


**Figure 3-4. The site selection principle. Major fracture zones delimit a large bedrock block (a target area), inside which minor fracture zones border a research area.** ***(Teollisuuden Voima 1992)***

The goal of the preliminary investigation phase is to identify intact, sufficiently large and homogeneous bedrock blocks that can be further studied to assess their suitability for final disposal. The chosen bedrock block must be large enough and have such properties that the final disposal facility can be constructed within at a safe distance from fracture zones. In practice, around 5 $km^2$ has been considered a sufficient size for a research area.

The first task is to update the lineament interpretations of the site. Based on this work, the boundaries of the possible research areas can be determined. The lineament interpretations carried out in 1983–1985 (*Salmi et al. 1985*), updates done after 1985 (*Kuivamäki 2009, Korja & Kosonen 2015*), an elevation model of the National Land Survey based on laser scanning data, and a rougher digital elevation model can be used as the initial data. Interpretation of the topographic lineaments can be supplemented by the interpretation of geophysical lineaments using low-altitude airborne magnetic and electromagnetic data by GTK. The lineaments can be divided into four size categories (Table 3-2) based on these data. The actual research areas will be defined based on the lineament interpretation. Typically, they are limited by class 2 or 3 lineaments (Figure 3-5).

**Table 3-2. Classification of the potential deformation zones (lineaments). Modified after Salmi et al. (*1985*).**

| LINEAMENT SIZE CLASS | LENGTH | WIDTH (ESTIMATED) |
|---|---|---|
| 1 | From tens of kilometers to several hundred kilometers | > 1000 m |
| 2 | From five kilometers to tens of kilometers | Several hundred meters |
| 3 | 1-5 km | 10-100 m |
| 4 | < 1 km | < 10 m |

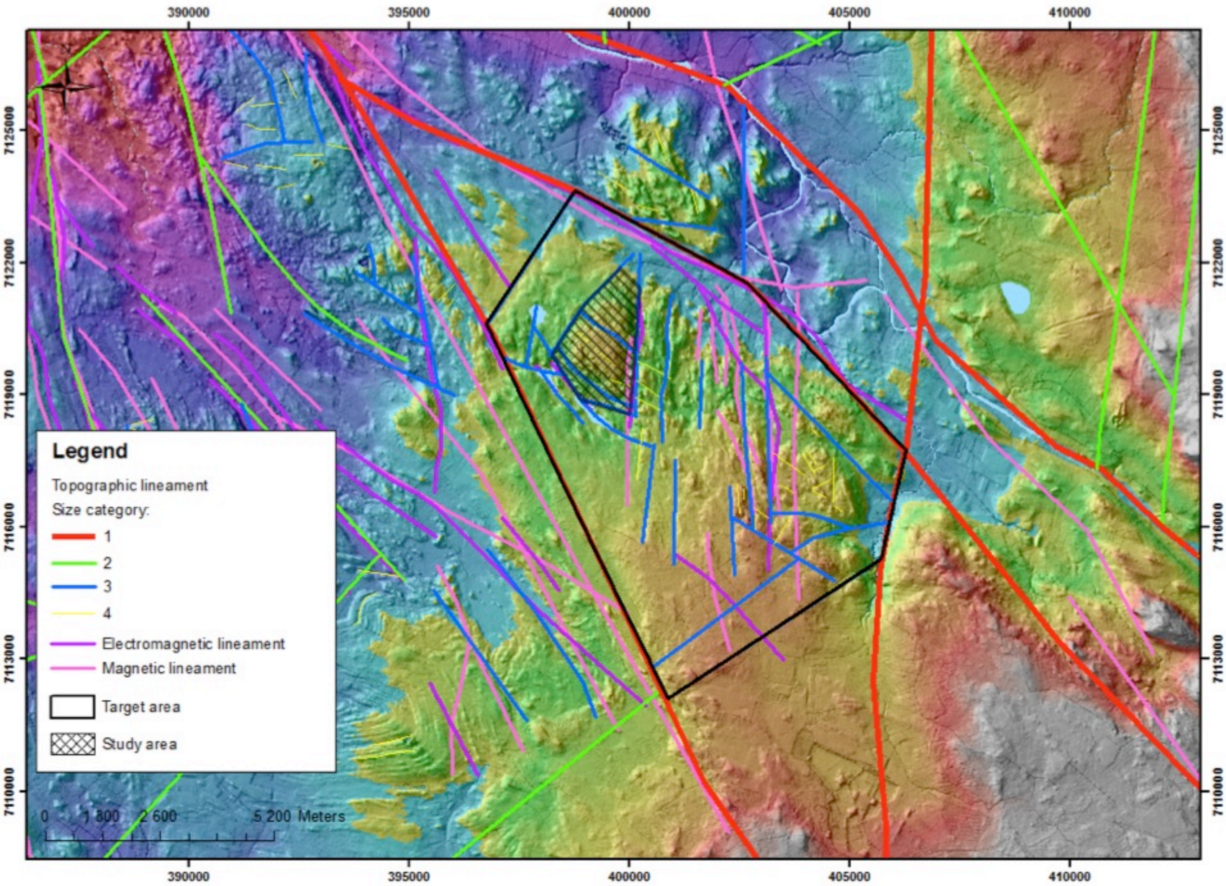


**Figure 3-5. An example of a research area limited by lineaments. The research area (marked in black) is determined mainly according to class 3 lineaments.**

In addition to the lineament interpretation, the most important suitability characteristics of the research areas will be determined, including lithology, size, number of outcrops, topography (differences in elevation), geophysics, mineral potential, existence of nature conservation and groundwater areas, and hydrogeology. Each parameter will be scored using a three-tier grading system of 1, 0, and -1, where 1 stands for the best and -1 for the worst rating. The table below (Table 3-3) provides the criteria to be used in the scoring.

**Table 3-2. Example of the criteria to be used when scoring the research areas.**

| PROPERTY | 1 | 0 | -1 |
|---|---|---|---|
| Rock type | One intrusive rock type | Two intrusive rock types | Supracrustal rock types (gneisses, schists, vulcanites) |
| Size, $km^2$ | > 10 | 5-10 | < 5 |
| Exposure | Very exposed | Fairly exposed | Poorly exposed |
| Topography (max. difference in altitude, m) | < 10 | 10-30 | > 30 |
| Number of fracture zones (lineaments) | Small | | Large (> 15) |
| Geophysical properties | No anomalies or random weak/ moderate anomalies | Moderate anomalies or random strong anomalies | Plenty of strong anomalies |
| Known ore-mineral deposits | No | No | Yes (exclusive) |
| Nature conservation areas and ground-water areas | No | No | Yes (exclusive) |

Based on the scores, the research areas will be divided into four classes as follows:

Class I: Primarily recommended research areas

The research areas in this class typically have well-exposed bedrock, consisting of only one felsic plutonic rock type, a smooth topography and a small number of internal lineaments (potential fracture zones). They are geophysically stable/non-anomalous.

Class II: Secondarily recommended research areas

The research areas of this class are closely comparable to the areas of Class I, except that they have stronger geophysical anomalies, which may reflect the structural heterogeneity of the bedrock. These areas may be suitable for further investigations, but a more detailed interpretation of geophysical data, possibly combined with geological field checking, is needed to clarify the nature of the geophysical anomalies.

Class III: Research areas recommended with reservations

These research areas are rather small, poorly exposed, lithologically heterogeneous, and they have strong geophysical anomalies. Due to the lack of bedrock outcrops, their geological characteristics are difficult to determine without extensive drilling.

Class IV: Not recommended research areas

These research areas include or are located near (within 500 meters) of a distinct nature conservation or groundwater area, or they have ore mineral potential. Areas with steep topography and large number of internal fracture zones (lineaments) are also included in this category.

Regardless of its properties, a research area will not be recommended for further investigation if there is an ore deposit within the research area, or if an important nature conservation or groundwater area is located within a radius of 500 meters from the research area.

An assessment of environmental factors will be done for research areas recommended primarily or secondarily for further investigation. Factors to be studied include land use planning and land use, settlements, real estates, landscape, cultural history, nature, conservation areas, and the transport network (Table 3-3). Based on these factors, suitability of the area for further investigation will be assessed and determined as good, moderate, or poor.

The potential of the areas for further investigation will be assessed based on the geological and environmental studies. Socio-economic factors and public acceptance will also be taken into account in the final selection.

Of the alternative locations listed in this EIA program, the preliminary research phase has been completed in Pyhäjoki. One research area that may be suitable for final disposal (Sydänneva) was identified. As for Eurajoki, the preliminary investigation phase will be started after the submission of the EIA program and the actual research area will be indicated prior to the EIA report phase (see Chapter 2.4.1).

**Table 3-3. An example of the aspects to be studied during the assessment of the research areas' environmental factors, the data to be studied, the scope of the research areas, and suitability factors.**

| ASPECT | STUDIED INFORMATION | SUITABILITY FACTORS |
|---|---|---|
| Land use planning and land use | Currently valid and pending regional plans, local master plans, local detailed plans, and other plans on the land use of the area prepared by the authorities. The size of the assessment area is around 5 km. | Current and planned land use of the area and activities determined with land use plan markings: **There are no major land use limitations for the area.** |
| Population | Residential buildings, vacation properties, and population centers in the research area, in the immediate vicinity of the research area, and at a radius of five and twenty kilometers from the research area. The assessment area's size is around 20 km. | Residential buildings and vacation properties in the area, buildings in the immediate vicinity (particularly less than 500 meters away from the area), and closest population centers: **The area is sparsely populated.** |
| Landscape and cultural history | Valuable landscapes (nationally and regionally valuable landscapes), sites of cultural or historical value (built cultural environments of national or regional significance), and historical monuments (antiquities, wrecks, loose relics of antiquity, etc.). The assessment area size is around 5 km. | Valuable landscape and cultural history sites in the area and in the immediate vicinity of the area, and their protection value: **There are no important landscape or cultural history sites to be protected in the area.** |
| Natural environment and protected areas | Natura areas, FINIBA and IBA bird areas, nature conservation areas, sites included in national nature conservation programs, bedrock areas, moraine formations, eolian deposits or shore deposits of national importance, surface water areas and groundwater areas, and any other nature values of the area. The assessment area size is around 10 km. | Sites in the area and in its immediate vicinity (especially Natura 2000 areas and other nature conservation areas): **There are no major conservation areas or protected sites in the area or in its immediate vicinity.** |
| Transport network | Existing ports and local traffic networks, including main roads and railroads. The assessment area size is around 5 km. | Location of transport networks in relation to the area: **There are no major transport networks in the area.** |
| Properties | Property limits and number of properties in the area. The assessment area size is around 1 km. | Property information was collected for background information and applicability of the area was assessed based on the number of residential buildings and vacation properties, and their locations. |

### 3.5.2 Research and planning phase

The research and planning phase will start with detailed characterization of the geological properties of the research areas that may be suitable for final disposal. The geological characterization will include deep drilling and research realized in boreholes to study, for instance, the quality of the bedrock, the groundwater and flow conditions, and the mechanical properties of the bedrock.

A description (or model) combining data from various branches of science will be prepared for each research area to be used when assessing suitability of the area for final disposal. Furthermore, an environmental impact assessment and a preliminary safety assessment of the final disposal site will be prepared for the Decision-in-Principle application, at the latest.

The research will proceed in stages so that a Decision-in-Principle for the construction of the encapsulation plant and final disposal facility can be applied for after several years of research. Once a positive Decision-in-Principle (see Chapter 4.3.1) has been obtained and the final disposal site has been selected, the studies of the bedrock properties will continue at the selected site. New research holes will be drilled from ground level to conduct more detailed groundwater and bedrock studies. The research area model will be updated and a decision on constructing an underground research facility will be made based on the results.

During the investigations at ground level, some trees will have to be felled from the research area to make room for drilling sites, measuring lines, and roads. Furthermore, some soil cover may have to be removed to reveal the surface of the bedrock for the geological survey of the bedrock. Once the research is complete, the research excavations made for these surveys will be covered up and landscaped. Water will be used during drilling to flush the drill head, and the return water will be pumped into the surrounding environment. The return water is tap water used during drilling mixed with the groundwater in the bedrock, which means that it is generally clean. However, groundwater from deep within the bedrock may be considerably saline. This is why collecting the return water in a tank and transporting it to a larger water system or a water treatment plant may be necessary, particularly with drilling holes more than 500 meters deep.

More detailed information about the final disposal concept for Fennovoima will be collected during the research and planning phase. The planning will include design of the disposal canister for the fuel assemblies used in the Fennovoima nuclear power plant. The design of the actual final disposal facility will begin during the planning phase. The results of the above-mentioned studies and the special characteristics of the site will be taken into account in the design. The design of the final disposal facility will be promoted throughout the research phase, and the facility plan will be updated with the more detailed information about the bedrock of the site. The design of the encapsulation plant will also start. The research, design, and development work of the encapsulation plant and final disposal facility will continue throughout the project period.

### 3.5.3 Construction phase

The research phase (see Chapter 3.5.2) will continue simultaneously with the construction phase to ensure that the properties of the bedrock are favorable for final disposal. The research facility will be constructed at the construction phase, followed by the underground final disposal facility.

#### *Construction of the research facility*

The underground research facility will be a tunnel or shaft excavated into the bedrock. The underground research facility will be connected to the final disposal facility at a later stage. The research facility can be used to study the bedrock in more detail using geological, hydrological, and geochemistry research methods to obtain more information about the geological properties and groundwater conditions at the final disposal depth. The studies will verify the suitability of the selected site for final disposal. The geological properties will be studied by drilling research holes from the research facility and studying the rock surfaces in great detail. The groundwater conditions can be studied from the research holes drilled from the research facility and investigation holes drilled during excavation. Furthermore, the strength of the bedrock and its mechanical properties can be studied by means of various measurements and test arrangements during the construction of the research facility. The research facility will be constructed with great care to ensure that the bedrock's properties that are favorable for final disposal will not be compromised.

A research facility tunnel will be constructed by means of drilling and blasting. The volume of the tunnel will be around 350,000 $m^3$ *(Hagros et al. 2014).* The dimensions of the tunnel and its layout plan will be specified as the project planning progresses.

### *Construction of the final disposal facility*

The final disposal facility to be excavated into the bedrock will consist of several parts, such as final disposal tunnels, central tunnels, and auxiliary underground technical facilities. A vehicle tunnel and vertical shafts, such as a personnel shaft, a canister shaft, and ventilation shafts, will run from the ground level to the final disposal facility. The final disposal facility could also be constructed without a separate vehicle tunnel. In such a case, the only access route to the final disposal facility would be an elevator. Construction of the final disposal facility for the spent nuclear fuel generated by Fennovoima will require around 50 hectares of bedrock suitable for final disposal *(Hagros et al. 2014)*.

Construction of the underground final disposal facility will start with the excavation of the central tunnels and final disposal tunnels. A construction license pursuant to the Nuclear Energy Act will be required for the construction of the final disposal tunnels. The final disposal tunnels will be excavated in stages, depending on the amount of spent fuel to be placed in the final disposal facility, probably by means of drilling and blasting. The excavation will be completed with great care to ensure that the bedrock's properties that are favorable towards final disposal are not compromised. The depth position of the final disposal facility will be determined by the geological properties of the selected final disposal site. In any case, the final disposal will take place at a depth of several hundred meters. According to preliminary estimates, the volume of the final disposal tunnels will be around 200,000–250,000 $m^3$ (*Hagros et al. 2014*). The dimensions of the final disposal tunnels will be specified as the project planning progresses.

Crushed rock will be generated during the excavation of the underground facilities. It will be placed in temporary heaps in the research area or in its immediate vicinity. Whenever possible, the crushed rock will be used to construct roads and fill the foundations of the buildings above ground level. Any excess crushed rock will be utilized outside the research area. The excavation, rock crushing, and sorting of the crushed rock will cause some noise, vibration, and dust formation in the immediate vicinity of the area.

Leakage water will gather in the facilities to be constructed. The leakage water will consist of groundwater from the bedrock, as well as drilling water and flushing water used in the tunnel during its construction. For example, 30–35 liters of water per minute seeps into the underground research facility ONKALO at Olkiluoto in Eurajoki *(Vaittinen et al. 2016)*. It is safe to assume that roughly a similar amount of water will seep into Fennovoima's underground research facility. If a vertical shaft is selected as the research facility format, it is likely that much less water will seep in. The estimate of leakage water will be specified based on the data obtained when studying the bedrock. The actual volume of water seeping into the tunnel or shaft cannot be measured until construction is underway. The amount of water seeping into the tunnel or shaft will be reduced by grouting of the rock, but the seeping can never be fully prevented. The leakage water will be pumped into a sedimentation basin to be built in the tunnel. When solids have settled at the bottom of the basin, the remaining water can, depending on the pH value and salinity of the groundwater, be drained into ditches, for example. The quality of the leakage water will be monitored, and the water can be neutralized, if necessary. Any oil that has leaked from machinery into the water in the sedimentation basin will be separated in oil traps or by using another method.

***Construction of the encapsulation plant and other facilities above ground level***

An encapsulation plant for spent nuclear fuel will be constructed above ground level. Other auxiliary facilities will also be constructed above ground level, such as a ventilation building, a hoist building, a research facility, offices, a building housing tunnel technology elements, maintenance halls, storage halls, and staff facilities. According to a preliminary estimate, around 30 hectares will be required to construct the buildings above ground level. If necessary, new roads and power lines will also be built for the area.

### 3.5.4 Operational phase

The operational phase includes the transport, encapsulation, and final disposal of the spent nuclear fuel in the bedrock. These activities are described in more detail in the following chapters. The construction and operational phases will partially overlap: the final disposal tunnels will be constructed in stages, depending on the amount of spent fuel.

#### 3.5.4.1 Transport of spent nuclear fuel

After interim storage in the Fennovoima nuclear power plant area, the spent nuclear fuel will be transported in transport containers specifically designed for this purpose to the encapsulation plant to be built at the final disposal site.

Transport containers specifically designed for this purpose will be used to transport the spent nuclear fuel from the Hanhikivi nuclear power plant to the encapsulation plant. Such containers are available from several manufacturers. The purpose of the transport containers is to protect the spent fuel from damage during transport and to protect the environment from the fuel in case of an accident. The containers must pass several different tests in order to be approved for use in the transport of spent nuclear fuel.

A preliminary report on the transport *(Fennovoima 2009)* states that large amounts of radioactive substances cannot spread into the environment in a potential accident involving the transport of spent nuclear fuel. Even in the most severe case, mainly the transport personnel and any people in the immediate vicinity of the accident site could be exposed to elevated radiation levels. The transport containers are designed in compliance with the statutory requirements in such a manner that an accident during transport will not have any direct health effects. STUK's YVL Guide D.2 (Transport of nuclear materials and nuclear waste) and the IAEA's Guides *(IAEA 2012 & 2008)* will be taken into account when planning the transport of spent nuclear fuel.

The spent nuclear fuel may be transported from the Hanhikivi nuclear power plant to the encapsulation plant and final disposal facility by road or using a combination of road, rail, and sea transport, depending on the location of the encapsulation plant.

In road transport, a special carriage hauled by a truck will be used. Road transport will take place under supervision, and each transport will be escorted by supervision and security personnel. In urban areas, police patrols will close off the crossing streets as the transport convoy passes the area. Taking into account the required stops, the average speed of the transport convoy will be approximately 35 km/h. In the road transportation alternative, the transport convoy would start at the Hanhikivi nuclear power plant and proceed via Hanhikiventie road to the Highway 8. From the intersection of Hanhikiventie and Highway 8, the spent nuclear fuel transport convoy would proceed towards the final disposal site.

If only road transport were to be used, around 120–180 transport convoys would drive from the nuclear power plant to the encapsulation plant and final disposal facility during the entire final disposal operation phase. The final disposal operation phase is expected to take around 20 years.

In rail transport, the train carrying the spent nuclear fuel may not encounter any train carriages carrying hazardous substances, all level crossings would have to be guarded, and the speed of the train would have to be limited to a maximum of 40 km/h. In the rail transportation alternative, the spent nuclear fuel would first be transported by road from the Hanhikivi nuclear power plant to the port in Raahe via the following route: nuclear power plant – from Hanhikiventie road to Highway 8 – northwards along Highway 8 – to Koksaamontie – to the railway stop of the Raahe port. The transport distance would be approximately 27 kilometers. At the Raahe railway stop, the transport container would be transferred to a low loader wagon designed for special heavy transport. From the railway stop, the rail transportation convoy would proceed towards the final disposal site, where the transport container would be transferred by road from the nearest rail transport offloading site to the final disposal site.

Sea transport would start at the Hanhikivi nuclear power plant. The planned dock basin and wharf to be constructed on the western shore of the Hanhikivi headland are designed in such a manner that spent nuclear fuel can be loaded into a vessel for sea transport. Sea transport of spent nuclear fuel would require a vessel specifically designed for the transport of high-level nuclear material.

More detailed transport methods and routes to the alternative final disposal sites will be determined in separate transport reports. The transport reports for the different modes of transport will be prepared in such a manner that they can be used in the EIA report.

#### 3.5.4.2 Encapsulation

The first of the final disposal measures will be the packaging of the spent nuclear fuel into a disposal canister at the encapsulation plant. According to a preliminary estimate, around 700–900 canisters to be placed in the final disposal facility will be needed. A disposal canister is a massive metal container with a cast iron insert and a copper shell (Figure 3-6).

At the encapsulation plant, the spent nuclear fuel will be taken in the transport container to a reception area at the encapsulation plant. The nuclear fuel elements will be transferred via remote control inside strong radiation protection walls from the transport container to the disposal canister. Once the canister is full, the air inside it will be replaced with inert gas, the cover of the insert will be screwed shut, and the leaktightness of the insert will be verified. The surface of the canister will be cleaned to remove any impurities. After encapsulation, the cover of the copper canister will be welded closed. After verification of the leaktightness of the weld, the disposal canister will be transferred in an elevator or via a vehicle tunnel to a disposal tunnel deep within the bedrock. *(Palomäki & Ristimäki 2012)*

The encapsulation plant will be designed in such a manner that the personnel will work in radiation protected areas. There will be under pressure in the nuclear fuel processing facilities to prevent radioactive releases from spreading from the processing facilities to the other parts of the plant during exceptional situations. Under normal conditions, no radioactive substances will be released into the encapsulation plant rooms. The worst-case scenario for the encapsulation plant is an accident where a canister falls from a canister hoist in such a manner that the fuel rods inside the canister are damaged and the canister itself is also damaged. Such an accident could lead to gaseous and particulate radioactive releases into the encapsulation plant, which would be collected by the filters of the ventilation system. (*Rossi & Suolanen 2013*) The plant's filtering systems will considerably reduce the amount of releases. According to the regulatory requirements, no radioactive releases into the environment that exceed the limit and guideline values may occur at the encapsulation plant.

All structures of the encapsulation plant and final disposal facility will be designed and constructed in compliance with nuclear regulations and in such a manner that any situations, even accidents during the different handling sequences of the spent nuclear fuel leading to major damage to the nuclear fuel, cannot pose any immediate health hazards to the personnel or the local residents.

Low and intermediate level operating waste, such as air and water filters, protective clothing and gloves, and radioactive solutions from the decontamination of radioactive surfaces, will be generated at the encapsulation plant during its operation. This waste will be processed and packaged. Separate facilities for the processing of low and intermediate level waste will be constructed at the encapsulation plant. The operating waste will be placed in a separate underground space in this area.

**Figure 3-6. The insert and outer shell of a disposal canister. The image shows a canister for the spent nuclear fuel from the Olkiluoto 1 and 2 reactors. It has a diameter of 1.05 meters and is 4.8 meters long. Figure by Posiva Oy. The Fennovoima canisters will be slightly longer and have a different type of insert.**

#### 3.5.4.3 Final disposal

The disposal canister will be transferred to the underground facility directly from the encapsulation plant on a pallet in an elevator or via a vehicle tunnel. The disposal canister will be taken to the actual final disposal tunnel with a transport vehicle specifically designed for this purpose.

Final disposal tunnels will be excavated in advance for the final disposal of each batch of spent nuclear fuel. The location of each final disposal tunnel will be verified by drilling a pilot hole and conducting geological and hydrogeological studies. A geological survey of the final disposal tunnel and leakage water studies will be conducted to determine where the final disposal holes should be drilled.

Also the final disposal holes will be drilled in the tunnel in advance. The final disposal holes will be filled in order, starting from the one at the back of the tunnel. A copper plate and blocks of bentonite will be placed in the bottom of each final disposal hole before the disposal canister. Bentonite is a type of naturally occurring clay that is able to absorb large amounts of water and swell to up to ten times its original volume. The swollen bentonite will seal the space surrounding the copper canister; this will prevent water from contacting the canister and also prevent radioactive substances from accessing the bedrock in case of a leak. In addition, the bentonite buffer around the canister will protect the canister from mechanical stress (i.e. any movements of the rock). *(Palomäki & Ristimäki 2012)*

When all the final disposal holes have been filled with canisters and sealed with bentonite, the tunnel will be backfilled and its mouth will be sealed with a plug structure specifically designed for this purpose. Final disposal holes and tunnels will be filled in stages throughout the final disposal operation phase. *(Palomäki & Ristimäki 2012)*

Placing a canister into a final disposal hole is illustrated in the image below (Figure 3-7).

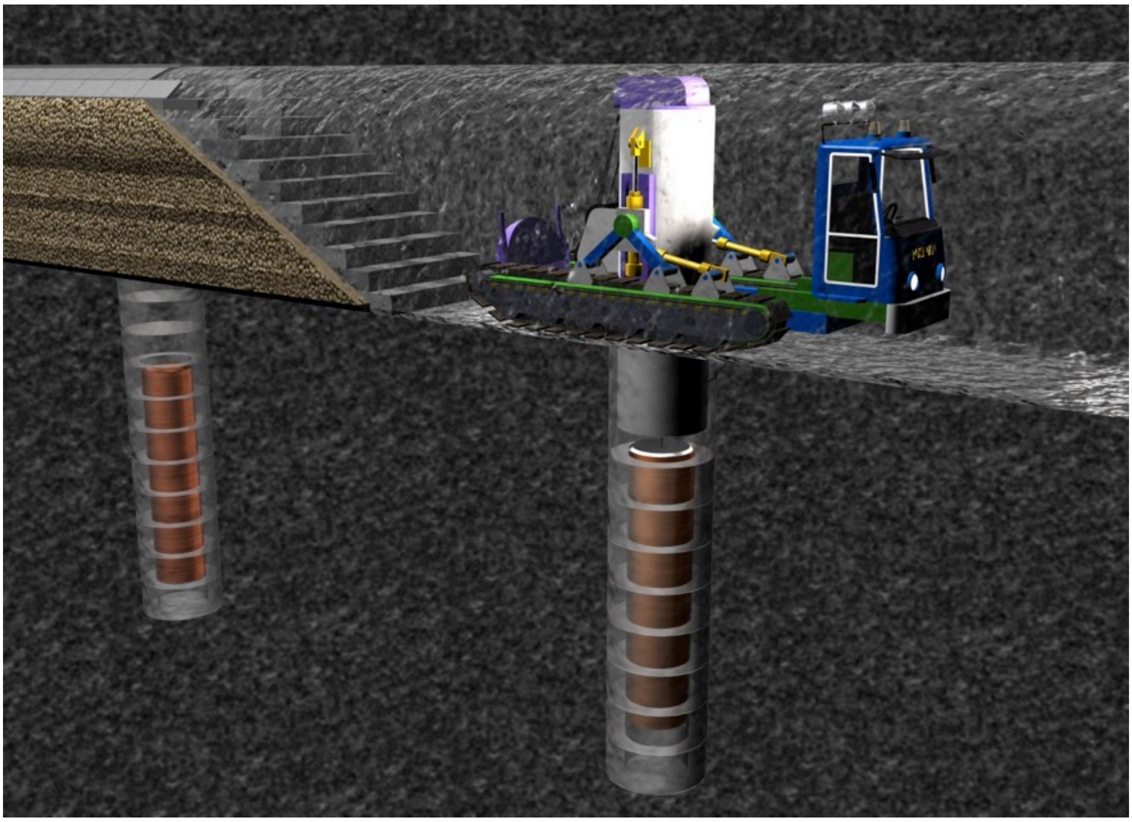

**Figure 3-7. Placing a canister in a final disposal hole. Figure by Posiva Oy.**

### 3.5.5 Decommissioning phase

The operational phase will end with the closure of the final disposal facility. At that time, the final disposal tunnels and the other underground facilities will be backfilled and sealed. The closure of the final disposal facility will take place partially during the operational phase and partially during the decommissioning phase.

The underground facilities will be closed by dismantling all the structures in the facilities, filling the facilities with backfill material (such as blocks of clay and clay pellets), and constructing any barrier structures. At the decommissioning phase, the auxiliary underground facilities and research holes will be closed first, followed by other tunnels at the final disposal depth and the access routes to the ground level (i.e. the vehicle tunnel and shafts). The closure of the final disposal facility will be realized in stages to keep the number of open facilities as low as possible. The most important functional requirements during closing will be preventing the creation of flow routes in between ground level and the final disposal facility, as well as preventing inadvertent intrusion into the final disposal facility. *(Palomäki & Ristimäki 2012)*

Of the buildings above ground level, the encapsulation plant and the ventilation building will be dismantled in the manner required for the dismantling of a nuclear facility, unless they can be used for another purpose. Any other unnecessary buildings above ground level will also be dismantled.

The encapsulation plant and final disposal facility will be considered decommissioned once the underground facilities have been closed in the manner required by the Nuclear Energy Act and the Nuclear Energy Decree and there are no longer any structures or facilities containing radioactivity above the ground level. When the facilities have been dismantled, the area will be landscaped in the required manner. The Radiation and Nuclear Safety Authority will approve the decommissioning. Once the Radiation and Nuclear Safety Authority has determined the encapsulation plant and final disposal facility to be properly decommissioned and the area free of radioactivity, the responsibility for the nuclear waste will transfer to the state, pursuant to the Nuclear Energy Act. According to the Nuclear Energy Act, final disposal must, in its entirety, be implemented in such a manner that no monitoring is required afterwards in order to ensure its safety.

# 4 PERMITS, PLANS, NOTIFICATIONS, AND DECISIONS REQUIRED FOR THE PROJECT

The licenses, permits, notifications, and decisions related to the construction and operation of the spent nuclear fuel encapsulation plant and final disposal facility are illustrated in the image below (Figure 4-1).

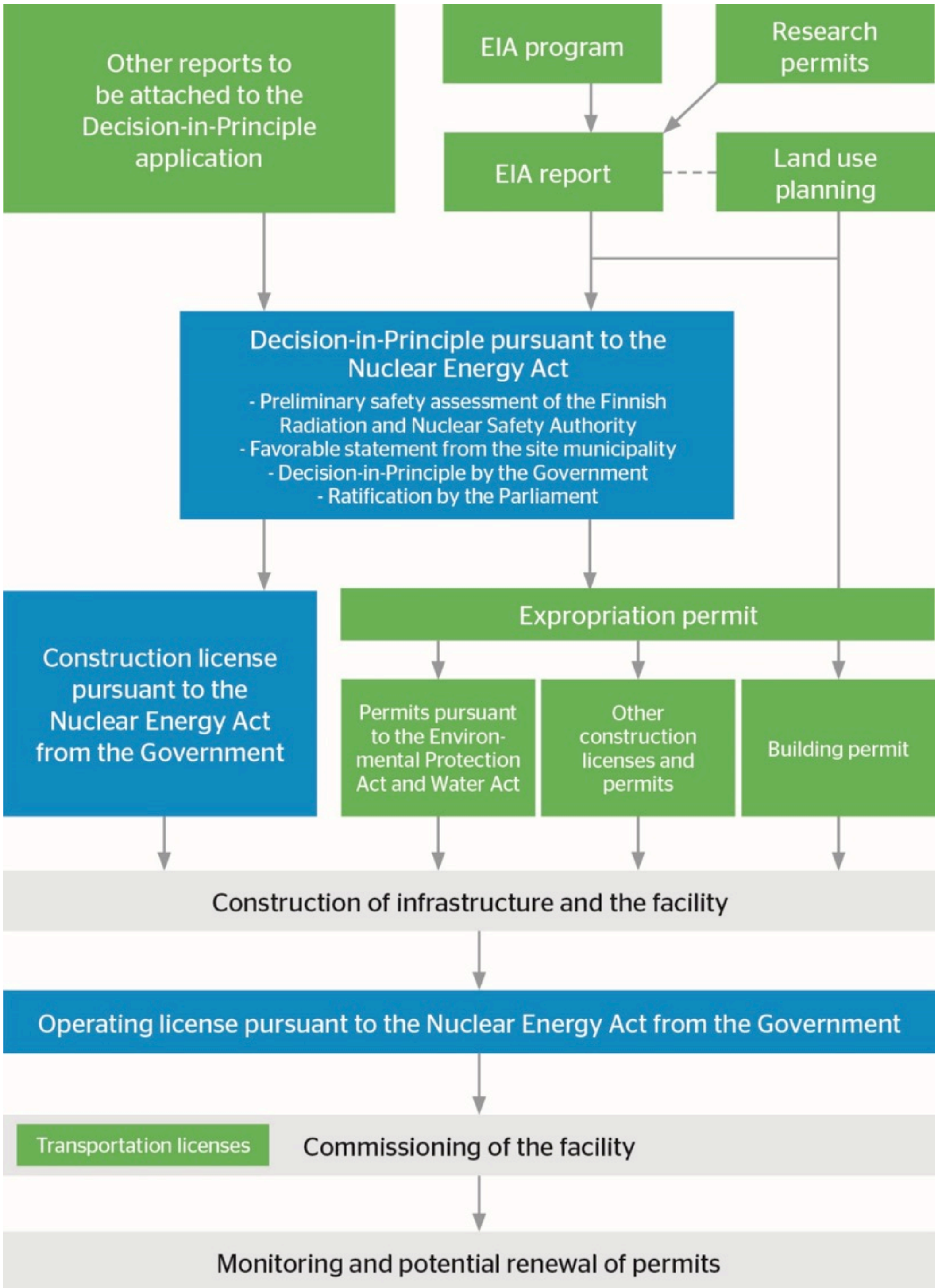


**Figure 4-1. License procedure in the construction and operation of the encapsulation plant and final disposal facility.**

## 4.1 Land use planning and national land use objectives

Land use and construction are regulated by the Land Use and Building Act (132/1999) and the Land Use and Building Decree (895/1999). The land use planning system consists of the national land use objectives and three planning levels: the regional plan, the local master plan, and the local detailed plan.

### *National land use objectives*

The national land use objectives (VAT) are part of the land use planning system pursuant to the Land Use and Building Act (132/1999). The purpose of the national land use objectives is to ensure that matters of national importance are taken into consideration in land use and planning in the entire country. The national land use objectives must be taken into account and promoted in the actions of all state authorities as well as in regional and municipal planning.

The objectives are mainly implemented in regional planning where the objectives are aligned with regional and local conditions and objectives. The objectives are also taken into consideration in the regional plan and regional programs. The nature of some objectives requires that they must be taken directly into account in municipal planning. In municipalities, the local master plan comprises the central plan level when concretizing the national land use objectives and the regional land use plan. *(Environmental Administration 2016a)*

The link between the project and the national land use objectives will be studied in connection with land use planning and taken into account in the land use planning of the area, where applicable.

### *Land use planning*

<u>The regional plan</u> is the master plan for land use within a region or a part thereof. It presents the principles of land use and the urban structure and indicates areas important for regional development. The purpose of the regional plan is to settle national, regional, and local issues regarding land use. The regional land use plan can also be prepared in stages, as a plan concerning a certain entity.

The regional plan guides planning in municipalities and other land use planning by the authorities. The plan is presented on a map using plan symbols and regulations. The regional plan also includes a review, presenting the plan's objectives, impact, and other information required for the interpretation and implementation of the plan.

The regional plan is prepared by the regional council and approved by the regional assembly. The plan is ratified by the Ministry of the Environment, after which it becomes legally valid. The council's decisions can be appealed to the Ministry of the Environment. The Ministry's decisions, in turn, can be appealed to the Administrative Court.

<u>A local master plan</u> is the general land use plan of a municipality. Its purpose is to define the locations for various urban functions, such as housing, services, workplaces, and recreational areas, as well as to organize the connections between them. Master planning defines the principles of targeted development and prescribes the preparation of town plans for the area.

The local master plan can apply to the entire municipality or a specific area, in which case it is called a 'component master plan'. The plan is presented on a map, including plan symbols, regulations, and a review.

The municipality is responsible for preparing the local master plan. The plan is approved by the city or municipal council. If municipalities have prepared a shared local master plan, it is approved by a joint body and ratified by the Ministry of the Environment. The master plan enters into force once its approval is publicly announced.

A local detailed plan defines the future use of an area. The plan defines, for example, the environment to be preserved, as well as what can be built and how. The plan can also define the location, size, and purpose of buildings. The local detailed plan can apply to an entire residential area, including housing, work, and recreational areas, or to a single lot. The local detailed plan is prepared by the municipality. The plan includes a map and plan symbols and regulations. The local detailed plan includes a review describing the plan's preparation process and key features. Building in coastal areas can be regulated with a shore plan.

At the environmental impact assessment phase of the project, the preparation and revision needs of the regional, general, and detailed plans for each project site due to the encapsulation plant and final disposal facility and related activities, such as traffic and power transmission connections, will be studied. The implementation of the plans and any changes to the plans will start at an appropriate stage so that the participation arrangements, studies, and assessments of land use planning and the environmental impact assessment can be combined where applicable.

Implementation of the encapsulation plant and final disposal facility requires that the necessary areas for the facility have been indicated in the land use plans for the planned site location. In practice, construction of the encapsulation plant and final disposal facility in the locations specified in this EIA program will require the preparation of land use plans at all the land use planning levels in compliance with the procedures laid down in the Land Use and Building Act (132/1999).

## 4.2 Environmental impact assessment and international hearing

According to the Act on Environmental Impact Assessment Procedure (468/1994) and the Decree on Environmental Impact Assessment Procedure (713/2006), an environmental impact assessment procedure is mandatory for facilities that are designed for the processing and final disposal of irradiated nuclear fuel. The environmental impact assessment report must be included in the Decision-in-Principle application concerning the facility.

Issues on environmental impact assessments crossing state borders have been agreed upon in the Espoo Convention (*Convention on Environmental Impact Assessment in a Transboundary Context*). Finland ratified this Convention of the United Nations Economic Commission for Europe in 1995. The Convention entered into force in 1997.

The parties to the Espoo Convention have the right to participate in an environmental impact assessment procedure carried out in Finland if the detrimental environmental impacts of the project being assessed are likely to affect the state in question. Similarly, Finland has the right to participate in an environmental impact assessment procedure concerning a project located in another state if the impacts of the project are likely to affect Finland.

This assessment in a transboundary context is to be applied to the Fennovoima spent nuclear fuel final disposal project. In Finland, the arrangements fall under the responsibility of the Ministry of the Environment, but the EIA coordinating authority (the Ministry of Economic Affairs and Employment) will compile and consider all statements received during the international hearing.

## 4.3 Licenses pursuant to the Nuclear Energy Act

The Nuclear Energy Act (990/1987) prescribes the general principles of the use of nuclear energy, the implementation of nuclear waste management, and the licenses required for using nuclear energy. The purpose of the Act is to ensure that the use of nuclear energy is in the overall interest of society and safe for people and the environment.

### 4.3.1 Decision-in-Principle

According to the Nuclear Energy Act, the construction of a nuclear facility of considerable general significance, such as an encapsulation plant and final disposal facility, requires a Government Decision-in-Principle on the construction of the encapsulation plant and final disposal facility being in line with the overall interest of society. The Decision-in-Principle must be applied for by submitting an application to the Government.

In addition to basic project information, the Decision-in-Principle application must include reports of the expertise and financial operational conditions available to the applicant and the nuclear facility's general significance for the nation's energy management, the use of nuclear power plants, and their nuclear waste management. Furthermore, the application must include general descriptions of the facility's technical operating principles, the safety principles to be followed in the project, as well as an outline plan for nuclear fuel management and the applicant's plans for organizing nuclear waste management. The application is also to include general descriptions of the ownership and administration of the planned location and its suitability for its intended purpose, as well as a report on the functions and planning arrangements at the facility's planned location and in its surroundings. The environmental impact assessment report must also be enclosed with the Decision-in-Principle application.

The Ministry of Economic Affairs and Employment must obtain a preliminary safety assessment from the Radiation and Nuclear Safety Authority on the basis of the application and request statements from the Ministry of the Environment, the municipal council of the selected municipality, and the neighboring municipalities.

Before the Decision-in-Principle is made, the applicant must compile a general public report about the plant project, its safety, and the expected environmental impact. The report must comply with the instructions issued by the Ministry of Economic Affairs and Employment, and it will be reviewed by the Ministry before being published. The report must be made publicly available. The Ministry of Economic Affairs and Employment must provide the residents and municipalities in the immediate vicinity of the nuclear facility, as well as the local authorities, with an opportunity to present their opinions regarding the project before the Decision-in-Principle is made. Furthermore, the Ministry must arrange a public event at the future location of the encapsulation plant and final disposal facility. The public will have an opportunity to state their opinions at the event. These opinions must be made known to the Government.

According to the Nuclear Energy Act, the Government can only give a favorable Decision-in-Principle regarding the plant location if the above-mentioned statement by the site municipality supports the project. Furthermore, the Government must be able to find that it is possible to build and operate the facility so that it is safe and does not cause any danger to people, the environment, or property. The Government must also consider the issue from the perspective of the overall interest of society, paying special to the following:

- Necessity of the nuclear facility for the nation's energy management
- Suitability of the nuclear facility's planned location and the nuclear facility's environmental impact
- Nuclear fuel and nuclear waste management arrangements.

The Government's Decision-in-Principle will be submitted to Parliament for review. The Parliament may reverse the Decision-in-Principle or decide that it is to remain in force as such, but it cannot amend its content. The Decision-in-Principle may include prerequisites. The license applicant may not make any significant and financially binding acquisition agreements related to the construction of the facility before the Decision-in-Principle has entered into force.

### 4.3.2 Construction license

A construction license for the encapsulation plant and final disposal facility will be granted by the Government. A construction license for a nuclear facility may be granted if the Decision-in-Principle ratified by Parliament has deemed the construction of the nuclear facility to be in line with the overall good of society and the preconditions for granting a construction license for a nuclear facility in section 19 of the Nuclear Energy Act are met. The construction license may include prerequisites. The preconditions for granting a construction license include:

- Plans concerning the nuclear facility entail sufficient safety in accordance with the Nuclear Energy Act, and the protection of workers and the safety of the population have been appropriately taken into account when planning the operations
- The location of the nuclear facility is appropriate with regard to safety and environmental protection has been appropriately taken into account.
- Safety arrangements have been taken into account in the planning of the operations
- An area has been reserved in the local detailed plan for the construction of the nuclear facility in compliance with the Land Use and Building Act, and the applicant has control over the area required for the facility
- Methods and plans available to the applicant for arranging nuclear fuel and nuclear waste management, final disposal of nuclear waste, and decommissioning of the plant are sufficient and appropriate
- The applicant has the necessary expertise available, possesses sufficient financial conditions, and is otherwise considered to have the prerequisites to engage in its operations safely and in accordance with the international contractual obligations of Finland.

### 4.3.3 Operating license

An operating license for the encapsulation plant and final disposal facility will be granted by the Government. The operating license may be issued once a construction license has been granted, provided that the preconditions listed in section 20 of the Nuclear Energy Act are met. The operating license may include prerequisites, and it is valid for a fixed period of time. The preconditions for granting a operating license include:

- The nuclear facility and its use meet the statutory safety-related requirements, and the safety of employees and residents, as well as environmental protection, have been appropriately taken into account

– Methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate
– The applicant has sufficient expertise available and, in particular, the competence of the operating staff and the operating organization of the nuclear facility are appropriate
– The applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with the international contractual obligations of Finland.

Operation of the encapsulation plant and final disposal facility may not be started on the basis of the license granted until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the prerequisites prescribed by law and the Ministry of Economic Affairs and Employment has verified that provisions for the cost of nuclear waste management have been arranged in the manner required by law.

## 4.4 Announcements and notifications pursuant to the Euratom Treaty

The European Atomic Energy Community (Euratom) Treaty requires that each Member State provides to the Commission plans regarding the final disposal of radioactive waste (Article 37), that the licensee submits to the Commission an investment notification (Article 41), and that the licensee declares to the Commission the technical characteristics of the facility for nuclear safeguards (Article 78).

## 4.5 Permit for possessing nuclear materials

Permits for possessing nuclear materials must be applied for from the Radiation and Nuclear Safety Authority.

## 4.6 Transportation license

By virtue of section 8 of the Nuclear Energy Act, a license is required for the transport of spent nuclear fuel, and by virtue of section 56 of the Nuclear Energy Decree (161/1988), licenses for the transport of nuclear-use items and nuclear waste are granted by the Radiation and Nuclear Safety Authority on a case-by-case basis.

The licensee must prepare a transportation plan, on the basis of which the Radiation and Nuclear Safety Authority will decide on the granting of the transportation license. STUK will assess matters such as the transportation plan, the structure of the transport container, the qualifications of the transportation personnel, as well as accident and vandalism preparedness plans.

The nuclear-use items or nuclear waste may not be transported until the Radiation and Nuclear Safety Authority has verified that the transport equipment, transport arrangements, safety arrangements, and emergency preparedness arrangements meet the prerequisites and that liability for nuclear damage has been determined (sections 56 and 115 of the Nuclear Energy Decree)..

## 4.7 Research permit

Permission from the owner of the land or water area must be obtained for any drilling or other studies that are not covered by the public right of access or the rights granted to state research facilities. If the land owner refuses to grant such permission, a permit may be applied for from the National Land Survey of Finland instead. When performing research, the rights of others may not be interfered with more than is absolutely necessary to complete the research activities, and no unnecessary disruption may be caused to the owner or right-holder. If necessary, the permit decision must clearly state what activities are allowed and what limitations apply to the research.

## 4.8 Permits pursuant to the Environmental Protection Act and Water Act

A permit pursuant to the Environmental Protection Act must be obtained for operations that cause a danger of pollution of the environment. A permit is required on the basis of the Environmental Protection Act (527/2014) and the Government Decree on Environmental Protection (713/2014), which has been enacted on the basis of the Environmental Protection Act. The permit may only be granted if the operations do not constitute a health hazard or cause significant pollution of the environment or a risk of such pollution. The permits required by the environmental protection legislation are to be applied for in sufficient time for the operations during the construction and operation of the encapsulation plant and final disposal facility.

Permits for modifying groundwater and conducting water pursuant to the Water Act (587/2011) must also be sought for the final disposal facility. These permits must be applied for before starting the operations, in compliance with the currently valid national and local regulations.

## 4.9 Legal impact of protection measures

The research area and its surroundings may include targets protected in different ways. If the implementation of the project is considered to have a detrimental effect on a protected area, a statutory permit must be obtained for the deviation from the protection decisions. For example, the Nature Conservation Act (1096/1996) and the Water Act (587/2011) include several alternative means for organizing the protection. Furthermore, excavating, covering, modifying, harming, removing, or otherwise tampering with a historical monument without a permit pursuant to the Antiquities Act (256/1963) is forbidden.

## 4.10 Permits required for construction

A building permit pursuant to the Land Use and Building Act (132/1999) must be sought for the encapsulation plant and final disposal facility. In the case of a large project, a building permit for the entire project or several permits for smaller parts may be applied for. A building permit may be separately sought for buildings above and below ground level. The building permit is obtained from the building permit authorities of the municipality in which the facility is located. Before granting the permit, the authorities will ensure that the plan complies with the ratified local detailed plan and the National Building Code. A building permit must be obtained before starting construction activities. A building permit will only be granted for the encapsulation plant and final disposal facility if the environmental impact assessment procedure has been completed.

Building permits must also be sought for temporary storage and office buildings during the construction phase, for example.

A planning permission for minor construction or a landscape work permit pursuant to the Land Use and Building Act must be obtained before starting earth-moving or excavation works in the facility area. A landscape work permit must be applied for work that will change the landscape and that is to be completed before the building permit enters into force, such as the felling of trees or the removal of soil. A landscape work permit is not required when implementing work required to realize the master plan or local detailed plan, or work required to realize a granted building permit or planning permission for minor construction. Notifications of starting construction and electrical installation work must be filed before starting the work. A separate written notification to the municipal environmental protection authority must be submitted for any temporary activities that will cause noise or vibration but for which an environmental permit is not required. Separate permits and notifications are also necessary when using and storing explosives or chemicals at the construction site.

## 4.11 Expropriation permit

Real estate must be purchased or redeemed in order to realize the project. The available alternatives are always studied on a case-by-case basis based on discussions with the landowners. Expropriation of real estate is regulated by the Act on the Redemption of Immoveable Property and Special Rights (603/1977). The reports specified in the Act on the Redemption of Immoveable Property and Special Rights, such as the EIA report and the statement by the coordinating authority on the EIA report, must be enclosed with the permit application. Expropriation permits are processed by the Ministry of Economic Affairs and Employment and granted by the Government.

## 4.12 Flight obstacle permit

If tall cranes must be used in the facility area during construction, a flight obstacle permit pursuant to the Aviation Act (864/2014) must be obtained. The flight obstacle permit must be applied for from the Finnish Transport Safety Agency (Trafi). A statement provided by the appropriate airline service supplier (Finavia Oy) must be enclosed with the application. The need to establish a no-fly zone will be separately studied during the EIA report phase.

## 4.13 Permits required for connected projects

The establishment of public and private roads is prescribed by the Highways Act (503/2005). Construction of public highways requires preparation of a general plan and a road plan, for example. The permit authority is the Finnish Transport Agency. A project permit pursuant to the Electricity Market Act (588/2013) and possibly a building permit must be obtained for power lines.

## 4.14 Other permits

Other permits of relevance with regard to environmental matters mainly include technical permits, the primary purpose of which is to ensure occupational safety and prevent property damage.

# 5 EIA PROCEDURE

## 5.1 Legislation

The Directive of the European Council on the Environmental Impact Assessment (85/337/EEC) has been implemented in Finland through the EIA Act (468/1994) and EIA Decree (713/2006) by virtue of Annex 20 of the Agreement on the European Economic Area.

All projects to which the environmental impact assessment procedure must be applied are determined in the Government Decree on Environmental Impact Assessment Procedure (713/2006), based on section 4, subsection 1 of the Act on Environmental Impact Assessment Procedure. In the case of item 7d in the project list in Chapter 2, section 6 of said decree, the assessment procedure based on the EIA Act applies to facilities that are designed for the processing and final disposal of irradiated nuclear fuel.

## 5.2 Objectives and content of the EIA procedure

The objective of the EIA procedure is to contribute to the environmental impact assessment and to ensure that environmental impacts are always taken into account in planning and decision-making. Another objective is to increase the availability of information to citizens and the possibility for them to participate in the planning of projects.

The environmental impacts of the project must be studied in a statutory assessment procedure prior to taking any action that is deemed necessary based on the environmental impacts. The aim of EIA procedure is not to make any decisions concerning the project or the final disposal location of spent nuclear fuel. Instead, the objective is to produce information to serve as a basis for decision-making.

The EIA procedure consists of the program phase and the report phase (Figure 5-1). This environmental impact assessment program (EIA program) is a plan for arranging an environmental impact assessment procedure and the required reports. The environmental impact assessment report (EIA report) to be prepared later will describe the project's characteristics and technical solutions, and offer an assessment of its environmental impacts based on the EIA procedure.

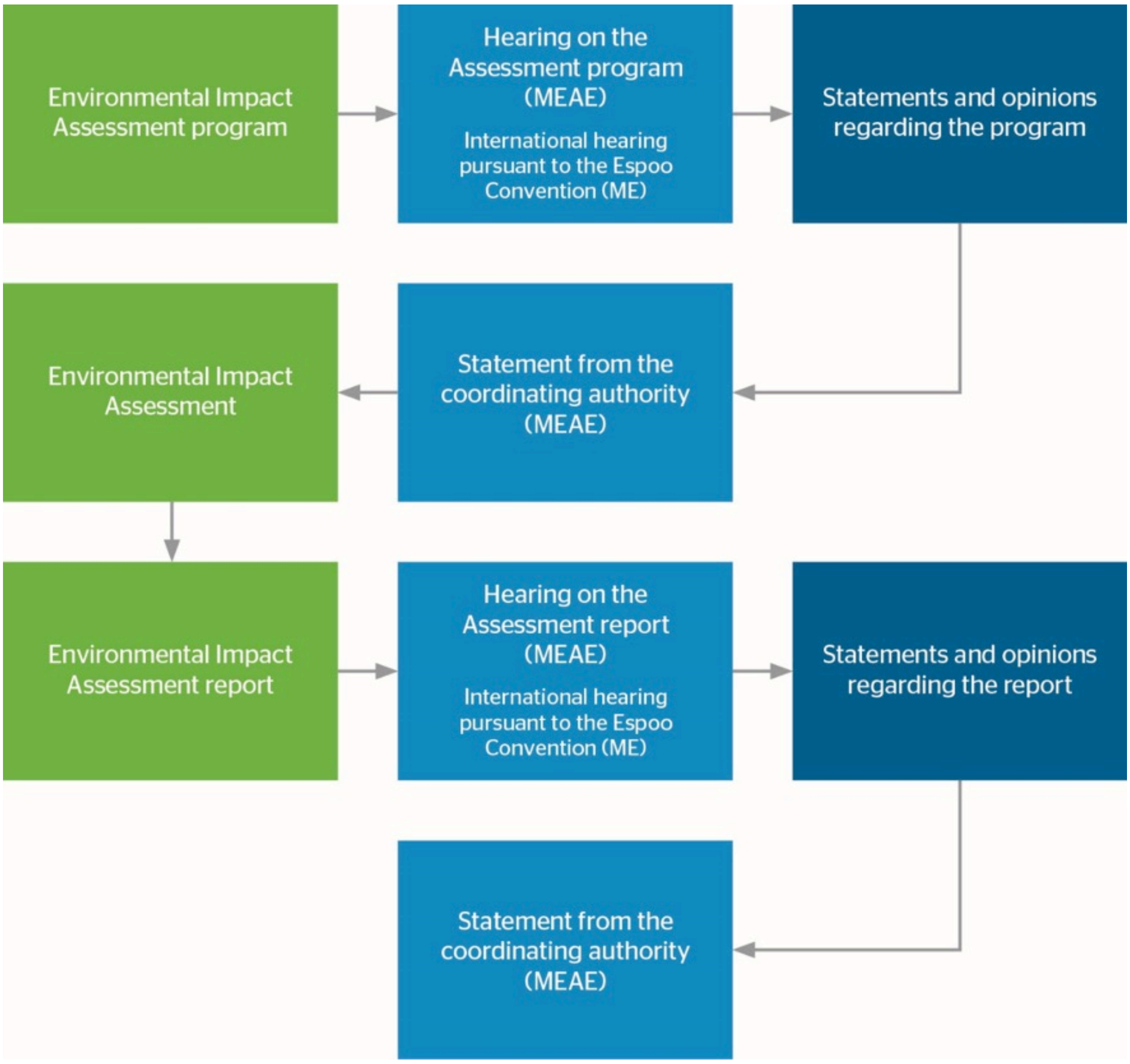


**Figure 5-1. Phases of the EIA procedure (MEAE = Ministry of Economic Affairs and Employment, ME = Ministry of the Environment).**

### *EIA program*

An EIA program is drafted during the first phase of the environmental impact assessment procedure. The EIA program is a review of the current status of the research areas and a plan (a work program) for the impacts to be studied and the method of implementing the studies. The program presents, among other issues, basic information about the project and the alternatives being studied, as well as a communication plan for the EIA procedure and an estimate of the project schedule.

The EIA procedure officially starts when the EIA program is submitted to the coordinating authority. The Ministry of Economic Affairs and Employment acts as the coordinating authority for projects associated with nuclear facilities pursuant to the Nuclear Energy Act. The coordinating authority announces the public display of the EIA program for example in local newspapers and on its website.

During the public display period, citizens may express their opinions about the EIA program to the coordinating authority. The coordinating authority also requests statements on the program from various authorities. The coordinating authority compiles the opinions and statements on the EIA program, and it issues its own statement based on these to the organization responsible for the project.

***EIA report***

The actual assessment of the environmental impacts will be carried out based on the EIA program, the coordinating authority's statement, and the other statements and opinions. The results of the assessment work are presented in the environmental impact assessment report (EIA report), which includes the following, for example:

- Revised information from the EIA program
- Description and the technical specifications of the project
- Relationship of the project to key plans and programs
- Current state of the environment
- Alternatives to be assessed
- Environmental impacts of the various alternatives and the zero-option, as well as the significance of these impacts
- Comparison of the alternatives
- Prevention and mitigation methods for adverse impacts
- Environmental impact assessment program proposal
- Description of interaction and participation during the EIA procedure
- Description of how the coordinating authority's statement on the EIA program has been taken into account when preparing the EIA report.

The coordinating authority will announce the public display of the completed EIA report in the same manner as the EIA program. During the public display period of the assessment report, the coordinating authority will request statements from various authorities. The local residents and other stakeholders will also have the opportunity to express their opinions to the coordinating authority. The coordinating authority compiles the opinions and statements on the EIA report, and issues its own statement based on these. The EIA procedure ends when the coordinating authority submits its statement on the EIA report.

The permit authorities and the organization responsible for the project will use the EIA report and the coordinating authority's statement on the report as the basis of their decision-making process (see Chapter 4). The project's permit decision must state how the EIA report and the related statement were taken into account in the decision.

## 5.3 Schedule of the EIA procedure

The environmental impact assessment procedure started in 2015 with the preparation of the EIA program. The EIA procedure was officially started when the EIA program was submitted to the coordinating authority in June 2016. The key phases of the EIA procedure and the planned schedule are presented in the image below (Figure 5-2).

After the EIA program phase, geological studies and other environmental impact assessment studies at the alternative locations will start. These studies will last several years. The EIA report will be completed in time to allow for the selection of the spent nuclear fuel disposal site in the 2040s. The EIA procedure will end when the coordinating authority issues its statement on the EIA report. The planned overall schedule of the EIA procedure is presented in Chapter 2.5 (Figure 2-2).

An international hearing pursuant to the Espoo Convention will be arranged during the public display period of the EIA program (Chapter 5.4.3). The Ministry of the Environment will be responsible for the arrangements.


**Figure 5-2. Key phases and schedule of the EIA program.**

## 5.4 Communication and participation plan

One of the main objectives of the EIA procedure is to improve communication related to the project and the possibilities of the general public to participate. The EIA procedure's communication and participation plan is presented in the following chapters in accordance with the phases of the EIA procedure. The parties participating in the EIA procedure of the Fennovoima spent nuclear fuel final disposal project are presented in the image below (Figure 5-3).

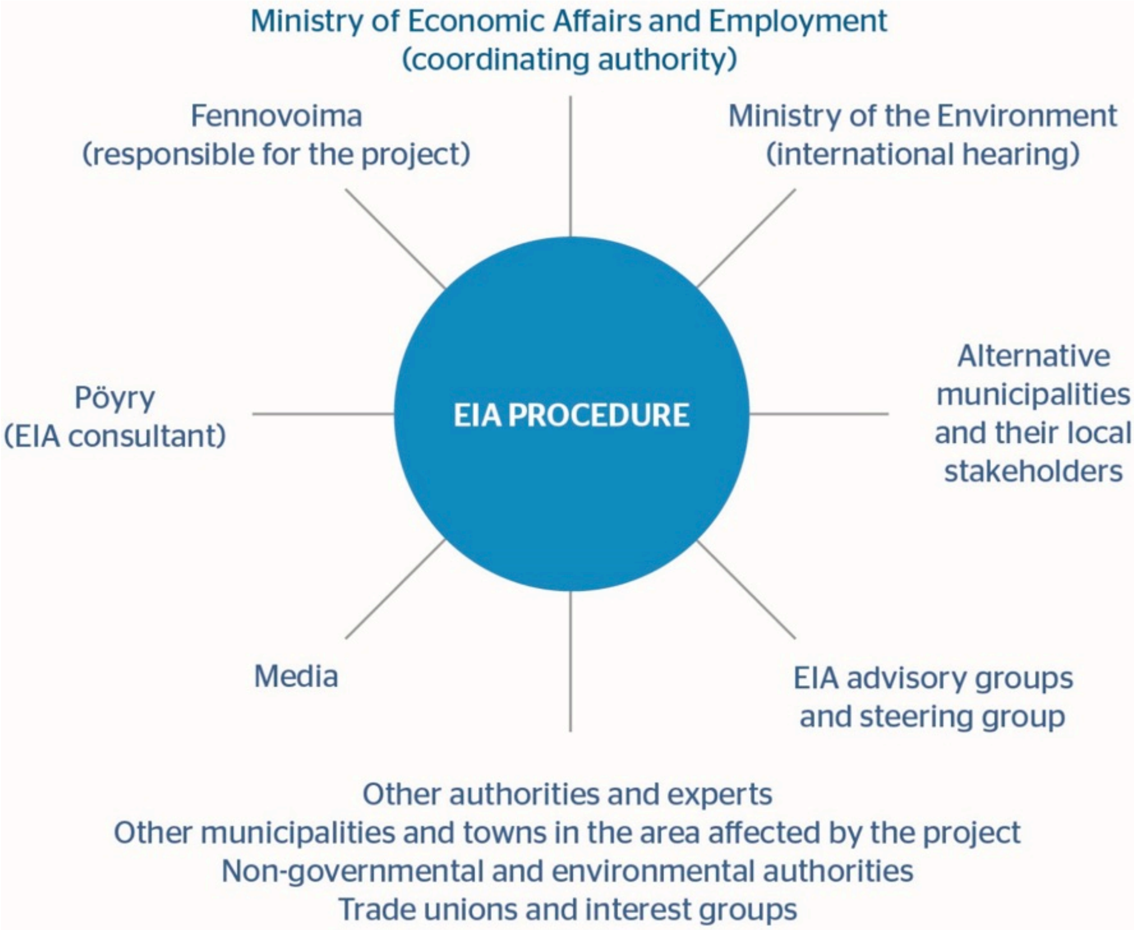


**Figure 5-3. Parties involved in the EIA procedure.**

### 5.4.1 Display of the EIA program and report

The Ministry of Economic Affairs and Employment will announce the public display of the EIA program after its completion at the alternative locations of the project. The public display will be carried out utilizing, among others, the website of the Ministry of Economic Affairs and Employment, municipal noticeboards, as well as local and national media.

The announcement will state where the assessment program is displayed and where statements and opinions regarding it are to be submitted. The prescribed time for delivering the opinions will start from the date the notification is published. According to the EIA Act, the minimum length of the display period is 30 days and the maximum length is 60 days. In the case of this project, the EIA program will be presented for 60 days. The Ministry of Economic Affairs and Employment will also request statements on the EIA program from various communities.

At a later phase of the EIA procedure, the EIA report will be displayed similarly, and statements and opinions can be issued correspondingly.

### 5.4.2 Information and discussion events

The Ministry of Economic Affairs and Employment will arrange public information and discussion events on the EIA program at the alternative locations. These events will be arranged during the public display period of the program in September 2016. More specific information about the public events will be given in the coordinating authority's announcement. The project and the EIA program will be presented at these events. At these events, the public will have the opportunity to express their opinions on the environmental impact assessment work, to receive information, and to discuss the EIA procedure with the organization responsible for the project, the coordinating authority, and the experts who prepared the EIA program.

Additional information and discussion events will be arranged once the environmental impact assessment report is ready. The results of the environmental impact assessment will be presented at this point, and the public will be able to provide their views on the environmental impact assessment work and its sufficiency.

### 5.4.3 International hearing

The Ministry of the Environment is responsible for the practical arrangements relating to the international hearing referred to in the UN Economic Commission for Europe (UNECE) Convention on Environmental Impact Assessment in a Transboundary Context (67/1997).

The Ministry of the Environment will notify the environmental authorities in the neighboring countries about the start of the EIA procedure for the spent nuclear fuel final disposal project and identify their willingness to take part in the procedure. A summary of the EIA program translated into all of the necessary languages and the EIA program translated into Swedish or English will be enclosed with the notification.

If one of the other countries decides to participate in the procedure, it will put the EIA program on public display for statements and opinions. The EIA report will also be displayed at a later phase of the EIA procedure. The Ministry of the Environment will compile the statements and opinions and send them to the coordinating authority to be taken into account in the statements on the EIA program and the EIA report.

### 5.4.4 Advisory group

Two advisory groups consisting of different stakeholders will be established and appointed by the EIA consultant, one for each alternative location municipality. The purpose of the advisory groups is to promote communication and exchange of information between the organization responsible for the project, the authorities, and other stakeholders. Members of the advisory groups will represent citizens or groups whose interests or conditions the project may affect. The willingness of stakeholders to participate in the advisory groups will be studied during the fall of 2016. Separate agreements on advisory group kickoff meetings will be made.

The EIA program, the environmental impact assessment methods included in the EIA program, the project, the project schedule, and the progress of the EIA procedure will be discussed at the advisory group meetings. At these events, the advisory groups will have the opportunity to express their opinions on the EIA program, to receive information, and to discuss the EIA procedure with the organization responsible for the project, the coordinating authority, and the experts who prepared the EIA program. At the kickoff meetings of the advisory groups, plans on interaction between the various stakeholders during the long EIA procedure period will be made.

### 5.4.5 Resident surveys

Surveys of the local residents will be completed during the EIA procedure at the alternative locations. The purpose of the resident surveys is to promote interaction by providing Fennovoima with information about the residents' attitudes towards the project and, on the other hand, by providing the residents with information about the project and its impact on their living environment. The survey will be implemented for the first time after the submission of the EIA program (in Eurajoki, once the research area has been determined), and the survey will be repeated at the EIA report phase. If necessary, more resident surveys can be arranged.

### 5.4.6 Small group events

Local residents may be invited to attend small group events during the EIA procedure. The groups will meet and participate in workshops during different project phases based on separate agreements.

The objective of the small group events is to provide more information about the results of the resident surveys and to obtain a clearer idea of the local residents' attitudes towards the project and its impact on their environment. In addition, the local residents will receive more information about the project and its environmental impacts. The events will be arranged to ensure that all of the issues pertinent in terms of the project's impacts are taken into account in the environmental impact assessment and further planning of the project.

### 5.4.7 Other communications

The EIA program and EIA report will be published on the website of the Ministry of Economic Affairs and Employment. They will also be made available on Fennovoima's website. Printed copies of the documents will be available at the alternative locations in a manner to be specified in the coordinating authority's announcement.

Topical information about the project, its phases, and the environmental impact assessment procedure, as well as information and discussion events arranged at the alternative locations, will be provided on Fennovoima's website. A more detailed communication plan will be prepared based on the needs of the alternative locations.

Views of local stakeholders on the sufficiency of information will be monitored in connection with the interaction during the EIA procedure. Communication about the project and the EIA procedure will be planned to correspond to the need for information.

# 6 CURRENT STATE OF THE ENVIRONMENT

The current state of the environment in the areas has been surveyed based on, for example, existing published materials, such as:

- GIS data from the National Land Survey of Finland
- Hertta and Karpalo databases of the Finnish environmental administration
- Avoin tieto database of the Finnish Environment Institute
- Land use data from regional councils and municipalities: currently valid and pending regional plans, local master plans, and local detailed plans, as well as published electronic land use plan reports
- Specific land use planning reports, such as reports on the landscape and environment
- Cultural environment registration portal of the National Board of Antiquities: register of monuments of antiquity and inventory of nationally valuable built cultural environments (RKY)
- Reports of the Ministry of the Environment on valuable landscapes, national and regional landscape inventories, and other publicly available landscape reports
- Information from BirdLife on important bird areas (FINIBA and IBA), as well as other reports on bird areas of regional significance
- Research data and databases from the Geological Survey of Finland
- Traffic volume maps from the Finnish Transport Agency
- Municipal data and key figures published by Statistics Finland
- Various map applications and aerial photos
- Any other applicable data published by municipalities and authorities.

More specific information on the data sources used is provided in the next chapters. Chapter 7 includes additional information on the methods used when describing the current status of the environment and supplementing the data on the current status in the EIA report

## 6.1 Eurajoki

The description of the current status at Eurajoki in this EIA program is a general description illustrating the entire municipality because no specific research area in Eurajoki has yet been determined (see Chapter 2.4.1). A research area will be determined at the EIA report phase, and the current status data will be specified to apply to the selected research area.

### 6.1.1 Location, settlement, and other activities

The municipality of Eurajoki is in the province of Satakunta, and it is limited by the Bothnian Sea in the west (Figure 6-1). The neighboring municipalities of Eurajoki are Luvia to the north, Nakkila to the northeast, Eura to the east, and Rauma to the south. The closest towns, Rauma and Pori, are located respectively 15 and 35 kilometers from the village of Eurajoki.

In 2014, 5,954 people lived in Eurajoki. Key figures of the municipality of Eurajoki are listed in the table below (Table 6-1). The municipalities of Luvia and Eurajoki will merge in 2017. After the merger, the municipality of Eurajoki will have more than 9,000 residents. The largest population center in Eurajoki is the Eurajoki village, located in the middle of the municipality. Other larger villages in Eurajoki include Lapijoki in the southern part of the municipality, Irjanne in the northeast part, and Kuivalahti in the western part. The residents are relatively evenly distributed among these larger villages. There are some dispersed settlements in the municipality, especially along the main roads. Most leisure residences are in the western part of the municipality and close to the small lakes in the middle of the municipality.

There are seven comprehensive schools, one upper secondary school, two municipal kindergartens, a retirement home, and a health center in Eurajoki. There are several recreational centers, such as Lahdenperä, Pinkjärvi, and Verkkokari. Furthermore, in the Eurajoki area there are jogging trails, sports fields, an indoor skating rink, and a nature trail. Local hunting societies are Eurajoen metsästysseura ry in Eurajoki, and Rauman metsästysseura ry in Rauma.

Teollisuuden Voima Oyj's nuclear power plant site and Posiva Oy's spent nuclear fuel encapsulation plant and final disposal facility are located in Olkiluoto, in the western part of the municipality of Eurajoki. Most of the industrial activities in Eurajoki are located in Olkiluoto, Köykkä, and Kuusimäkelä areas.

The provisions of the environmental and water permits for the Olkiluoto nuclear power plant are currently being reviewed. Review applications regarding the environmental permit and water permit for a landfill for organic and biodegradable waste located at the Olkiluoto nuclear power plant site as well as the Olkiluoto backup power plant are currently pending. Furthermore, several permit applications regarding the production of peat, the processing of waste, animal shelters, and fish farming are pending in the municipality of Eurajoki. *(Regional State Administrative Agency 2016)*

**Table 6-1. Key figures of the municipality of Eurajoki *(Statistics Finland 2016).***

| | EURAJOKI |
|---|---|
| Share of population centers, %, in 2014 | 63.5 |
| Population in 2014 | 5,954 |
| Change in population from the previous year, %, 2014 | 0.4 |
| Positive/negative migration between municipalities, persons, 2014 | 21 |
| Share of unemployed in the workforce, %, 2013 | 11.1 |
| Share of pensioners in the population, %, 2013 | 26.7 |
| Dependency ratio, 2013 | 142.1 |
| Share of jobs in primary production, %, 2013 | 4.9 |
| Share of jobs in refining, %, 2013 | 54.4 |
| Share of jobs in the service sector, %, 2013 | 39.9 |

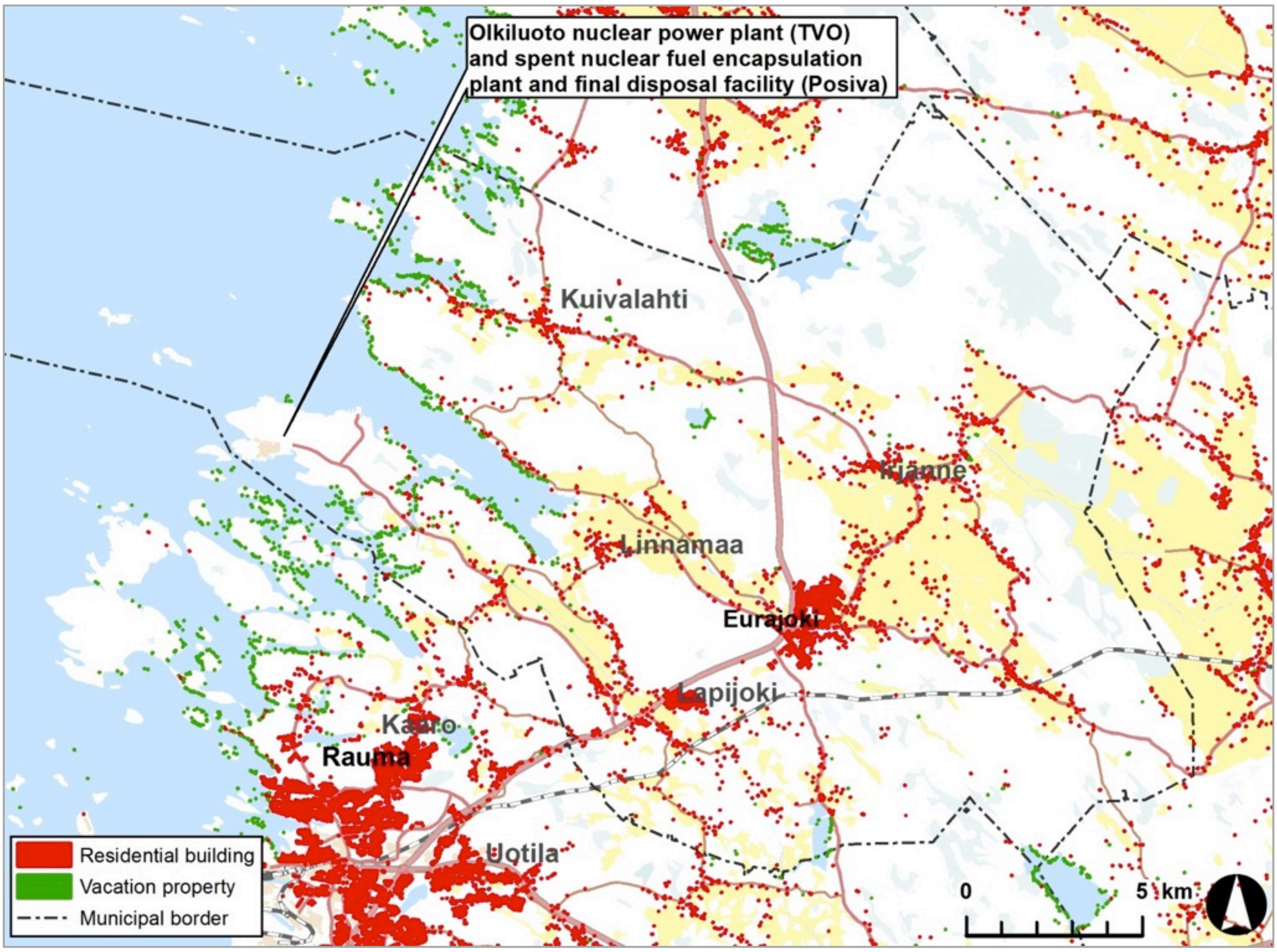


**Figure 6-1. Location of the municipality of Eurajoki, as well as residential buildings, holiday homes, and other activities in the municipality.**

### 6.1.2 Land use planning

#### *Regional land use plan*

The Satakunta regional plan (Figure 6-2) (no YM1/5222/2010) governs land use in the municipality of Eurajoki. The Ministry of the Environment ratified the said plan on November 30, 2011. The regional plan replaced the previous regional plan for the area, the fifth regional plan for Satakunta. The Satakunta regional plan became legally valid based on a decision of the Supreme Administrative Court on March 13, 2013. *(Regional Council of Satakunta 2013)*

The first Satakunta regional stage plan became legally valid on May 6, 2016, and the second-stage plan is currently being prepared. The second plan will specify wind power production areas of regional importance and related energy supply constructs. The area north of the village of Kuivalahti has been determined as a wind power plant area (tv-1) in the regional stage plan. *(Regional Council of Satakunta 2016).*

The Regional Council of Satakunta is currently still preparing the second regional stage plan for Satakunta. The goal is to increase energy production in Finland and improve the security of supply. The Board of the Regional Council approved the regional stage plan participation and assessment scheme in November 2015. *(Regional Council of Satakunta 2016).*

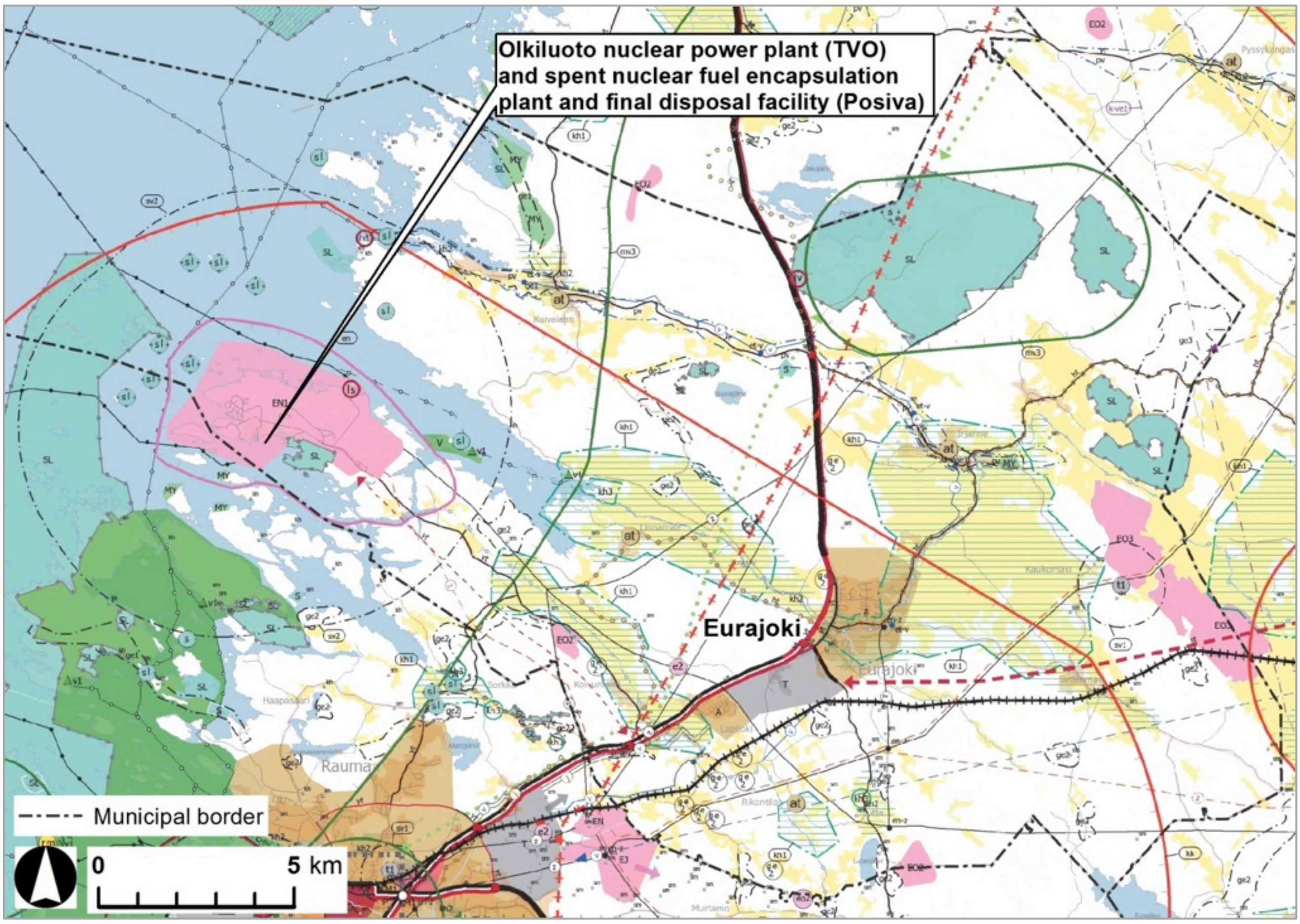


**Figure 6-2. The Satakunta regional plan for the Eurajoki area *(Regional Council of Satakunta 2013).***

## *Other land use plans*

Master plans

There is a currently valid component master plan for the center of Eurajoki and the adjacent areas (Figure 6-3, site no. 3).

There is also a valid master shore plan in force for the shores in Eurajoki. It was ratified on October 25, 2000 and amended on December 12, 2015 and August 31, 2015 (Figure 6-3, site no. 4). The master shore plan covers all of the seashore areas and islands in Eurajoki.

The Olkiluoto component master plan in force covers the island of Olkiluoto. The municipal council approved the component master plan on May 19, 2008 (Figure 6-3, site no. 5). The plan became legally valid in the summer of 2010.

A component master plan for a wind farm is currently pending for the Lemlahti area, which is located between Eurajoki and Luvia. The plan is to build eight wind power plants in this area. All of the wind farm structures will be within the municipality of Luvia. A protective zone for the wind farm will be partially located in the area of Eurajoki municipality. *(Municipality of Eurajoki 2016, Karpalo map service of the Finnish environmental administration 2016)*

Local detailed plans

There are local detailed plans currently in force for the Eurajoki and Lapijoki areas. These plans were prepared over the course of several decades (Figure 6-3, site no. 1). (*Municipality of Eurajoki 2016*) Several shore plans have been prepared for the area based on initiatives from landowners (Figure 6-3).

There are several currently valid local detailed plans and shore plans for the island of Olkiluoto (a local detailed plan for final disposal of nuclear waste, an amendment to the local detailed plan and partial revocation of the shore plan, a shore plan, and the third Olkiluoto local detailed plan; (Figure 6-3, site no. 2). In addition, in 2008 the town of Rauma started the preparation of an amendment to the local detailed plan due to the expansion of land used for energy production at Olkiluoto. The land use plan area is limited to the east by the border of the municipality of Eurajoki and the Olkiluoto nuclear power plant site. Land use planning processes concerning the Ketunpesä and Köyry areas are also pending. *(Municipality of Eurajoki 2016)*

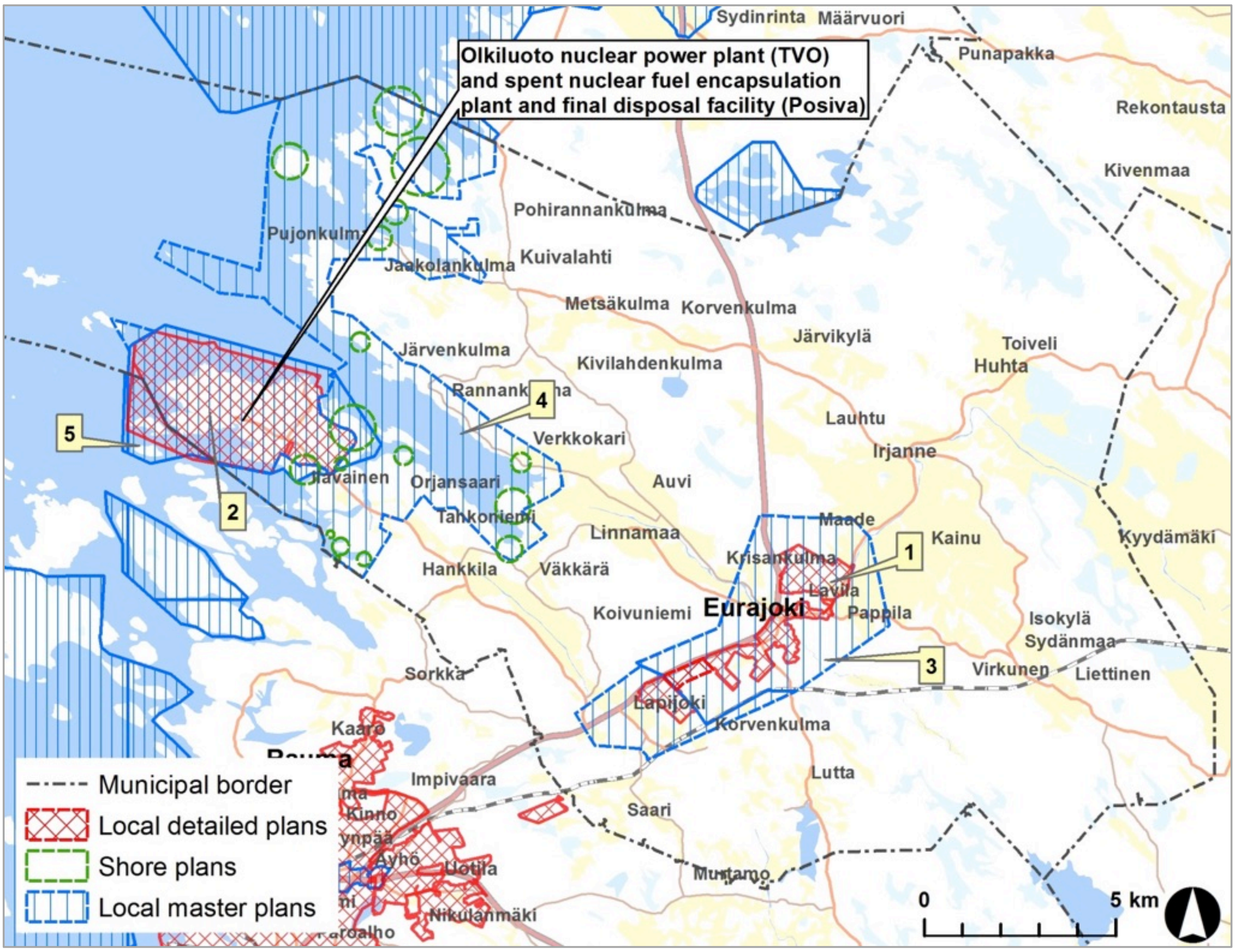


**Figure 6-3. Land use planning by the municipality of Eurajoki *(Karpalo map service of the Finnish environmental administration 2016, Municipality of Eurajoki 2016).***

### 6.1.3 Landscape and the cultural environment

#### *General description of the landscape*

According to the landscape province division by the Landscape Committee of the Ministry of the Environment, the municipality of Eurajoki is located in the landscape province of Lounaismaa, more specifically in the Satakunta shore area. Basic features of the landscape in Lounaismaa vary from fragmental archipelago and gently rolling, partially bare bedrock to wide, flat, and fertile areas of loamy soil interspersed with a number of rivers. The coastal areas in Satakunta differ from the Archipelago Sea and the southwest coast area, and hence they have been classified as a separate region. The archipelago zone becomes clearly narrower towards the north, and the environment is more rugged. However, there are varied archipelago areas in this region as well. The landscape is low-lying due to the variety of terrain types: there are areas with bare bedrock, areas with basal till and hummocky moraine, some areas with loamy soil, and some eskers. The coast has long sheltered bays dominated by common reed that are slowly turning to land due to land uplift. The traditional livelihood in this region is fishing, and farming is an important secondary occupation in the coastal areas. (*Satakunta Regional Council 2014, Ministry of the Environment 1993*)

#### *Valuable landscape and cultural environment sites, as well as historical monuments*

There are several valuable cultural environment sites and landscape areas in the municipality of Eurajoki. The island of Kaunissaari to the northeast of the island of Olkiluoto is a regionally important landscape site (Figure 6-4, site no. 1). The Vuojoki cultural landscape is to the west (Figure 6-4, site no. 2), the Lapinjoki cultural landscape to the southwest (Figure 6-4, site no. 3), and the cultural landscape of the village of Eurajoki-Irjanne (Figure 6-4, site no. 4) is to the east of the village of Eurajoki. All of these areas are RKY areas. (*RKY 1993*) The above-mentioned areas are also classified as regionally important landscape areas in the regional plan. Other regionally important landscape areas are the villages of Kuivalahti (site no. 5), Jaakolankulma (site no. 6), Lutta (site no. 8), and Rikantila (site no. 7). The cultural landscape of the village of Rikantila is also an RKY area (*RKY 1993*).

There are two important sites included in the built heritage register in the municipality of Eurajoki: Eurajoki Church and Irjanne Village Church (*National Board of Antiquities 2016*). Furthermore, there are traditional biotope sites in the coastal areas of the municipality of Eurajoki (*Southwest Finland Centre for Economic Development, Transport and the Environment 2011*). There are several historical monuments in the municipality of Eurajoki (Figure 6-4).

A supplementary inventory of valuable landscape areas is currently ongoing in Satakunta. Based on this inventory, a redefinition of the Eurajoki cultural landscape area (a regionally important landscape area) has been proposed (*Southwest Finland Centre for Economic Development, Transport and the Environment 2014*).

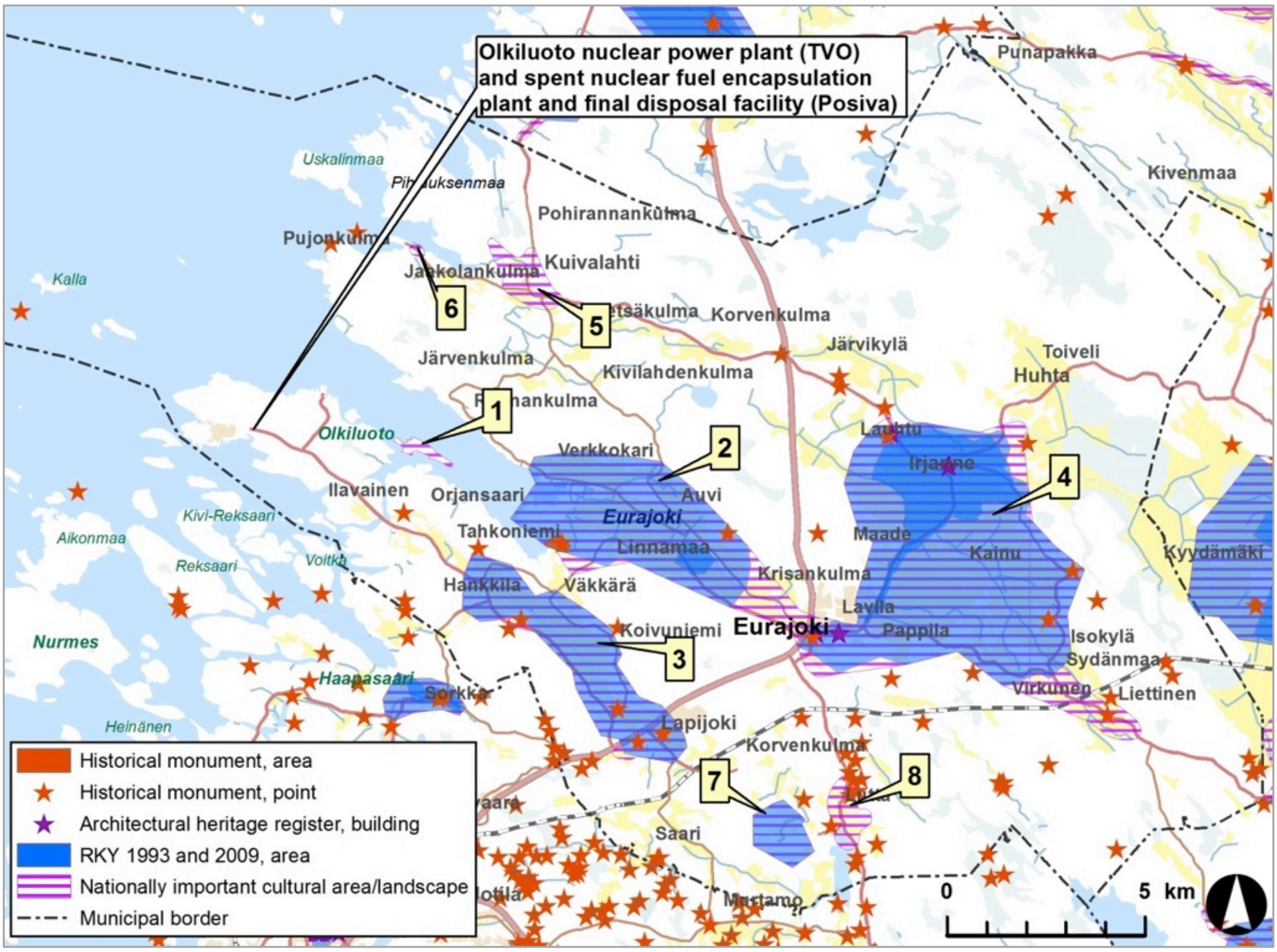


**Figure 6-4. Valuable cultural environment sites and landscape areas in the municipality of Eurajoki and its immediate vicinity. The numbers included in the image are explained in the legend. *(National Land Survey of Finland 2016, Karpalo map service of the Finnish environmental administration 2016)***

## 6.1.4 Soil and bedrock

According to bedrock geological mappings by the Geological Survey of Finland carried out in the map sheet areas 1132 Rauma (*Suominen and Torssonen 1993, Suominen et al. 1997*), 1134 Kokemäki (*Hämäläinen 1994, Veräjämäki 1998)*, 1141 Luvia (*Pihlaja and Kujala 1994)*, and 1143 Pori (*Pihlaja 1994*), the bedrock of Eurajoki consists of 1,800–1,900 million years old Svecofennian supracrustal and igneous rocks, as well as younger rapakivi granites, sandstones, and olivine diabases (Figure 6-5). Supracrustal mica gneisses are mostly migmatites, which are composed of an older mica gneissic part (palaeosome) and younger granitic veins and dikes (neosome), which often occur parallel to the foliation of the mica gneiss (*Suominen et al. 1997*). The area also includes granodioritic and tonalitic igneous formations of varying sizes. This group of igneous rocks also includes gneissose granodiorites, which resemble coarse-grained mica gneisses but are lacking in the porphyroblasts that are typical of mica gneisses (*Suominen et al. 1997*).

North of Olkiluoto lies a large formation of coarse-grained pegmatite granite, and the same rock type also occurs south of the center of the Eurajoki village. Granites and pegmatites are usually heterogeneous, containing numerous inclusions of mica gneisses. The chemical composition indicates that they derive from partial melting of sedimentary rocks (*Suominen et al. 1997*).

The eastern part of Eurajoki largely consists of rapakivi granite belonging to the Laitila rapakivi batholith, which was emplaced about 1,580 million years ago (*Vorma 1976, Vaasjoki 1996*). The Laitila rapakivi batholith is composed of several different types, which differ from each other in texture and mineral composition (*Vorma 1976*). In the Eurajoki area, the batholith is mostly composed of pyterlitic and even-grained rapakivi granites (*Veräjämäki 1998*). The pyterlitic rapakivi granite is characterized by roundish potassium feldspar grains or ovoids with diameters of 2–4 cm, which are usually lacking in the plagioclase mantle which is typical of the wiborgitic rapakivi granite of the Vyborg batholith in south-eastern Finland (*Vorma 1976, Veräjämäki 1998*). In the fringe areas of the Laitila rapakivi, even-grained rapakivi granite with or without small potassium feldspar ovoids occurs. It usually gradually changes to pyterlitic rapakivi granite. The contact between the rapakivi and the older country rocks is sharp and steeply cuts the older structures of the bedrock (*Veräjämäki 1998*).

Located about three kilometers east of Olkiluoto the Eurajoki rapakivi stock, age about 1,550–1,570 million years, is a satellite massif of the Laitila batholith and can be divided into two types: outer hornblende-bearing Tarkki granite and inner topaz-bearing Väkkärä granite (*Haapala 1977*). Hot hydrous fluids that emanated from the Väkkärä granite have formed ‘greisen veins’ in the fractures of the rapakivi granites. The main minerals of the greisen veins are quartz, micas, and iron-rich chlorite. Often they also contain abundant topaz, fluorine, garnet, beryl, genthelvite, and bertnandite (*Haapala 1977*).

According to a gravimetric survey (*Laurén 1970*), the average thickness of the Laitila batholith is five kilometers, with the maximum thickness being about 20 kilometers. The Väkkärä granite of the Eurajoki rapakivi stock extends downwards and outwards in every direction, its depth exceeding five kilometers (*Elo 2001*). According to an interpretation of the gravimetric data, the western contact of the rapakivi dips 50–58 degrees to the west (*Paulamäki et al. 2002*), so that it is expected to occur in Olkiluoto at the depth of about three kilometers. This interpretation is supported by the results of the HIRE reflection seismic survey (*Kukkonen et al. 2010*).

The topaz-bearing Väkkärä granite resembles typical tin granites in chemical composition, and consequently, the greisens veins of the Eurajoki rapakivi have been explored due to their tin, beryllium, and tungsten mineralization (*Haapala 1977*). The most common ore minerals include sphalerite, cassiterite, chalcopyrite, wolframite, gahnite, molybdenite, rutile, secondary iron oxide, pyrite, pyrrhotite, arsenopyrite, and galena. The possibility to use the Väkkärä granite as an economic potassium feldspar-cassiterite-topaz-columbite deposit has also been considered (*Haapala 1973*). *Al Ani and Sarapää (2011)* conducted a preliminary study of the hi-tech-metal potential of the Eurajoki rapakivi.

The Satakunta sandstone, about 1,300–1,400 million years old, lies northeast of and partly inside the Eurajoki area. It has been preserved in a northwest-to-southeast-trending graben structure formed by block movements (*Kohonen et al. 1993*). Based on deep drilling, the thickness of the sandstone is at least 600 m, but according to geophysical studies, the maximum thickness could be about 1,800 m (*Elo 1982*). The sandstone is partly bordered by northwest-to-southeast-trending, probably vertical, faults. The bedding of the sandstone is usually horizontal, but in the northeastern contact, the sandstone layers dip about 35 degrees to the southwest, towards the center of the basin, indicating block movements after the layering.

Satakunta olivine diabase, dated at around 1,250–1,270 million years (*Suominen 1991*), cuts all the other rock types. It occurs either as long, vertical dikes or as large horizontal sills (*Hämäläinen 1987, Suominen et al. 1997*). In the Kokemäki map sheet area, the thickness of the sills is estimated to be 40–80 meters, and in the Rauma map sheet area they are up to 200–300 meters, based on geophysical studies (*Suominen et al. 1997, Elo 2001*). The contact of the olivine diabases against the country rocks is usually sharp, but occasionally the diabase magma has partially melted the country rocks, making the contact diffuse (*Veräjämäki 1998*).

The magnetic map of Eurajoki (Figure 6-6) is dominated by fairly distinct magnetic anomalies related to olivine-diabase dikes. The petrophysical properties of these diabases are well known, and remanent magnetization deviating from the Earth's magnetic field (azimuth 40° and inclination -34°; *Pesonen 1987*) is typical of them. This plays a role in causing the clear magnetic minima (Figure 6-6, the blue areas on the map) to the north of the positive anomalies. In southern Satakunta, there are also geophysical indications of possible younger diabase dikes: on the airborne low-altitude magnetic map of Kokemäki, north-to-south-trending anomaly zones are observed, cross-cutting the olivine-diabase dikes (*Veräjämäki 1998*).

Distinct magnetic anomalies are also observed in places in the mica gneiss area in the western part of Eurajoki. Both petrographic and petrophysical investigations *(Paananen 2013)* indicate that the most important cause of the magnetic anomalies within this area is pyrrhotite. The Laitila rapakivi and the narrow section of the Satakunta sandstone in the eastern part of Eurajoki are magnetically stable. The southwestern contact of the Satakunta sandstone can be detected as a northwest-to-southeast-trending zone of minima. The roundish Eurajoki rapakivi stock to the west of the Laitila batholith has a somewhat stronger magnetization. The Tarkki granite at the outer boundary of the stock, in particular, induces a curved magnetic anomaly. The inner section of the formation, Väkkärä granite, is magnetically more stable.

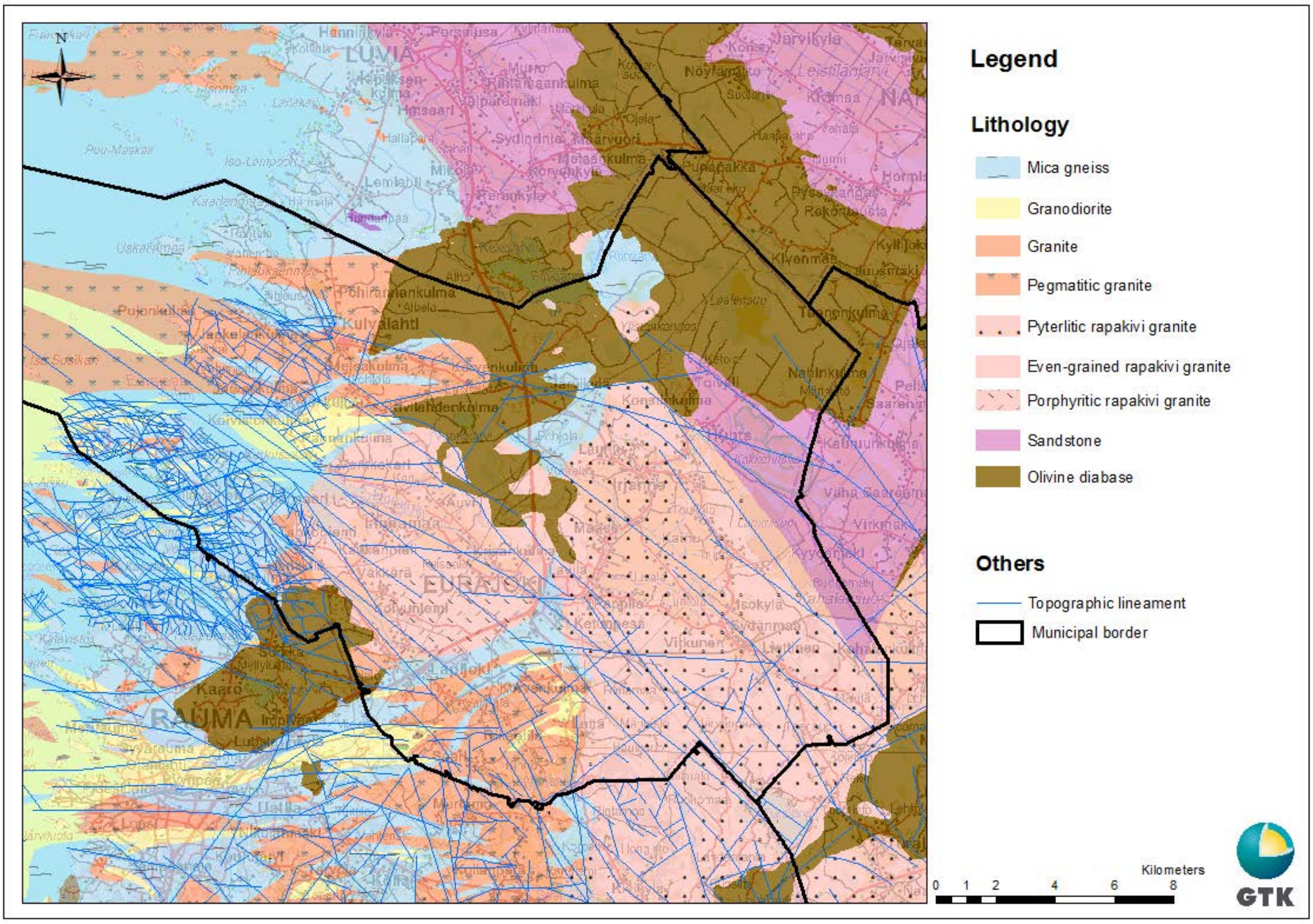


**Figure 6-5. Bedrock in Eurajoki (*Hämäläinen 1994, Pihlaja 1994, Pihlaja and Kujala 1993, Suominen and Torssonen 1993*). Topographic lineaments according to Korhonen et al. (2005) and data from the Geological Survey of Finland.**

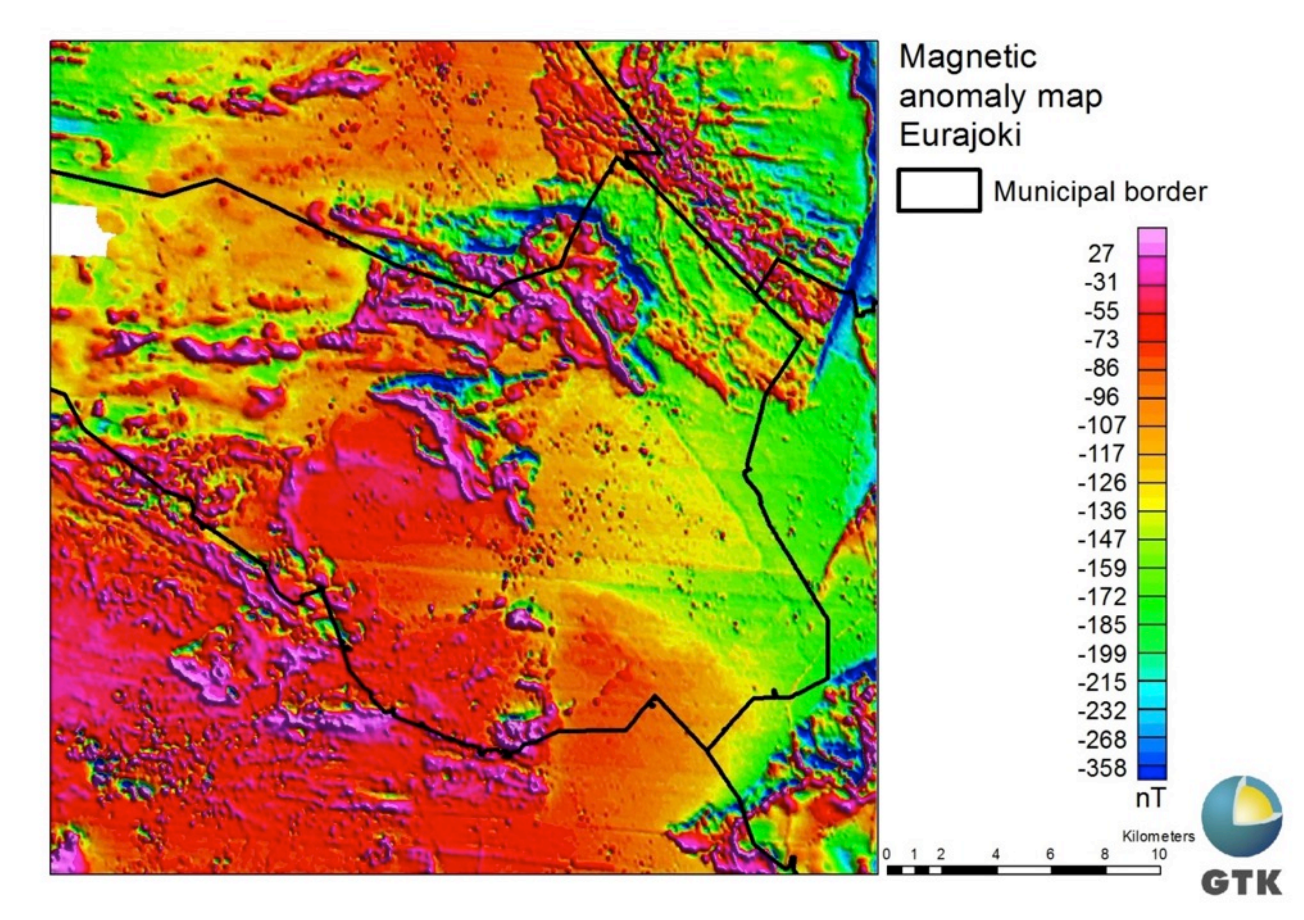


**Figure 6-6. Magnetic anomaly map of Eurajoki. Strong anomalies (color variations in the research area) indicate potential variation of rock types and fragmental bedrock. The causes of the anomalies will be studied during the bedrock surveys.**

According to interpretations of the digital elevation model and laser scanning (LiDAR) data (*Korhonen et al. 2005*, among others), the Eurajoki area is dominated by northwest-to-southeast- and northeast-to-southwest-trending topographic lineaments (probable fracture zones; Figure 6-5). The most significant of these are the northwest-to-southeast-trending Lapijoki and Eurajoki river valleys. Lineament interpretations have also been made based on geophysical data (*Korhonen et al. 2005, Paananen 2013*). Also the lineament interpretations of the geophysical data indicate the main trend of northwest-to-southeast-trending lineaments. In Olkiluoto, some of these features have been verified by drillings.

The bedrock outcrops are most abundant in the southern and southwestern parts of Eurajoki, where they form large, continuous areas (Figure 6-7). Within these areas, the outcrops can take up more than 40 % of the total land area. Glacial sandy till is the most common soil type, and it covers about 40 % of the land area in the entire Eurajoki area (*Lindroos et al. 1983*). Most of the till is sandy till. The till deposits are 1–4 meters thick.

A fragmental, west-to-northwest-/east-to-southeast-trending chain of eskers extends from Kuivalahti to Irjanne (Figure 6-7). The esker is composed of gravel and sand, and according to a seismic sounding in Kuivalahti, its thickness is 10–12 meters (*Kukkonen et al. 1985a*). At the margins of the esker chain, there are shore deposits several meters thick consisting of gravel and sand. Shore deposits also occur northeast of the Lapijoki river valley.

The fine-grained sediments in the area occur in bedrock depressions and river valleys. The largest continuous clay deposits occur south of Irjanne, and in the Lapijoki and Eurajoki river valleys (Figure 6-7). In the Lapijoki and Eurajoki valleys, the average thickness of clay is seven meters, but the maximum thickness can be more than 25 meters (*Lindroos et al. 1983, Kukkonen et al. 1985b, Kukkonen et al. 1987a*). At the eastern border of Eurajoki, under the Kahilansuo peat bog, the clay deposit is 16 meters thick at its thickest (*Kukkonen et al. 1987b*). Peat deposits cover 3 % of the Rauma map sheet area in the western part of Eurajoki, and 11% of the Kokemäki area in the eastern part of Eurajoki.

The elevation of the terrain rises evenly from the seashore inland, so that in the western mica gneiss area it is less than ten meters above the sea level, whereas in the central and eastern rapakivi areas it is usually 10–40 meters above the sea level (*Lindroos et al. 1983*). The highest bedrock hills are 50–60 meters above the sea level in the areas covered by olivine diabase. The terrain is at its lowest in the Lapijoki and Eurajoki valleys, which lie only one meter above sea level. The rapakivi area is characterized by varying terrain and small bluffs.

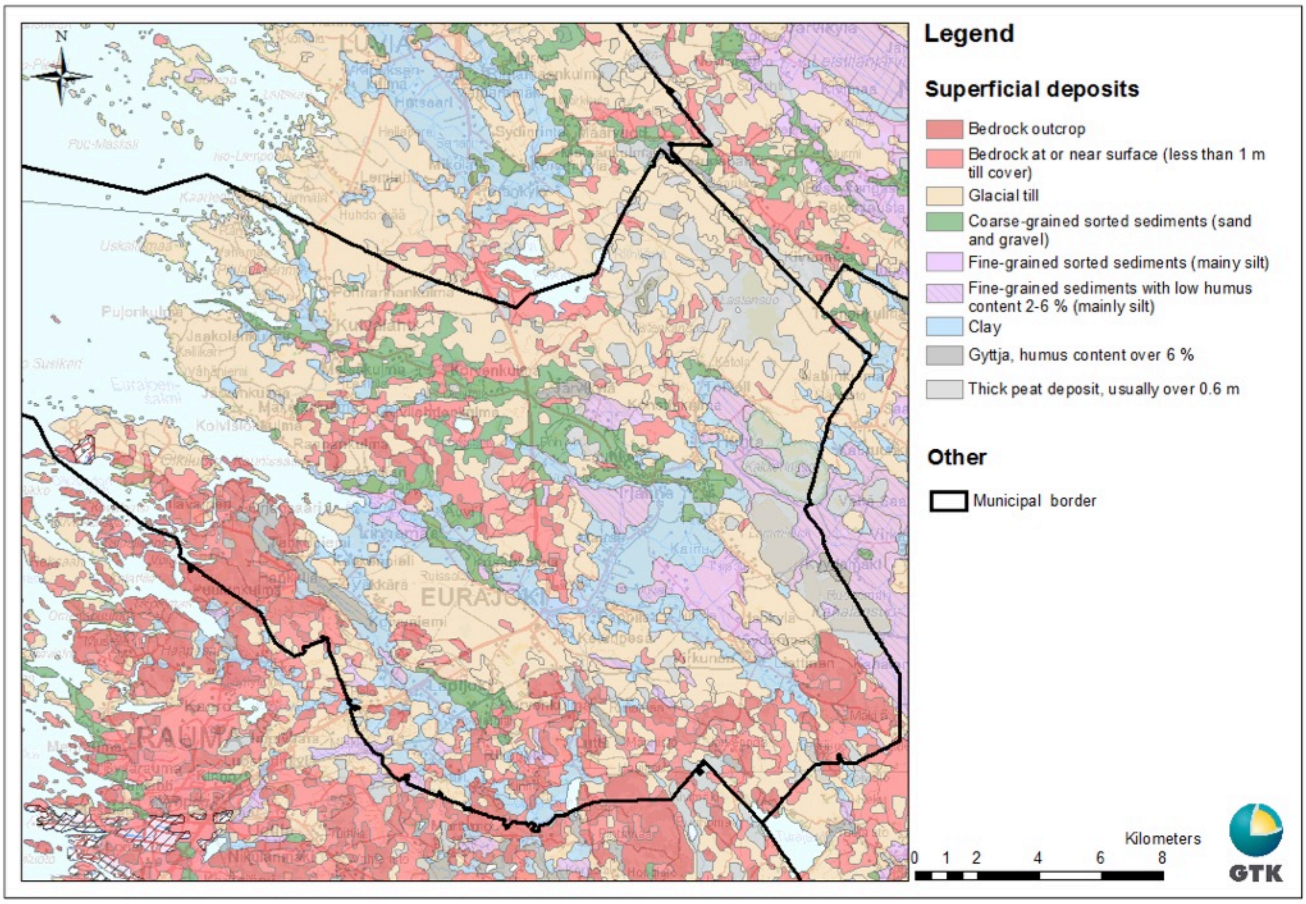


**Figure 6-7. The soil cover in Eurajoki *(Lindroos 1973 & 1974).***

### 6.1.5 Groundwater and surface waters

#### *Groundwater*

Classified groundwater catchment areas in the municipality of Eurajoki are: Kuivalahti groundwater catchment area (0205104), which is an important water supply area (Figure 6-8, site no. 1); Metsäkulma groundwater catchment area (0205102), which is an important water supply area (Figure 6-8, site no. 2); Korvenkulma groundwater catchment area (0205106), which is an important water supply area (Figure 6-8, site no. 3); Irjanne groundwater catchment area (0205101), which is an important water supply area (Figure 6-8, site no. 4); and Mullila groundwater catchment area (0205103), which is an important water supply area (Figure 6-8, site no. 5). *(Environmental administration 2016b)*

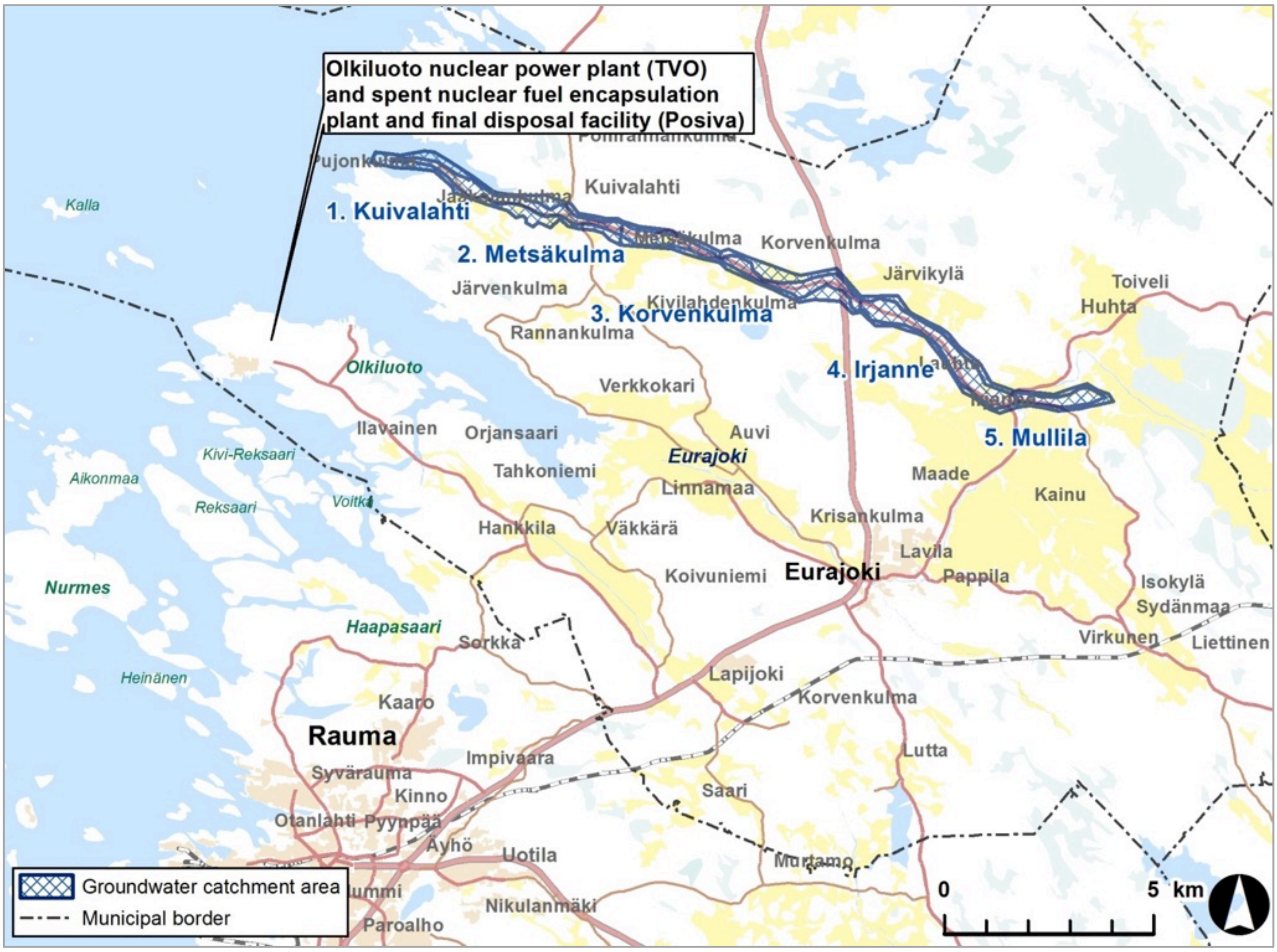


**Figure 6-8. Groundwater catchment areas in Eurajoki *(Environmental administration 2016b)***

#### *Surface waters*

The Bothnian Sea opens to the west of Eurajoki. A bay lying off the Bothnian Sea, Eurajoensalmi, is a small sea area to the north of Olkiluoto. Eurajoensalmi is around 1.5 kilometers wide and eight kilometers long. The Eurajoki and Lapinjoki rivers, the latter of which originates in Koskeljärvi lake, discharge into Eurajoensalmi. Both of these rivers run through the municipality of Eurajoki. There are surface waters only here and there in Eurajoki (Figure 6-9). The largest lake in the municipality is Pinkjärvi (surface area 292.63 hectares), which is in the northern part of Eurajoki. However, most of the lake is in Pori. Other larger lakes in Eurajoki include Vuonajärvi in the middle of the municipality (surface area 29.14 hectares), Luttilanjärvi in the southern part of the municipality (4.69 hectares), and Lutanjärvi, also in the southern part of the municipality (38.66 hectares). There are also some smaller lakes and ponds in Eurajoki. *(National Land Survey of Finland 2016)*

The sea area in front of Eurajoki is part of the Selkämeri coast catchment area (83), and inland Eurajoki is divided into 20 catchment areas.

The sea area in front of Eurajoki is part of the water management areas of the Kokemäenjoki River, the Archipelago Sea, and the Bothnian Sea. Close to Olkiluoto, the sea area is divided into two water bodies in accordance with the EU Water Framework Directive. The area to the west of Olkiluoto is part of a water body called Olkiluodonvesi-Haapasaarenvesi, which is of the type “inner coastal waters of the Bothnian Sea.” It is not a heavily modified water body. Its ecological and chemical status are both good. The water area to the east of Olkiluoto is part of a water body called Eurajoensalmi. Its type is the same as the water body mentioned above. Its ecological status is satisfactory, and its chemical status is good. *(Environmental administration 2016b)*

The area in front of the municipality of Eurajoki is a shallow coastal area with quite many small islands and islets. The sea area in front of Eurajoki is fairly open. The water quality, ecological condition, and production in the sea area are affected by the general status of the coastal waters of the Bothnian Sea, as well as nutrients and other substances carried by the rivers.

Furthermore, the water quality close to the shore is affected by the nutrient load caused by the Eurajoki and Lapinjoki rivers. The water quality of Eurajoki and Lapinjoki rivers is affected by diffuse pollution and point source pollution. The status of the water in Eurajoki and Lapinjoki is satisfactory, and the water is turbid due to suspended clay. Both rivers have been modified by cleaning, embankments, and dams. The water flow in Eurajoki is regulated in order to obtain hydroelectric power and in order to protect the area from flooding. Both rivers are used as a source of raw water.

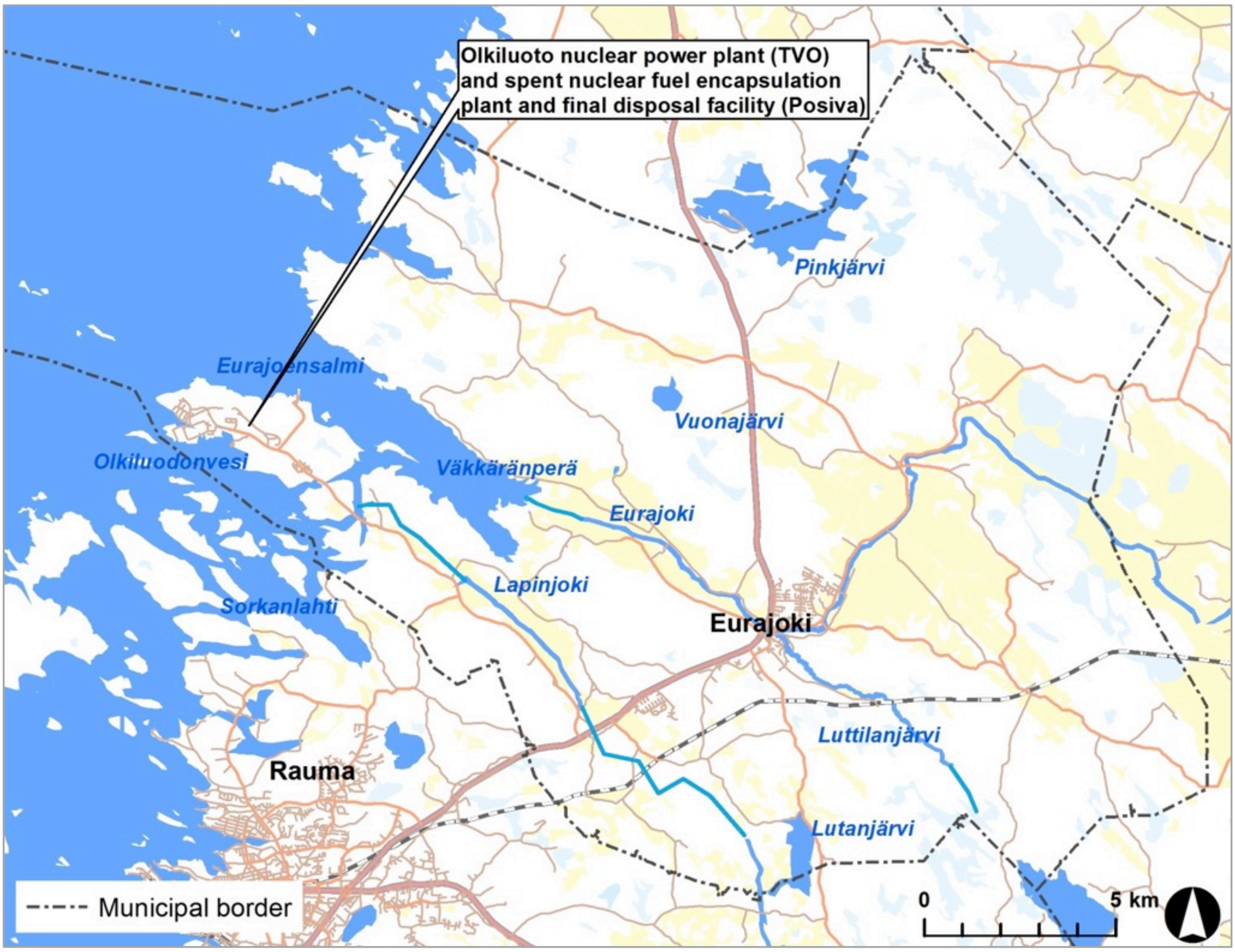


**Figure 6-9. Surface waters in Eurajoki *(National Land Survey of Finland 2016).***

## 6.1.6 Flora, fauna, and protection sites

In terms of vegetation, the municipality of Eurajoki is located in the anemone belt, or Lounaismaa part of the southern boreal vegetation zone. The peatland zone type is the raised bogs of Southern Finland. In terms of species, the area is part of the province of Satakunta. *(Karpalo map service of the Finnish environmental administration 2016)*

The Eurajoki area is part of the coastal area of the Gulf of Bothnia. Characteristics of this area include rapid land uplift and consequent clearly discernible vegetation zones along the seashores. The coastal areas in Eurajoki include rocky islets and till islets in the outer archipelago, forested islands in the inner archipelago, sandbanks with eskers, shallow gulfs, seashore meadows, groves of common alder, and lush estuaries *(Lampolahti 1993).* There are important coastal bird nesting areas in both the outer archipelago and close to the shores. A viable moor frog population and areas favored by bats *(Matikainen & Matikainen 2013)* lie in the coastal areas of Eurajoki. Endangered species in the coastal area include the clouded Apollo butterfly (*Parnassius mnemosyne*). The northern limit of the range of fumewort (*Corydalis solida*), the primary food source of the clouded Apollo, runs to the north of the Eurajoki estuary *(Kemppainen 2014).* The moor frog, bats, and the clouded Apollo are species listed in Annex IV(a) of the Habitats Directive.

Several nature surveys have been completed during the land use planning of the island of Olkiluoto, which is located in the southern part of the coastal area in Eurajoki (*e.g., Insinööritoimisto Paavo Ristola Oy 2007, Nieminen et al. 2009, Nieminen et al. 2011*). According to the surveys, the natural environment of the island has been heavily modified by human activity, but some of the coastal forests are almost in their natural state. Species occurring in Olkiluoto include moose, white-tailed deer, roe deer, raccoon dog, red fox, pine marten, American mink, stoat, European polecat, European badger, mountain hare, and brown hare *(Insinööritoimisto Paavo Ristola Oy 2007)*. There are traditional landscapes with a long land use history in the Olkiluoto-Orjansaari-Eurajoki estuary area *(Härjämäki et al. 2011, Kemppainen 2014)*.

Based on the studied maps and aerial photos, there are forest areas, villages, and fields in the inland areas of Eurajoki. There are more considerable peatland areas in the eastern part. Part of the peatlands are used for the production of peat. The area surrounding the village of Eurajoki is mostly managed forest, and no Siberian flying squirrels, for example, have been observed there *(Oja & Oja 2014)*. The Siberian flying squirrel, a species included in Annex IV(a) of the Habitats Directive, can be found in the Pinkjärvi area, for example *(Southwest Finland Centre for Economic Development, Transport and the Environment 2013b)*, and Siberian flying squirrels have been observed in nature surveys made during the EIA procedures for power lines *(Fingrid Oyj 2003 & 2012).* Surveys of vegetation, birdlife, and dragonflies, among others, have been completed for the village of Eurajoki and the Eurajoki River, which runs through the field areas *(Eurajoki.info 2016).* In the Finnish breeding bird atlas *(Valkama et al. 2011)*, most of the municipality of Eurajoki is located within 10 $km^2$ squares where 110–120 bird species definitely, probably, or possibly nest. The largest numbers of nesting species were observed in the Olkiluoto and Linnamaa areas (areas no. 680:320 and 680:321 on the map): 141 and 145 species, respectively.

### Natura 2000 areas, nature conservation areas, and nature sites of national importance

All known sites in the research area (*Karpalo database of the Finnish environmental administration 2016*) are listed below and shown in the figure below (Figure 6-10).

1. **Bothnian Sea National Park** (KPU020037). The national park was established by virtue of Finnish Act no. 326/2011 to protect the underwater environment of the open Bothnian Sea, the archipelago, islets, wetlands in the coastal areas, and related species. Furthermore, the aim is also to maintain their habitats, retain the natural and cultural heritage, ensure that people have the opportunity to observe nature, and to ensure the possibility to use the area for teaching and research activities, and for monitoring environmental changes. The national park is in a sea area of around 160 kilometers, extending from Kustavi to Merikarvia. It consists of around 91,200 hectares of land and water areas. Around 6,000 hectares in the middle of the national park are located in Eurajoki. Furthermore, of the separate areas that are also part of the national park, a small water area to the west of Kornamaa island to the north of Olkiluoto within the Eurajoki municipality.
2. **Rauma archipelago Natura area**. (FI0200073, SAC, 5,350 ha). The Natura area includes parts of the outer Bothnian Sea archipelago and sea zone archipelago that are important for seabirds, and parts of the inner archipelago, which include groves with important vegetation (*Southwest Finland Centre for Economic Development, Transport and the Environment 2013a*). The northern part of the undivided outer archipelago and sea area included in the Natura area is located in Eurajoki, as well as some separate islands. Most of the area is included in the Rauma archipelago shore conservation program site

(RSO020020), the Bothnian Sea National Park, and IBA and FINIBA bird areas. The Natura area also includes the forested Liiklankari area in Eurajoki (around 50 hectares), which is in the southern part of the island of Olkiluoto. The Liiklankari area is included in a national old forest conservation program (AMO020001), and it is protected as the Liiklankari nature conservation area (VMA020001).

3. **Rauma-Luvia archipelago IBA** (45) and **Rauma-Luvia-Pori archipelago FINIBA (**120074, 27,371 ha). The Rauma-Luvia archipelago, an important bird area in Finland, is an extensive, undivided archipelago area and an important seabird nesting area. The area is part of the Rauma-Luvia-Pori archipelago, which is a Finnish Important Bird Area (FINIBA; *Leivo et al. 2002).* The middle parts of both areas are in Eurajoki. The northern archipelago area of Rauma and Eurajoki, which has been classified as a regionally important nesting and migration area, includes the archipelago and water areas on the western shore of the island of Olkiluoto *(Porin lintutieteellinen yhdistys ry & Rauman seudun lintuharrastajat ry 2014).*
4. **Kuivalahti FINIBA area** (120077, 1,026 ha). The water area on the northern coast of Eurajoki is a Finnish Important Bird Area (FINIBA; *Leivo et al. 2002*). The northern edge of the area is outside the municipality of Eurajoki.
5. **Leppäkari nature conservation area** (YSA206417). The area is on the northern coast of Eurajoki.
6. Southern parts of the **Luvia archipelago shore conservation program site** (RSO020021). The shore conservation program site includes two separate southern areas located on the northern coast of Eurajoki along the Santalahdensalmi straits.
7. **Kornamaa old forest conservation program site** (AMO000093). The forested area of around three hectares is in the western part of the island of Kornamaa to the north of Olkiluoto. A small water area in front of the site is part of the Archipelago Sea National Park.
8. **Eurajoki estuary FINIBA area** (120075, 1,605 ha). The Eurajoki estuary is a Finnish Important Bird Area (FINIBA; *Leivo et al. 2002*). It includes riverbank fields, water areas in the estuary, islands, and coastal forests. The estuary area and the adjacent fields are some of the most important resting areas for wetland birds in the spring (*Porin lintutieteellinen yhdistys ry & Rauman seudun lintuharrastajat ry 2014*).
9. Easternmost part of **Prami grove conservation program site** (LHO020058). The other parts of the grove conservation program site are included in the Rauma diabase Natura area (FI0200002, SAC, 76 ha). These areas are outside the municipality of Eurajoki.
10. **Vuonajärvi Natura area** (FI0200174, SAC, 24 ha). The area, comprising three adjacent forest areas, is located in the northern part of Eurajoki. The largest of the areas, the easternmost one, and part of the middle area are protected as the Vuonajärvi nature conservation area (YSA206232 and YSA206697).
11. **Pinkjärvi Natura area** (FI0200078, SAC, 1,681 ha). The Natura area consists of three areas included in the Pinkjärvi-Ylistenjärvi shore conservation program site (RSO020024) and the surrounding forests. The vegetation of these lakes is unusual as the lakes are naturally eutrophic. The forests are partially in their natural state or have been restored. (*Southwest Finland Centre for Economic*

*Development, Transport and the Environment 2013b*) The area is in the northeastern part of Eurajoki.

12. **Lastensuo Natura area** (FI0200009, SAC, 279 ha). An area that is slightly smaller than the Natura area is included in the national peatland conservation program (site SSO020048). The area is in the northeastern part of Eurajoki.
13. **Huhdansuo-Kakkeriansuo Natura area** (FI0200087, SAC, 365 ha) **and peatland conservation area** (SSA020014). An area that is slightly smaller than the Natura area is included in a national peatland conservation program (site SSO020047). The area is in the northeastern part of Eurajoki. The eastern edge of the area is outside the municipality of Eurajoki.
14. Nationally valuable till formation **Jakoniitty terminal moraine shoal** (MOR-Y02-013). The area is in the northeastern part of Eurajoki.

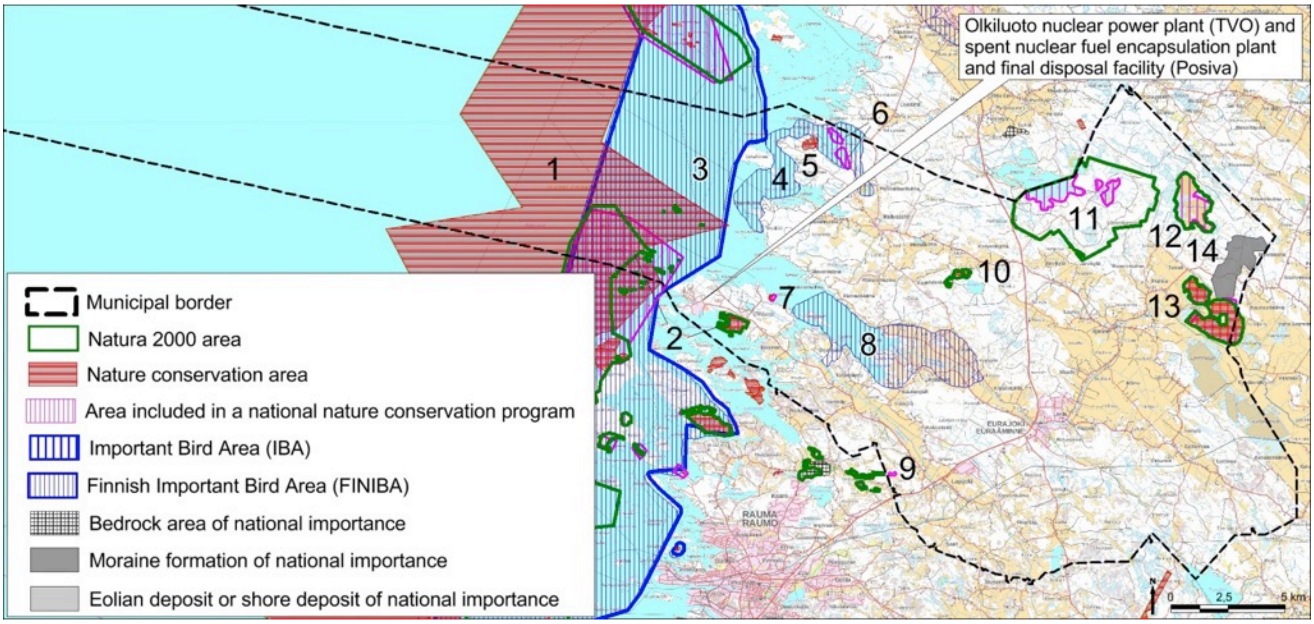


**Figure 6-10. Natura 2000 sites, nature conservation areas, and nationally valuable nature sites in Eurajoki.**

## 6.1.7 Climate and air quality

Eurajoki is located in the province of Satakunta. The climate of Satakunta is dual in nature, since the province consists of coastal areas and continental inland areas. The annual average temperature varies from around +5°C in the coastal area between Rauma and Pori to around +3°C in the northeast. Annual precipitation is, on average, a little less than 600 mm on the Bothnian Sea coast and 600–650 mm in the other parts of the province. The maximum snow cover thickness in the southern and middle parts of Satakunta is 20–30 cm. The growing season is 170–190 days. *(Finnish Meteorological Institute 2016)* The prevailing wind direction is from the southwest *(Tuuliatlas 2016).*

Emissions into the air are minor in Eurajoki. The amount of emissions from smaller industrial plants, also known as point sources, as well as 'area sources' (houses, saunas, etc.), has not been assessed. There is no air quality monitoring at Eurajoki. The closest monitoring measurement point is in Rauma. Air quality is also monitored at the industrial locations of Harjavalta and Pori. *(Posiva 2012c)*

### 6.1.8 Traffic

Highway 8 (Porintie) goes through Eurajoki. In 2014, the average vehicle traffic on Porintie at Eurajoki was around 6,300–10,200 vehicles per day. Around 800–1,000 of these were heavy vehicles. (*Finnish Transport Agency 2016*) Several smaller roads to different parts of the municipality of Eurajoki intersect with Porintie (Figure 6-11). The largest roads intersecting with Porintie and their traffic volumes are listed in the table below (Table 6-2). There are also a large number of smaller roads in the municipality of Eurajoki.

The Rauma-Kokemäki railway line goes through the southeast part of Eurajoki. The Rauma railway is a section included in the Finnish railway network. It goes from Kokemäki to Rauma. Most of the trains using the Rauma-Kokemäki railway line are freight trains.

There is an industrial port on the northern side of the island of Olkiluoto. A six-meter passage leads from the west, north of the island of Kalla, to the port. The port is open during the open water season. The port handles both import and export. Around 90–100 vessels stop at the port annually *(Teollisuuden Voima Oyj 2008)*. Furthermore, there are piers of the Olkiluoto nuclear power plant on the southern shore of the island of Olkiluoto. There is a five-meter passage to these piers. One to two vessels per year, or less, stop at the Olkiluoto 1 pier (and probably also at the OL3 pier). There is a fishing harbor with a two-meter passage at Pujonkulma.

**Table 6-2. Largest roads intersecting Highway 8 (Porintie) and their traffic volumes in Eurajoki *(Finnish Transport Agency 2016).***

| NAME AND NUMBER OF ROAD | AVERAGE VEHICLE TRAFFIC (vehicles per day) in 2014 | HEAVY TRAFFIC (vehicles per day) in 2014 |
|---|---|---|
| Olkiluodontie (2 176) | 2,281 | 181 |
| Taipaleentie (12 775) | 507 | 26 |
| Lapintie/Eurajoentie (2 070) | 1,053 | 145 |
| Kirkkotie/Huhdantie (2 170) | 4,884 | 201 |
| Linnanmaantie (12 773) | 661 | 15 |
| Kämpäntie (2 171) | 434 | 59 |

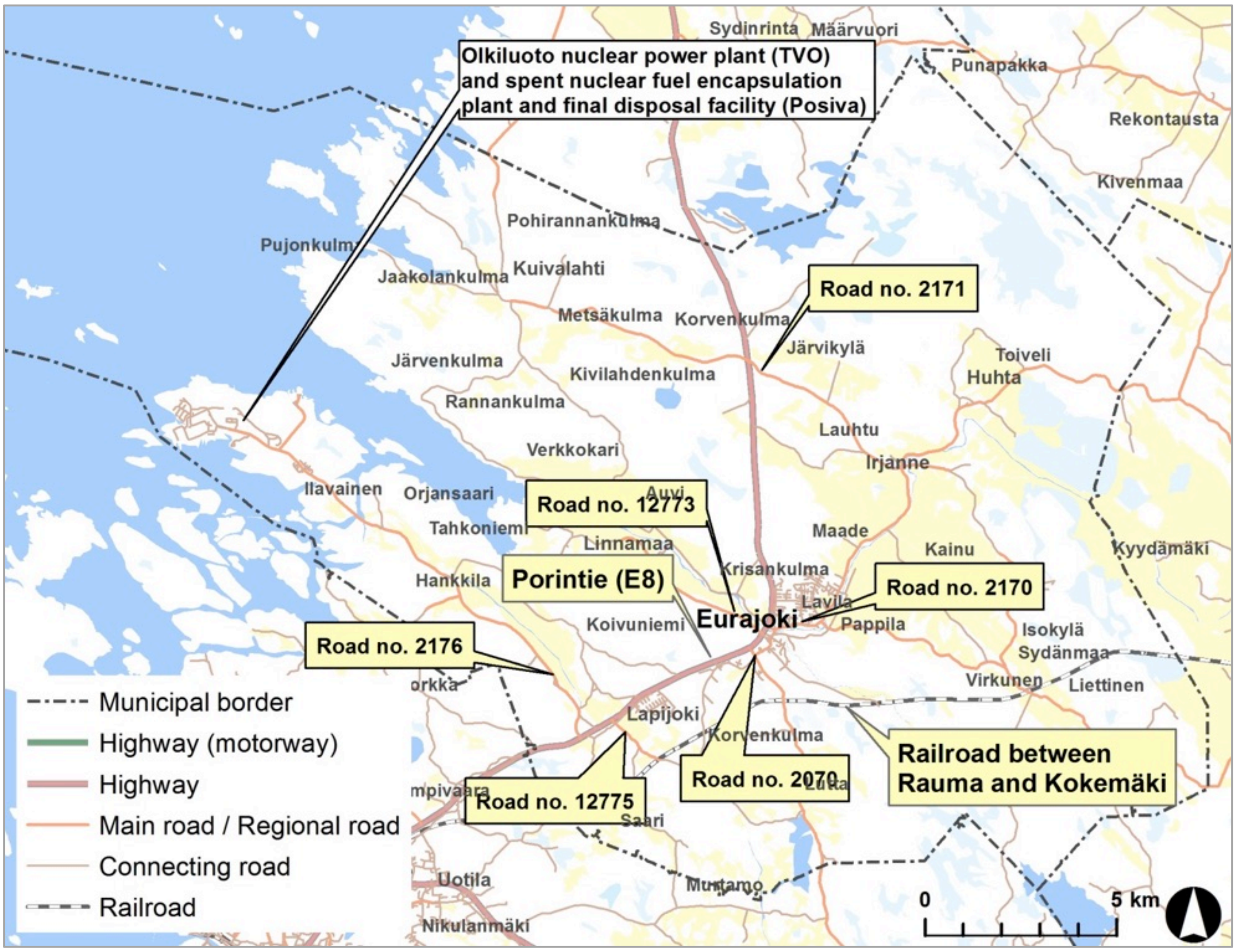


**Figure 6-11. Roads in Eurajoki and its immediate vicinity.**

## 6.1.9 Noise and vibration

In most of Eurajoki, the major source of noise is traffic. There is more noise in the areas adjacent to industrial activities, Olkiluoto in particular. In addition to the current Teollisuuden Voima Oyj plant units OL1 and OL2, the noise level in the immediate vicinity of the Olkiluoto nuclear power plant site is affected by the construction site of the OL3 plant unit, a wind power station, the ONKALO construction site of Posiva Oy, the port, and a gas turbine power plant of Fingrid Oyj. According to noise modeling *(Posiva 2012c)*, if the Teollisuuden Voima Oyj nuclear power plant units OL1, OL2, and OL3 were all in operation, the Posiva Oy encapsulation plant and final disposal facility was under construction and rock was being blasted, the noise levels during the day and at night at the closest residential properties and holiday homes would still remain below the guideline values.

Most vibration in Eurajoki is caused by heavy traffic and affects the areas in the immediate vicinity of the roads. Construction sites, those at Olkiluoto in particular, also cause vibration in their vicinity. In the Olkiluoto area, vibration is caused by activities during the construction of the Olkiluoto nuclear power plant (OL3) of Teollisuuden Voima Oyj and the construction of the encapsulation plant and final disposal facility of Posiva Oy, such as blasting, excavation, and the operation of vehicles and working machinery. The vibration caused by the blasting at the ONKALO construction site has had a maximum magnitude of around 0.7 *(Posiva 2012c)*.

## 6.2 Sydänneva in Pyhäjoki

### 6.2.1 Location and adjacent activities

The Sydänneva research area (of around 13 km$^2$) is located in the municipality of Pyhäjoki in the province of Northern Ostrobothnia (Figure 6-12). The research area is bounded to the south by the border of the municipality of Kalajoki and to the east by the border of the municipality of Merijärvi. The closest residential areas include Merijärvi, around six kilometers to the southeast of the research area; Pyhäjoki, around 11 kilometers to the north; Alavieska, around 13 kilometers to the south; and Kalajoki, around 13 kilometers to the southwest.

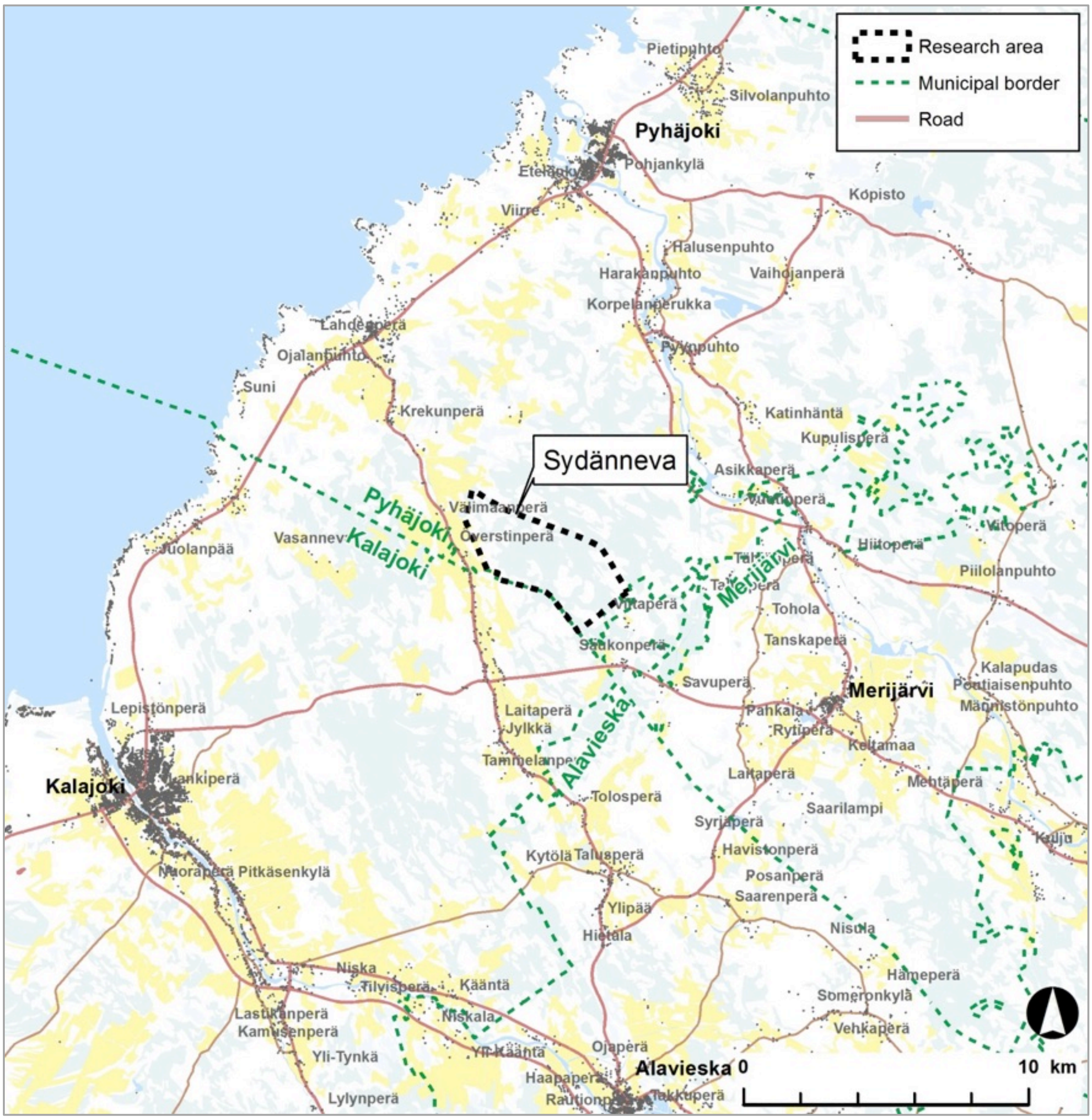


**Figure 6-12. Location of the Sydänneva research area.**

At present, most of the research area is in forestry use; there are fields only at the western edge of the research area. No industrial activities are practiced in the area. There are currently valid soil extraction permits for the Ylihautala area (around 0.3 kilometers to the north of the research area) and the Poro-Pirkola area in Metsäniitty (around 0.6 kilometers to the north of the research area *(Karpalo map service of the Finnish environmental administration 2016)*. The Mäkikangas wind farm is around 4.2 kilometers to the west of the research area. The wind farm was commissioned in 2016. (*wpd Finland Oy 2016*) Based on a map survey, there are fur farms in the Krekunperä area along Mehtäkyläntie road, around four kilometers to the northwest of the research area. Merijärvi, Pyhäjoki, and Pyhänkoski wind farm project of Puhuri Oy is currently ongoing at Merijärvi, around six kilometers to the southeast of the research area (*Puhuri Oy 2016*). Fennovoima Oy's Hanhikivi 1 nuclear power plant site is in Pyhäjoki, around 18 kilometers north of the research area. Industrial activities are also practiced in the Kalajoki area, around 13 kilometers to the southwest of the research area. There is a gravel pit in the Yläsalo area, 3.7 kilometers to the northeast of the research area.

The Karhunnevankangas wind farm project of wpd Finland Oy covers part of the research area. The project's EIA procedure has been concluded, and the land use planning process is ongoing. The proposed wind farm area is around 12 kilometers to the southeast of the center of Pyhäjoki, in a forested area between Pyhäjoki and Yppäri. The proposed wind farm area is around 2,590 hectares in size. The plan is to build 36–40 wind power plants of 3 MW in Karhunnevankangas. Depending on the selected wind farm alternative, around five of the wind power plants will be built at the northern edge of Fennovoima's Sydänneva research area.

There are no other currently ongoing EIA projects or known projects for which an environmental permit or water permit is required in the research area. There are a high-voltage power line and a regular power line (supply voltage) around 1.3 kilometers to the south of the research area, and a regular power line (supply voltage) around 0.7 kilometers to the west. The plan is to construct the 110 kV power line required to connect the Hanhikivi 1 nuclear power plant to the external grid around 1.3 kilometers to the south of the research area, next to the already-existing high-voltage power line. The EIA procedure on the power lines required to connect the Hanhikivi 1 nuclear power plant to the external grid is currently ongoing, and the EIA report was submitted to the coordinating authority in early June 2016.

### 6.2.2 Residences, people, and communities

There are no residential properties in the Sydänneva research area (Figure 6-13). The closest residential properties to the west of the research area are along Yppärintie road (connecting road no. 7840), around 300 meters away. The closest residential buildings to the southeast of the area, in the Saukonperä and Överstinperä areas, are around 300–600 meters away. The closest population centers within a 20-kilometer radius of the research area are Merijärvi, Pyhäjoki, Kalajoki, and Alavieska (Figure 6-14Figure ).

There is one holiday home in the Sydänneva research area, in the southeast on the shore of Umpilampi lake (Figure 6-13). There are some holiday homes in the immediate vicinity of the research area; the closest of them are 400 meters to the west and to the north.

The closest schools are around four kilometers to the south in Mehtäkylä in the municipality of Kalajoki, and around six kilometers to the southeast in Merijärvi. These locations also house the closest kindergartens, retirement homes, and health centers. A canoeing route runs from north to south around 0.5 kilometers to the west of the research area in Yppärinjoki. The closest public beach is around four kilometers to the south, on the shore of a pond to the east of Yli-Limpsiä. *(Paikkatietoikkuna 2016)*

Hunting societies active in the area include Pyhäjoen metsästysseura ry in Pyhäjoki, Kalajoen Metsästysyhdistys ry in Kalajoki, and Merijärven Metsästäjät ry in Merijärvi. There are no hunting lodges in the research area. Recreational use of the Sydänneva research area is mainly limited to local recreational use, such as picking berries and mushrooms, and hunting.

Key figures of the municipality of Pyhäjoki are listed in the table below (Table 6-3).

**Table 6-3. Key figures of the municipality of Pyhäjoki *(Statistics Finland 2016).***

| | PYHÄJOKI |
|---|---|
| Share of population centers, %, in 2014 | 70.7 |
| Population in 2014 | 3,290 |
| Change in population from the previous year, %, 2014 | -2 |
| Positive/negative migration between municipalities, persons, 2014 | -64 |
| Share of unemployed in the workforce, %, 2013 | 12.7 |
| Share of pensioners in the population, %, 2013 | 30.2 |
| Dependency ratio, 2013 | 176.4 |
| Share of jobs in primary production, %, 2013 | 14.2 |
| Share of jobs in refining, %, 2013 | 29.0 |
| Share of jobs in the service sector, %, 2013 | 55.1 |

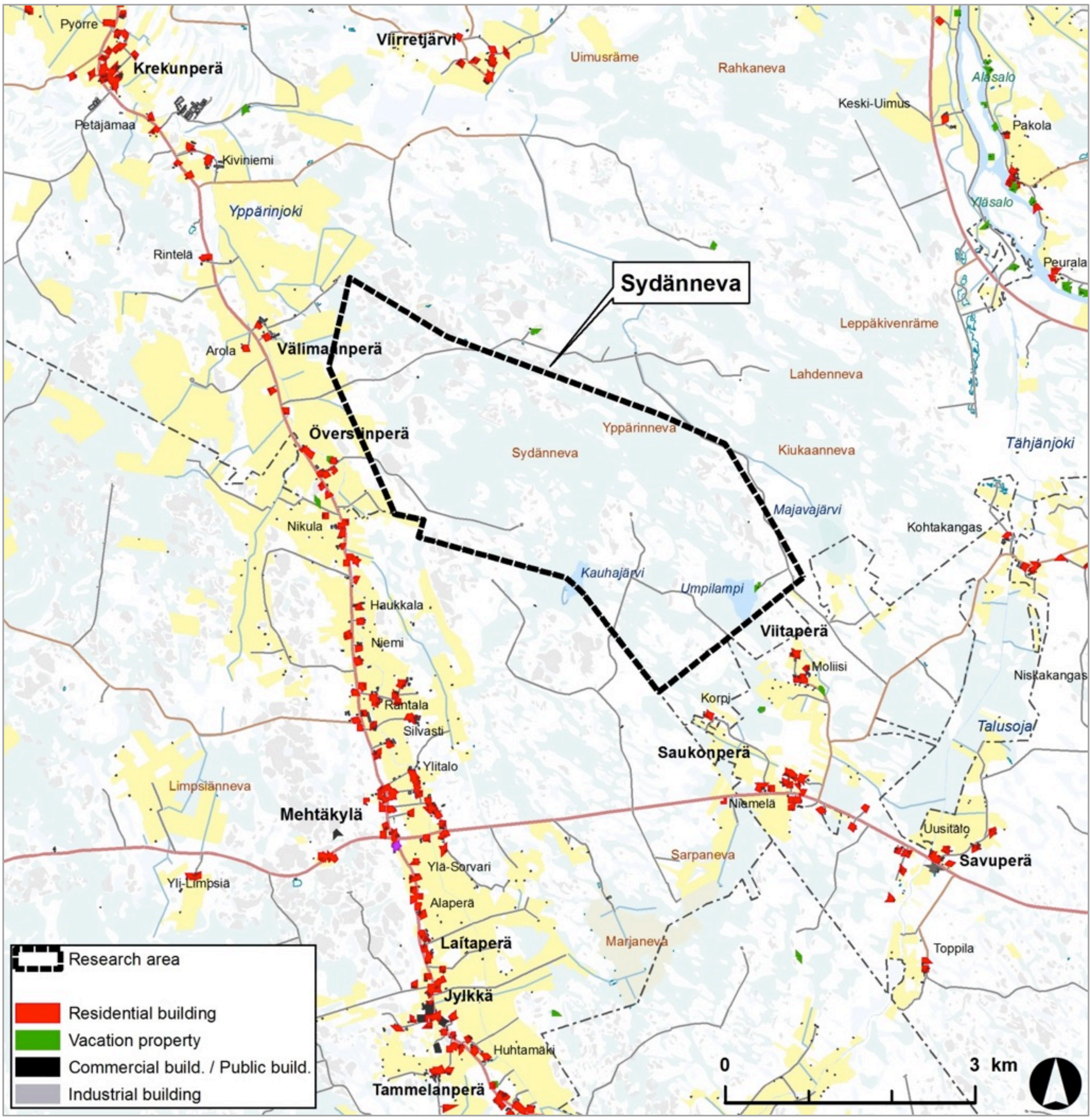


**Figure 6-13. Built environment (residential buildings and holiday homes) in the Sydänneva research area.**


**Figure 6-14. Residential buildings and holiday homes within five-kilometer and twenty-kilometer radii of the Sydänneva research area.**

## 6.2.3 Land use planning

### *Regional land use plan*

Land use in the Sydänneva research area is governed by the Northern Ostrobothnia regional land use plan. The Northern Ostrobothnia regional land use plan in force was approved by the regional council in 2003 and ratified by the Ministry of the Environment in 2005. The regional plan became legally valid based on a decision of the Supreme Administrative Court on August 25, 2006. The first, second, and third regional stage plans for Northern Ostrobothnia are currently in process, but they do not include any area reservations in the Sydänneva research area. *(Council of Oulu Region 2016*)

Most of the Sydänneva research area consists of areas that have not been reserved for any purpose in the regional land use plan (Figure 6-15). There are three monuments of antiquity marked in the regional land use plan in the research area or its immediate vicinity. They are protected by the virtue of the Antiquities Act (295/1963). The Mehtäkylä population center, listed in the regional land use plan, is around 200 meters to the west of the research area. The regional land use plan shows a main power line and a local road (Oulaistentie) around 1.3 kilometers to the south of the research area. The regional land use plan shows a border between an urban area and a rural area around two kilometers to the north of the research area and the border of Pyhälaakso rural development area around three kilometers to the east of the research area.

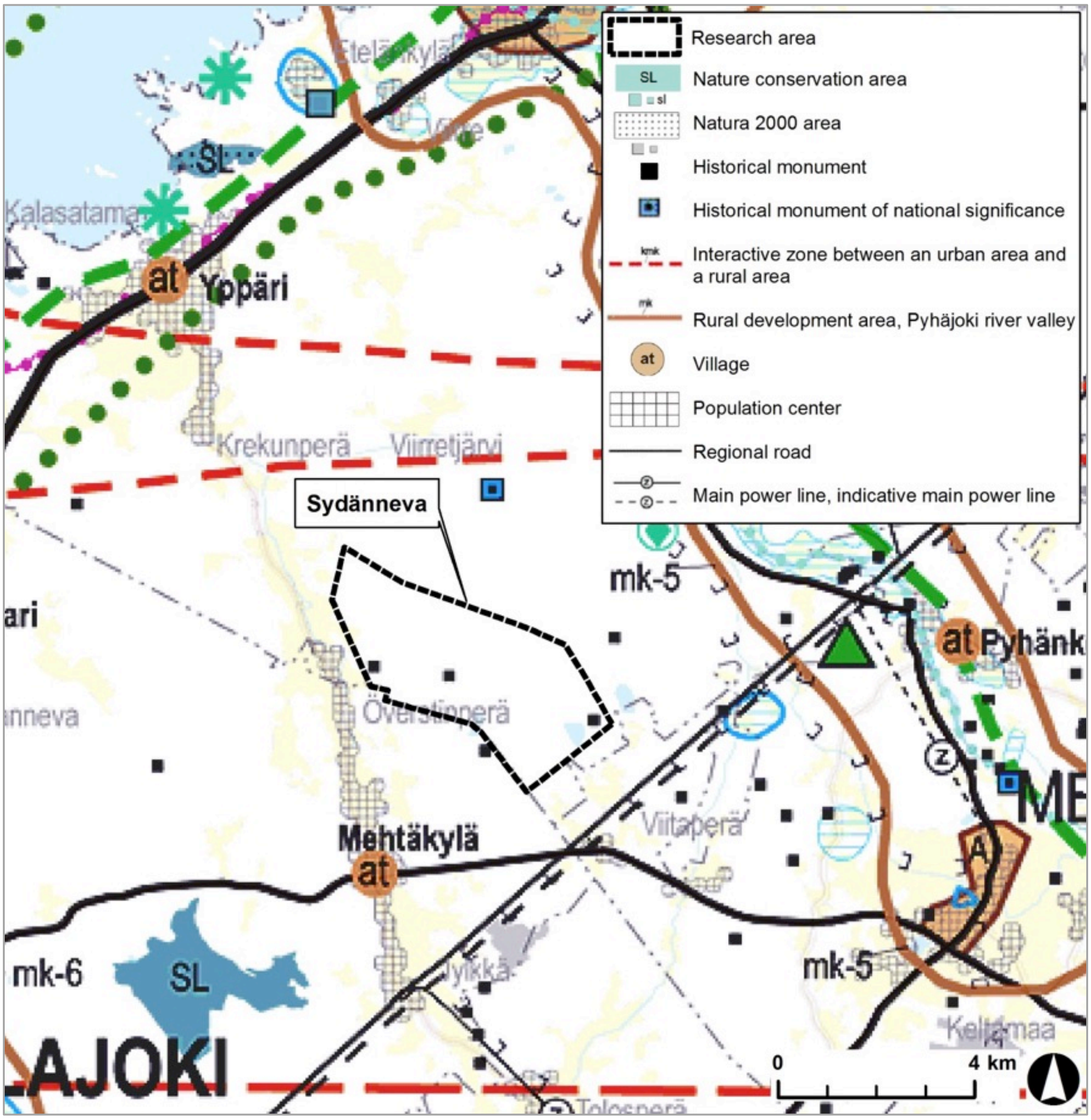


**Figure 6-15. Markings on the Northern Osthtobothnia regional land use plan in and in the vicinity of the Sydänneva research area. The research area is in the area covered by the Northern Ostrobothnia regional land use plan. (*Council of Oulu Region 2006*).**

### *Master and local detailed plans*

A component master plan for the Karhunnevankangas wind farm is currently pending. The proposed wind farm site is at the northern edge of the Sydänneva research area.

The closest other local master plans are those of Merijärvi, Ristivuori, and Pyhänkoski, around 4.2 kilometers to the east of the research area, and a component master plan for the Mäkikangas wind farm in Pyhäjoki, around 4.2 kilometers to the west of the research area. The closest local detailed plan is for Merijärvi, around 7.9 kilometers to the southeast of the research area.

## 6.2.4 Landscape and the cultural environment

### *General description of the landscape*

According to the landscape province division by the Landscape Committee of the Ministry of the Environment, the Sydänneva research area is located in the landscape province of Ostrobothnia, more specifically in the Central Ostrobothnia river region and coastal area (*Ministry of the Environment 1992*). The Central Ostrobothnia river region and coastal area is characterized by fairly narrow croplands in the river valleys and fairly large, rugged, and marshy till ridges in between the croplands. The terrain is fairly level. There are some knolls and extensive mires in the level areas. Most of the residential areas upriver in Central Ostrobothnia are located on knolls overlooking valleys. There is usually a field in between the residences and the river. At the middle and lower reaches of rivers, buildings are usually on the river bank. In addition to crop cultivation, cattle has traditionally been a more important livelihood than in Southern Ostrobothnia. However, fur farming has recently become an important livelihood.

The landscape in the Sydänneva research area is characterized by peat bogs, mires, and marshes, some of them not trenched. The area is fairly level as a whole, and there are no major elevation differences. There are some forested rocky areas and hilltops around the peatland areas. The landscape in the southern part of the research area is characterized by two lakes. There are no buildings on the shores of the first lake, and there is one holiday home on the shore of the other lake. There are fields located to the west of the research area.

### *Valuable landscape and cultural environment sites*

A nationally valuable cultural environment site called Talusperä (Figure 6-16, site no. 4) is located around two kilometers to the east of the research area. Another nationally valuable cultural environment site called Jylkkä Farm (Figure 6-16, site no. 7) is located around three kilometers to the southeast of the research area *(National Board of Antiquities 2016)*

A valuable esker formation is located around three kilometers to the northeast of the research area, to the east of Kiuasneva. It is also an area of national importance for the conservation of landscapes (Figure 6-16, site no. 5). The Pyhänkoski area (Figure 6-16, site no. 6), an area of national importance for the conservation of landscapes, is located around four kilometers to the northeast of the research area, and the Tanskanperä area (Figure 6-16, site no. 4), a landscape area of regional importance, is located around 4.7 kilometers to the southeast of the research area. (*Council of Oulu Region 2006*) An inventory of regionally valuable landscape areas in Northern Ostrobothnia took place in 2014 (*Council of Oulu Region 2014*). No new valuable landscape areas were found in the vicinity of the Sydänneva research area.

### *Historical monuments*

There are three monuments of antiquity in the Sydänneva area: the Sydännevansaaret barrow (a stone structure) in the middle of the area (Figure 6-16, site no. 1), the Lähdekangas E barrow in the western part of the area (Figure 6-16, site no. 2), and the Korkiakangas SE barrow in the eastern part of the area (Figure 6-16, site no. 3). The fixed Sydännevasaaret monument of antiquity from the Early Metal Age is a rocky islet of heath surrounded by marshes. The barrow lies upon bedrock, and the middle of the barrow has been partially opened, but it is still in good condition. It is a fairly impressive monument of antiquity. The Lähdekangas E barrow is an asymmetrical barrow of rocks on top of the bedrock. Its diameter is around 5–6 meters. The barrow consists of one layer of rocks. It could be better characterized as a mound than a barrow, but it is clear-ly a man-made structure. The Korkiakangas SE barrow is a partially demolished small barrow, around 7 x 3 meters in size. In addition, four new monuments of antiquity were found during surveys in the immediate vicinity of the research area in 2015 *(Itäpalo & Schulz 2015)*. There are several other monuments of antiquity outside the research ar-ea; at the closest within 900 meters of the research area.

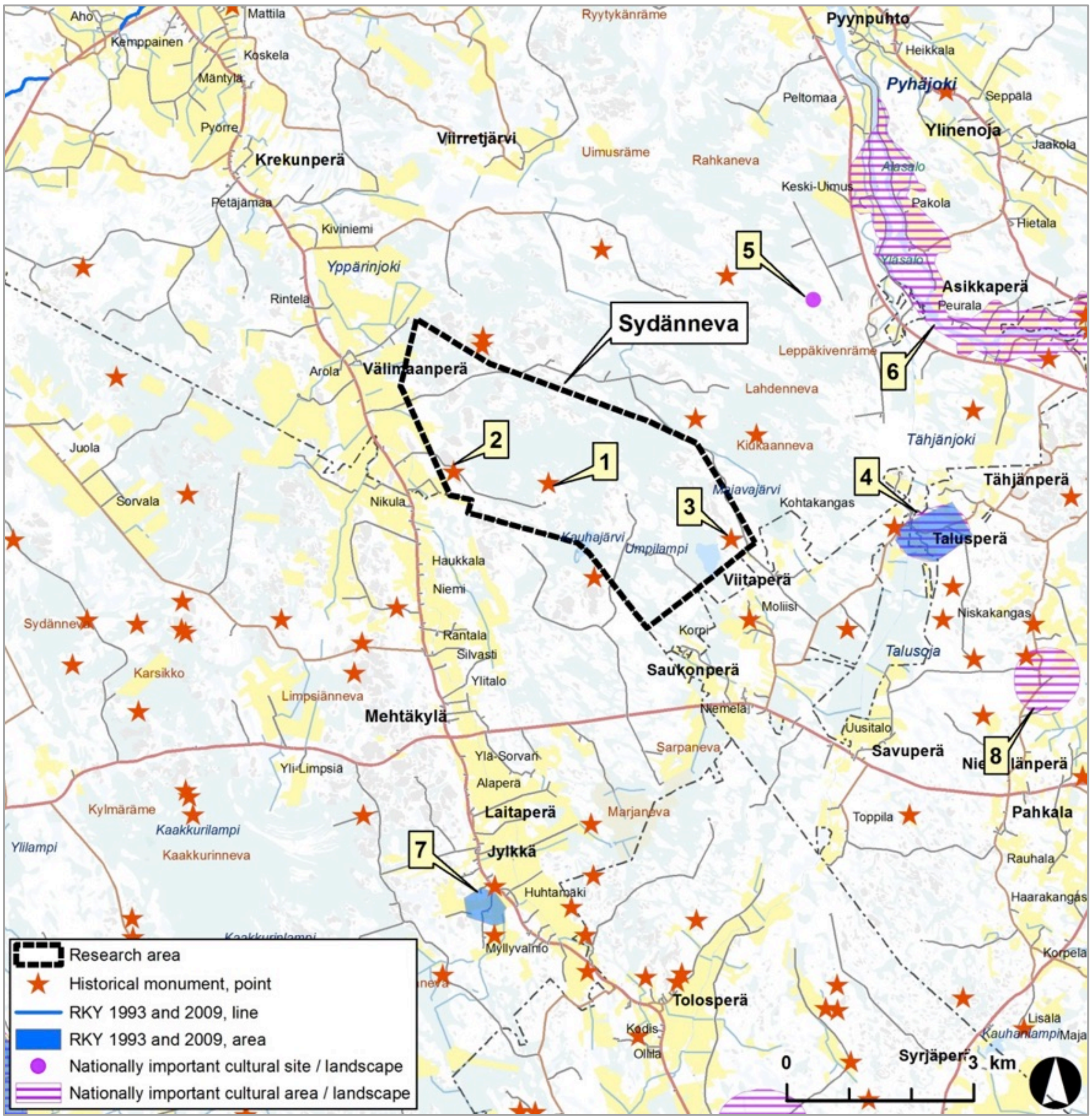


**Figure 6-16. Valuable cultural environment sites and landscape areas in and in the immediate vicinity of the Sydänneva research area. The numbers included in the image are explained in the legend. *(National Land Survey of Finland 2016, Karpalo map service of the Finnish environmental administration 2016)***

## 6.2.5 Soil and bedrock

The Sydänneva research area is situated within the Palaeoproterozoic supracrustal Ostrobothnia belt, where granitoids (granites, granodiorites) 1.88 Ga old crosscut the supracrustal metasedimentary and metavolcanic rocks. The bedrock in the Sydänneva research area varies from medium-grained granodiorite (Figure 6-17), to porphyritic granodiorite with K-feldspar phenocrysts (*Salli 1966*). Schist inclusions and granitic veins are common.

On the basis of lineament interpretations, the Sydänneva research area is a bedrock block, defined by possible fracture zones of size category 2 in the north, east and west, and by a fracture zone of size category 3 in the south. There is a fracture zone of size category 1 in the west, less than one kilometer from the research area. The fracture zone classification is described in Chapter 3.4.3.

Geophysically, the Sydänneva research area is stable (Figure 6-18). There are no discernible magnetic or electromagnetic anomalies within the area, but a slight magnetic gradient of around 20 nT/km towards the north/north-northwest can be observed within the research area. Only at the northern edge of the area, north of the Yppärinneva swamp, is there a small-sized magnetic maximum, which is probably related to a mica gneiss inclusion or a basic formation (gabbro, diorite). A stronger arching magnetic anomaly zone, located 1–2 kilometers to the north and northeast of the area, is related to mica gneiss.

The research area contains abundant bedrock outcrops (10% of the total area) with intervening silty till (25 %) and peat (65 %). On the basis studies in the Sydänneva mire in the middle of the area, the peat deposits are usually less than two meters thick (*Turunen & Laatikainen 2007*). Topography of the research area is very even. The difference in altitude within the area is usually not more than three meters, with the maximum difference in the altitudes being only six meters. Fracture frequency of bedrock outcrops, according to the field observations of a 1985 site selection survey (*Salmi et al. 1985*), is 0.84 fractures per meter measured along perpendicular north-to-south- and east-to-west-trending lines. A sulfate soil study was conducted in the immediate vicinity of the research area. According to the survey, there is some acid sulfate soil in the peatland parts of the research area (*Auri 2015*).

The entire research area is included in a potential area for precious metals and kaolin. The Sydänneva research area does not contain any known mineral deposits or occurrences, but some mineralized boulders anomalous mostly for iron (Fe) have been reported. The research area does not intersect with any mining or exploration areas.

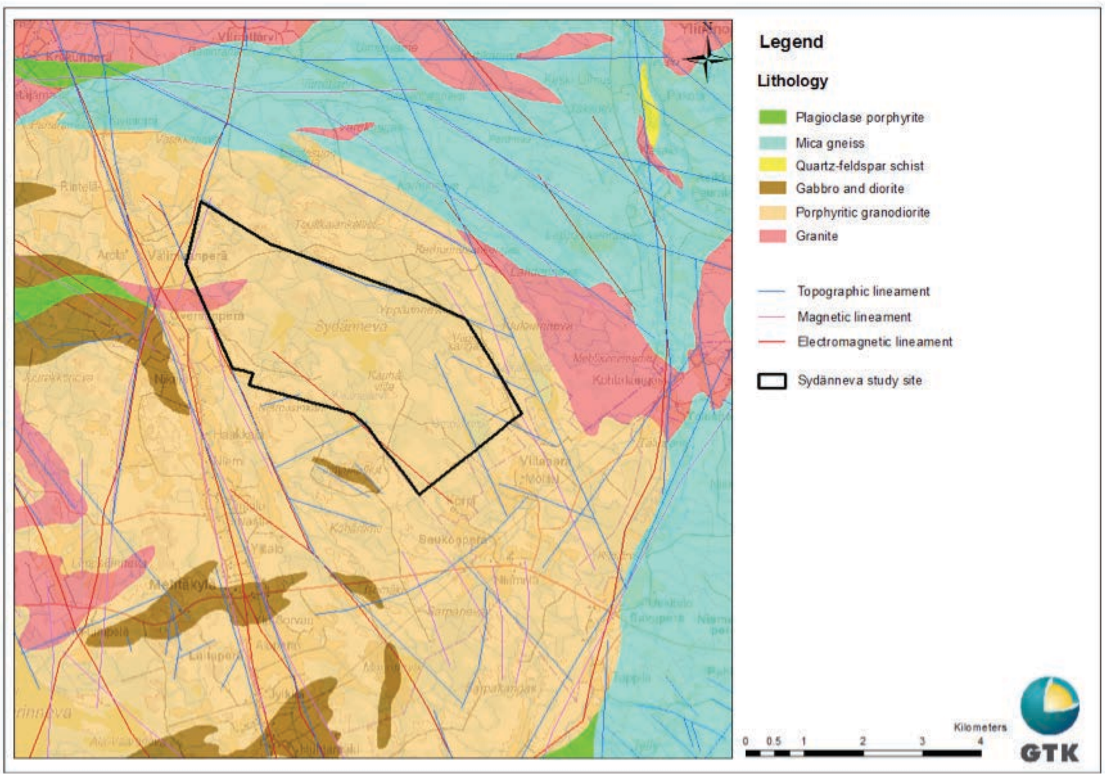


**Figure 6-17. Bedrock in and in the immediate vicinity of the Sydänneva research area (*Salli 1965*). Lineaments presented are according to data by the Geological Survey of Finland.**

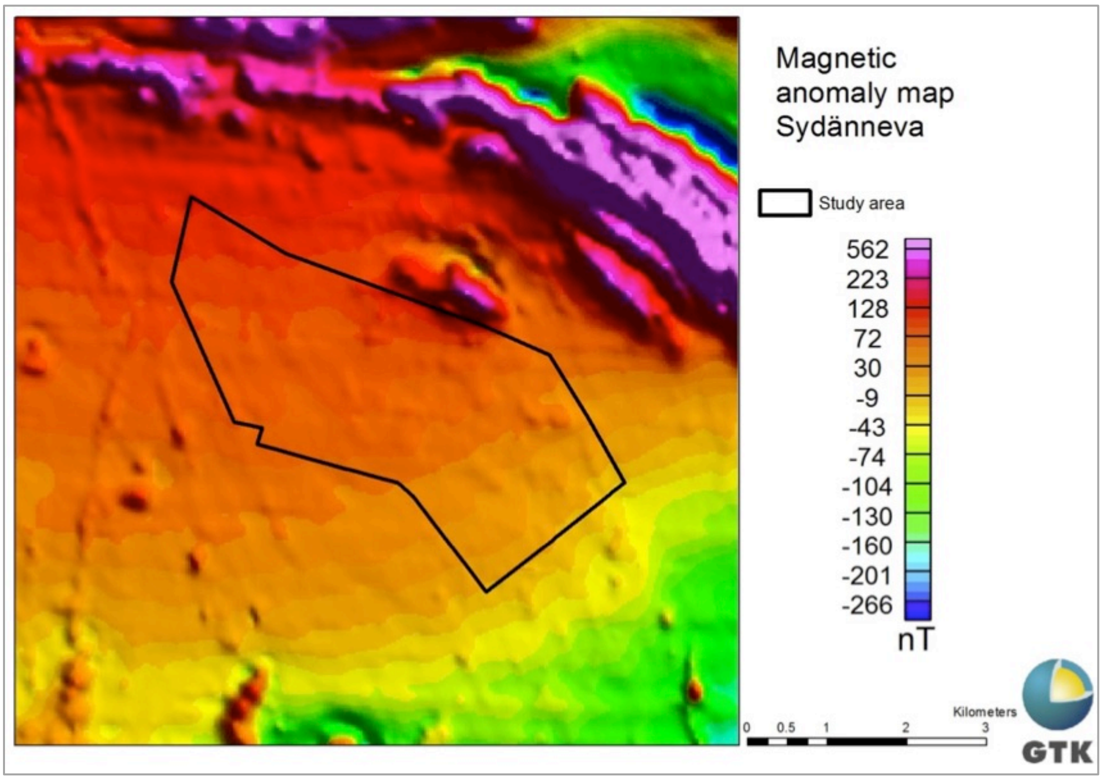


**Figure 6-18. Magnetic anomaly map of the Sydänneva research area and its immediate vicinity. Strong anomalies (color variations in the research area) indicate potential variation of rock types and fragmental bedrock. The causes of the anomalies will be studied during the bedrock surveys.**

### 6.2.6 Groundwater and surface waters

#### *Groundwater*

The Sydänneva research area is not located in a classified groundwater catchment area (Figure 6-19). The unclassified groundwater catchment area of Kaivosoja (other groundwater area, 11625005) is around 1.8 kilometers to the north of the research area (Figure 6-19, site no. 1). The unclassified groundwater catchment area of Tähjänjoki (other groundwater area, 11625004) is around 2.8 kilometers to the northeast of the research area (Figure 6-19Figure, site no. 2), and Kötinkangas groundwater catchment area (11625002), an area important for water supply, is around ten kilometers to the northeast of the research area (Figure 6-19Figure, site no. 3).

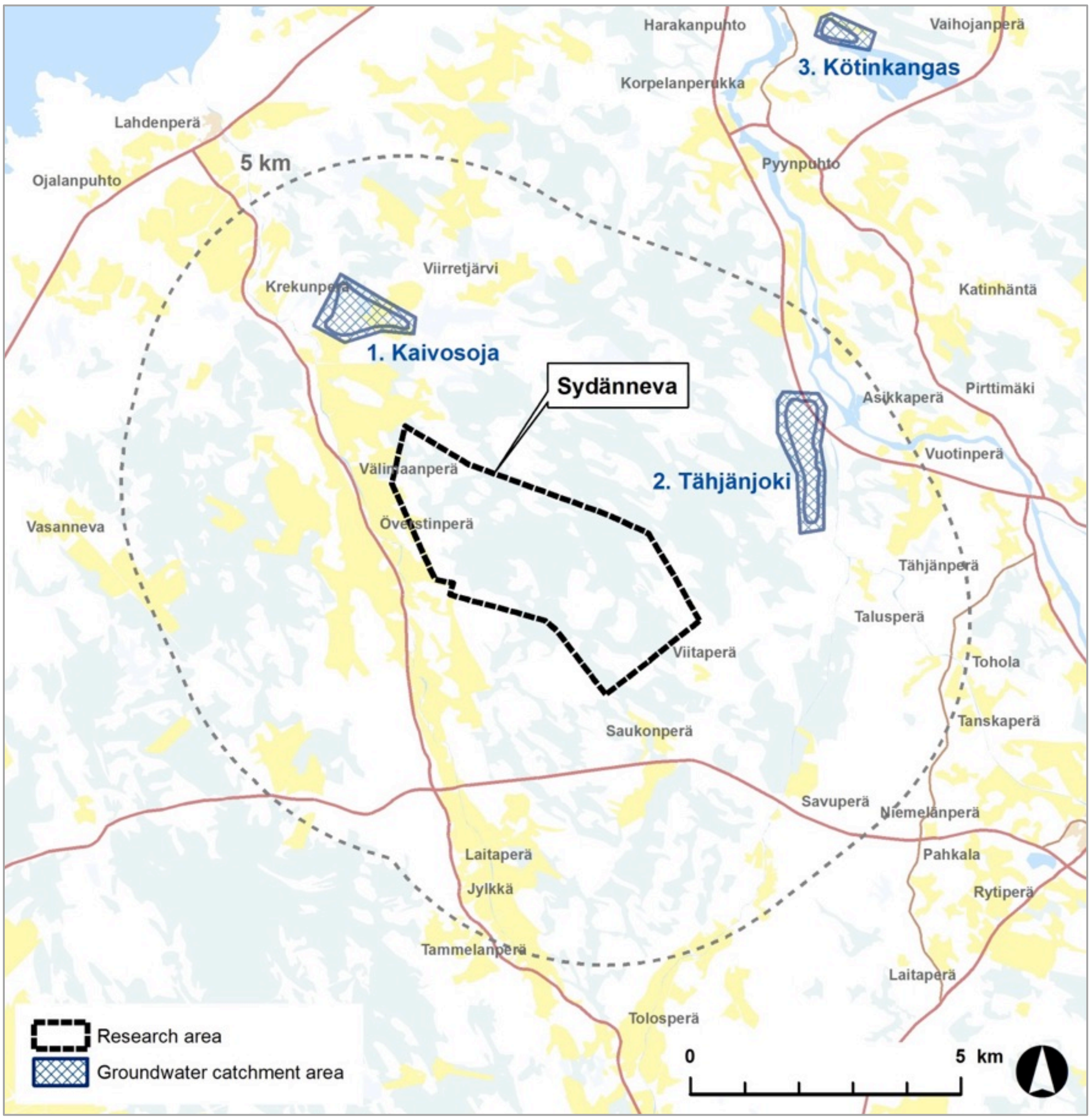


**Figure 6-19. Groundwater catchment areas closest to the Sydänneva research area. The five-kilometer range from the research area is indicated by a gray dashed line. *(Environmental administration 2016b)***

### *Surface waters*

The western part of the Sydänneva research area is within the catchment area of the Yppärijoki River (84.079), and the eastern part of the area is in the catchment area of the Talusoja River (54.019). Surface water bodies in and near the research area are illustrated in the map below (Figure 6-20). *(National Land Survey of Finland 2016)*

Kauhajärvi lake (surface area around 0.8 hectares) and Umpilampi lake (around 1.6 hectares) are surface waters at the southern edge of the research area. There are no buildings on the shores of Kauhajärvi. There is one holiday home on the shore of Umpilampi. The shores of these lakes are mostly peatland and partially forest. Kauhajärvi is within the catchment area of Yppärinjoki, and Umpilampi within the catchment area of Talusoja. According to the base map, there is a spring in the Översti area at the western edge of the research area. *(National Land Survey of Finland 2016)*

Majavajärvi lake is located around 500 meters to the east and the Yppärinjoki river around 700 meters to the west of the research area. Yppärinjoki changes to Iso-oja close to the village of Mehtäkylä. *(National Land Survey of Finland 2016)*

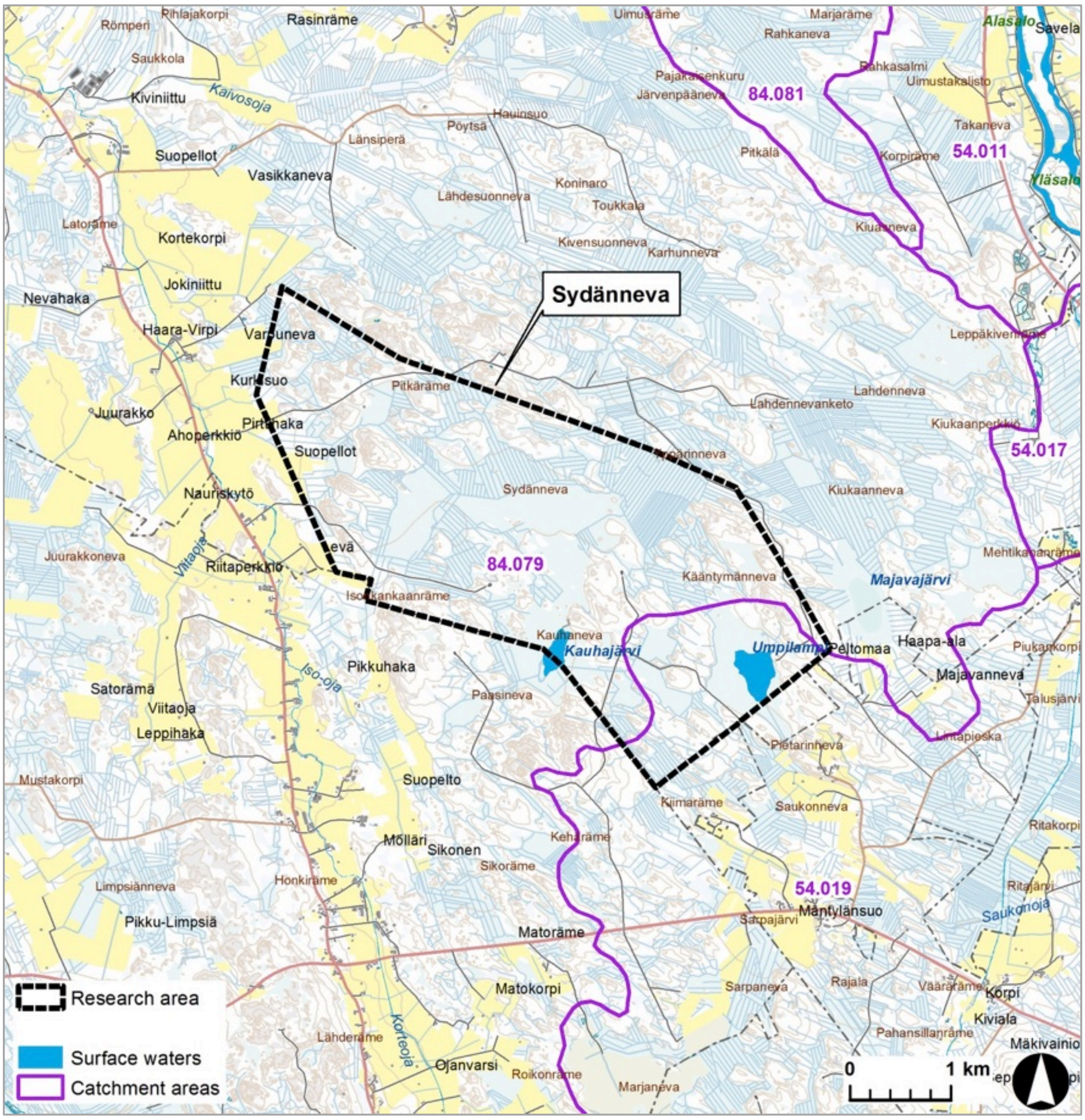


**Figure 6-20. Surface waters in and in the vicinity of the Sydänneva research area. *(National Land Survey of Finland 2016)***

## 6.2.7 Flora, fauna, and protection sites

The Sydänneva research area is in the Ostrobothnia belt of the mid-boreal vegetation zone. The peatland zone type is Ostrobothnia's raised bogs and *Fuscum* pine swamps. In terms of species, the area is part of the province of Central Ostrobothnia, even though it is located in Northern Ostrobothnia. *(Karpalo map service of the Finnish environmental administration 2016)*

Characteristics of the province of Northern Ostrobothnia include the low-lying land-uplift coast of the Bothnian Bay with its primary succession forests and seashore meadows, as well as the rivers flowing to the Bothnian Bay with their valleys, which are mostly used as agricultural areas (*Northern Ostrobothnia Centre for Economic Development, Transport and the Environment 2015*). Based on the studied maps and aerial photos, the research area is a peatland and rocky area that also includes low-lying forested rock and silt hills and two small lakes in the southern part of the area. The cultivated river valley to the west remains outside the research area, except for some fields at the very edge of the valley. Prevailing vegetation types possibly include dried peatland forests, modified mires, and fairly rugged heath forest and rock forests dominated by conifers. The age of the forests varies: there are fairly many felled and young forests, and only a few older forests. An area of around one square kilometer in the middle of the Sydänneva research area is not trenched, and this area is partly open mire. The peatlands around the lakes have not been trenched either.

The animal species in the research area are most likely those indigenous to heath forests, peatlands, and small lakes. Of larger mammals, moose, red fox, and mountain hare probably live in the area (*Natural Resources Institute Finland 2016a*). A couple of northern bats were observed in the area covered by a bat inventory in the immediate vicinity of the research area, but the area is not a typical northern bat habitat (*Ahlman 2015a*).

In the Finnish breeding bird atlas (*Valkama et al. 2011*), the research area is located within the 10 $km^2$ squares of Yppäri in Pyhäjoki and Mehtäkylä in Kalajoki (714:336 and 713:336), where the number of definitely, probably, or possibly nesting bird species is 114 and 99, respectively. The migration routes of several birds go through Pyhäjoki along the shoreline of the Bothnian Bay *(Hölttä 2013)*. Spring and autumn migration of birds was surveyed in the immediate vicinity of the research area in 2014 and 2015 *(Ahlman 2015b, Ahlman & Luoma 2014)*. In addition, a survey of the routes of birds of prey was completed in 2015 *(Luukkonen 2015)*.

***Natura 2000 areas, nature conservation areas, and nature sites of national importance***

A small nature conservation area is partially located within the research area. The research area does not include any Natura 2000 areas, other nature conservation areas, or known valuable national nature sites. All known sites within a ten-kilometer range from the research area (*Karpalo database of the Finnish environmental administration 2016*) are shown in the figure below (Figure 6-21).

1. **Haapala nature conservation area** (YSA230514). The forested nature conservation area of a little less than ten hectares is located at the northern edge of the research area. Its southern tip is within the research area, and its middle and northern parts are outside the research area.
2. Nationally valuable **Korpiräme rock area** (KAO110014). The rock area is 2.6 kilometers to the northeast of the research area.
3. **Kaakkurineva mire conservation program site** (SSO110331). A small part of the area, at the southern tip, is protected as the Myllylä and Iso-Myllylä nature conservation areas (YSA117843 and YSA118347). The Kaakkurineva mire and Pitkäsenkylä fields to the southwest of Kaakkurineva have been classified as migratory birds' resting area of national importance *(Hölttä 2013)*. The mire is 5.4 kilometers to the southwest of the research area. The nature conservation areas are 7.7 kilometers from the research area.
4. **Niemenkallio nature conservation area** (YSA204859). The small site is on the eastern shore of the Pyhäjoki River, 6.9 kilometers to the east of the research area.

5. **Yppärinjokisuu seashore meadow and beach**, which is a protected habitat type under the Nature Conservation Act (LTA110002). The site is included in the FINIBA site Yppärin lahdet. It is 7.4 kilometers to the northwest of the research area. The FINIBA site is slightly closer to the research area, 7.2 kilometers away.
6. **Kumpele beach and dune**, which is a protected habitat type under the Nature Conservation Act (LTA203201). The two-part site is also a nationally valuable wind and shore deposit (TUU-11-141 and TUU-11-144). It is located in the Yppäri beach area, 7.8 kilometers to the northwest of the research area.
7. **Rajalahti-Perilahti Natura area** (FI1104202, SAC and SPA, 91 ha), a waterfowl conservation program site (LVO110254) and nature conservation area (YSA200526). The Natura area is included in the FINIBA site Yppärin lahdet. The area is 7.9 kilometers to the northwest of the research area.
8. **Kiviäijä beach**, which is a protected habitat type under the Nature Conservation Act (LTA203183). The small site is 8.6 kilometers to the northwest of the research area.
9. **Suni Natura area** (FI1104203, SAC, 93 ha) **and Suni nature conservation area** (YSA200524). The nationally valuable Hietaranta wind and shore deposit (TUU-11-012) is in the northern part of the area. The site is 8.7 kilometers to the west-northwest of the research area.
10. **Rajaniemi old forest conservation area** (YSA117716). The small site is 8.8 kilometers to the north of the research area.
11. **Haanpäänperukka seashore meadow and beach**, which is a protected habitat type under the Nature Conservation Act (LTA206935). The site is 8.9 kilometers to the west-northwest of the research area.
12. **Veteraanimaja seashore meadow and beach**, which is a protected habitat type under the Nature Conservation Act (LTA11004). The site is included in the FINIBA site Yppärin lahdet. It is 9.2 kilometers to the northwest of the research area.
13. **Tiirasaari beach and dune**, which is a protected habitat type under the Nature Conservation Act (LTA203206). The small site is 9.3 kilometers to the northwest of the research area.
14. **Vainionhaka Natura area** (FI0200009, SAC, 1 ha). The small traditional biotope site is 9.6 kilometers to the west of the research area.
15. **Ryökönkangas Natura area** (FI1002011, SAC, 25 ha), an old forest conservation program site (VMA110082) and a nature conservation area (VMA110082). The site is 9.8 kilometers to the southeast of the research area.

Furthermore, there are Natura areas, nature conservation program areas, nature conservation areas, nationally valuable wind and shore deposits, and FINIBAs more than ten kilometers to the southwest of the research area, in the Kalajoki river estuary, Maristonpakat, and the Vihaslahti-Keihäslahti area. The sites closest to the research area are the Kalajoki estuary Natura area, a shore conservation program area, and a nature conservation area, which are around 13 kilometers from the research area (Figure 6-21; these sites, which are more than ten kilometers away, have not been numbered in the figure).

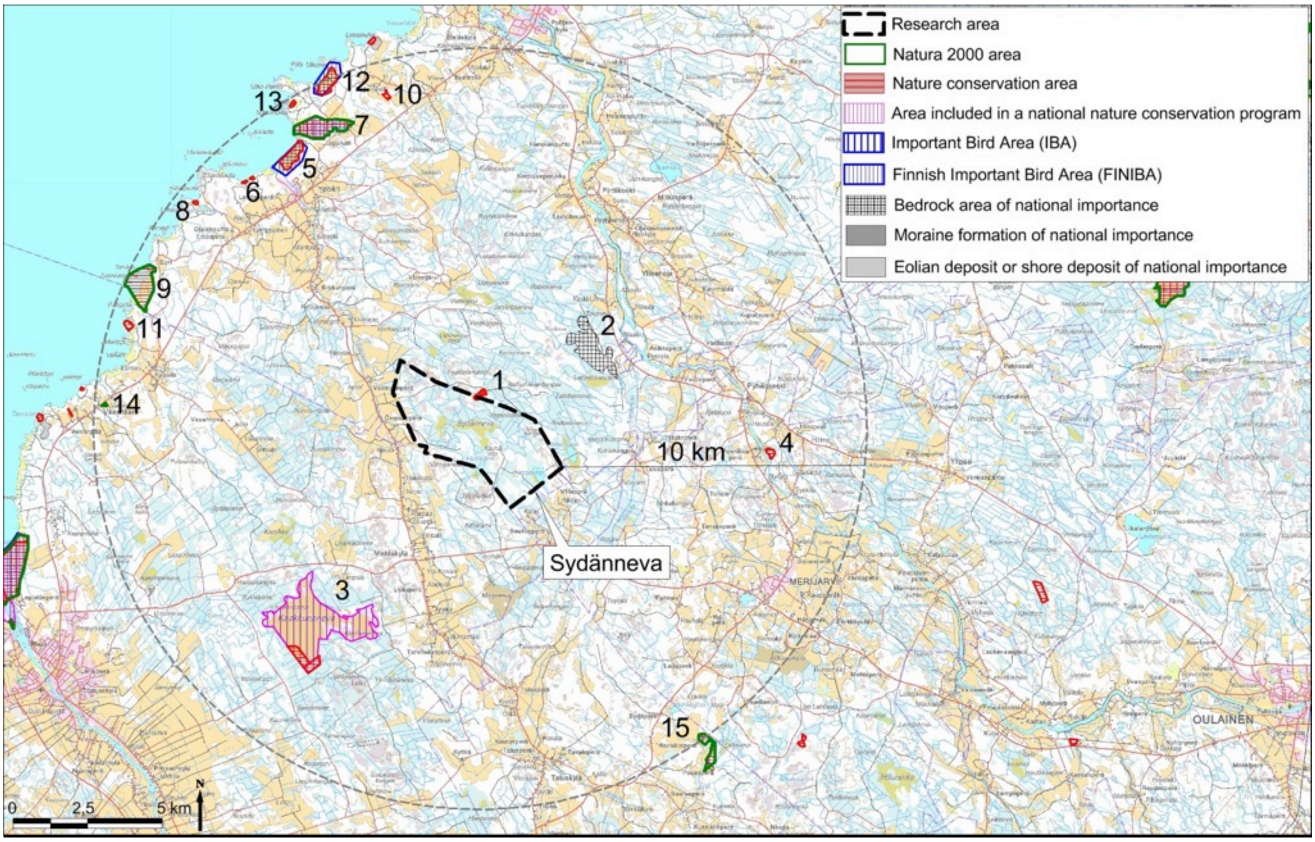


**Figure 6-21. Natura 2000 areas, nature conservation areas, and nationally valuable nature sites within a ten-kilometer radius of the Sydänneva research area.**

### *Other nature sites*

Of the migratory birds' resting areas of national importance in the Kalajoki-Pyhäjoki area, the southernmost part of the Yppäri fields is in the vicinity of the research area (to the northwest). A very small part of the resting area is within the research area (Figure 6-22, site a; *Hölttä 2013*). A forested area of a little less than ten hectares (the Haapala nature conservation area) is at the northern edge of the research area. In the spring of 2015, a three-part Siberian flying squirrel habitat was identified in the Saukonperä area, 1.5 kilometers to the southeast of the research area (Figure 6-22, site b; *Fingrid Oyj 2016*)..

No other known regionally or locally valuable nature sites are located within or less than one kilometer away from the research area (*Repo & Auvinen 2011, Vainio & Kekäläinen 1997*).

In the Northern Ostrobothnia regional land use plan, the Pyhäjoki coastal area, which is around eight kilometers to the northwest of the research area, has been classified as an area with valuable nature sites. The area is important particularly for the protection of habitats and species typical to the land uplift coast (*Council of Oulu Region 2006*). The Pyhäjoki River has been classified as a valuable water body in the regional land use plan, and the island of Yläsalo in the Pyhäjoki River has been classified as a particularly valuable concentration of endangered plant species that is important for biodiversity. The island is around four kilometers to the northeast of the research area.

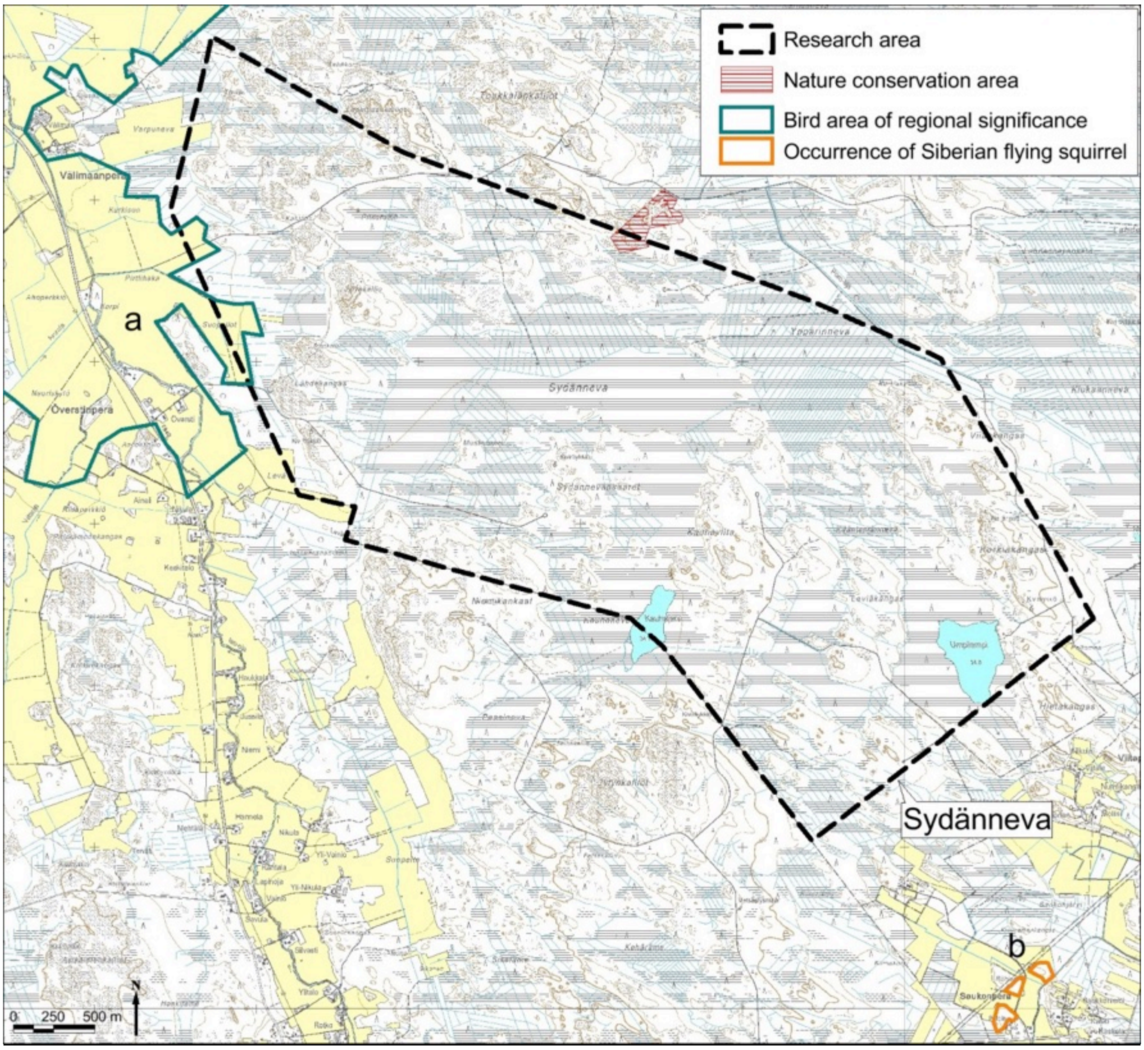


**Figure 6-22. Nature sites in and in the vicinity of the Sydänneva research area.**

## 6.2.8 Climate and air quality

The Sydänneva research area is in the western part of the province of Northern Ostrobothnia, around ten kilometers from the seashore. The research area is in the mid-boreal climate zone. The climate is affected by the Bothnian Bay, but the climate towards inland (close to the Suomenselkä area) becomes more continental. The annual average temperature is around +2.5 °C, and the annual precipitation is usually 500–600 mm. The snow cover thickness is around 50–65 cm. The growing season is 160–170 days. *(Finnish Meteorological Institute 2016)* The prevailing wind direction is from the southwest *(Tuuliatlas 2016).*

There is no air quality monitoring in the vicinity of the Sydänneva research area. The amount of emissions from local industrial plants and other point sources (houses, saunas, etc.) has not been assessed. The closest air quality monitoring point is in the town of Raahe. The town of Raahe monitors the impact of industry and traffic on the air quality within the frameworks of an extensive air quality monitoring program. In 2012, the air quality in Raahe was mostly good (*Ramboll 2013*).

### 6.2.9 Traffic

Yppärintie/Mehtäkyläntie road (connecting road 7840) travels around 800 meters to the west of the research area. In 2014, the average vehicle traffic on this road near the research area was 531 vehicles per day. Around 42 of these were heavy vehicles. *(Finnish Transport Agency 2016)*

Oulaistentie road (local road 786) passes around one kilometer to the south of the research area. In 2014, the average vehicle traffic on this road in the vicinity of the research area was 688 vehicles per day. 56 of these were heavy vehicles. (*Finnish Transport Agency 2016*) Several private roads travel in or near the research area. Highway 8 (Kokkolantie) is around seven kilometers to the northwest of the research area. The roads in and near the Sydänneva research area are illustrated in the figure below (Figure 6-23).

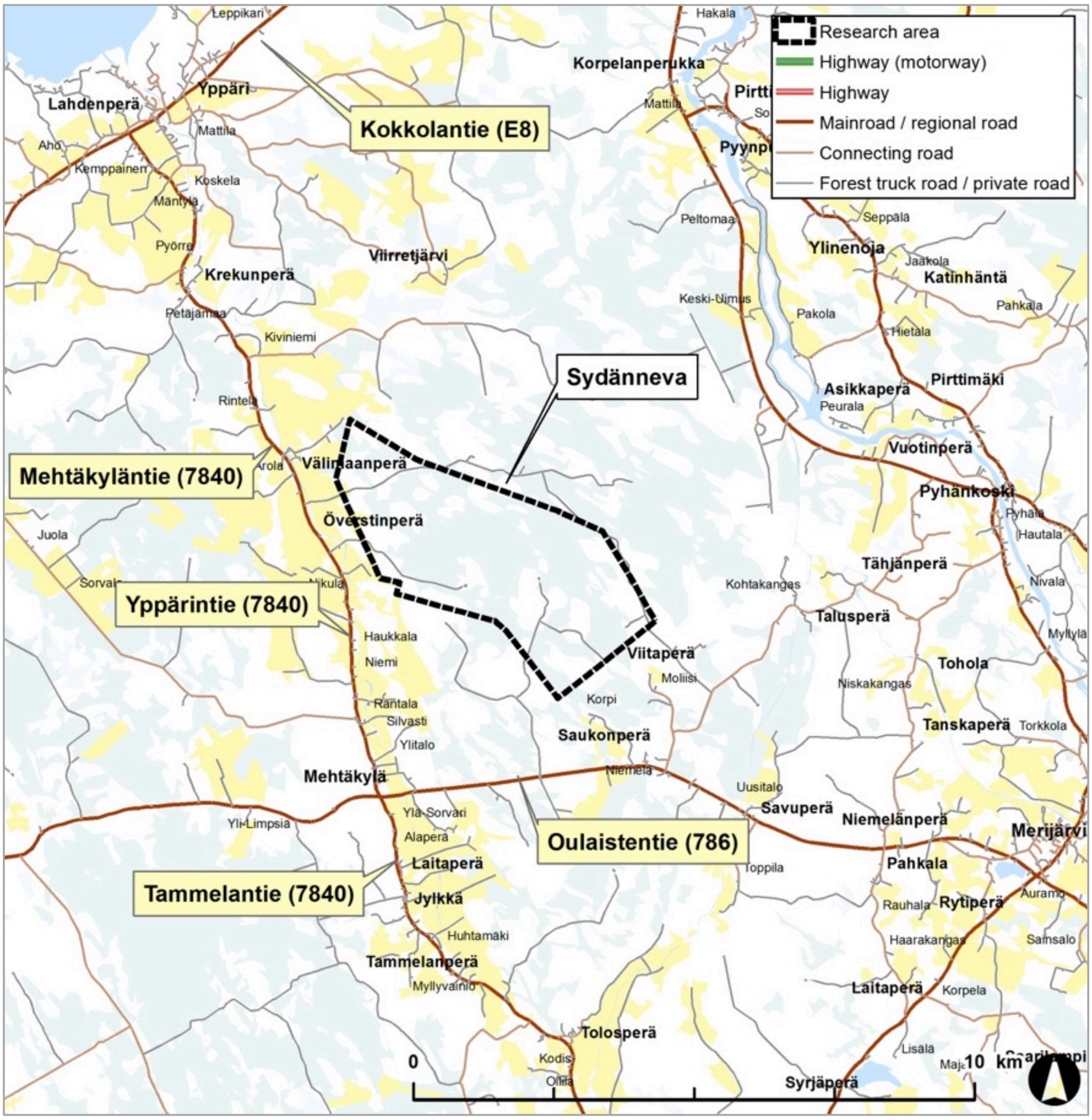


**Figure 6-23. Roads in and in the vicinity of the Sydänneva research area.**

### 6.2.10 Noise and vibration

There are some soil extraction sites in the immediate vicinity of the Sydänneva research area. They may cause minor noise and vibration in the area. The closest wind farm is more than four kilometers away, and it is unlikely that any noise would carry from the wind farm to the area.

# 7 PLAN FOR THE ENVIRONMENTAL IMPACT ASSESSMENT OF THE PROJECT AND THE METHODSTO BE USED

## 7.1 Impacts to be assessed and limitations of the assessment

In this project, the term ‘environmental impact’ refers to the direct and indirect impacts of the project on the environment. In the assessment, the impacts during all the different project phases (see Chapter 2.3) are studied. According to the EIA Act, an environmental impact assessment must cover the environmental impact of the project on the following:

- Human health, living conditions, and well-being
- Soil, water systems, air, climate, flora, fauna, and biodiversity
- Infrastructure, buildings, landscape, cityscape, and cultural heritage
- Utilization of natural resources
- Mutual interaction between the above-mentioned factors.

Currently, the most important identified environmental impacts of the project are impacts on the soil, bedrock, and groundwater due to the underground construction activities and long duration of the project. Furthermore, impacts on humans, particularly those that can be experienced in different ways by different people, may become important during the project period. In the EIA report, the significance of environmental impacts is assessed by, for instance, comparing the tolerance of the environment with regard to each environmental burden, taking into account the current status and environmental load of the area. Furthermore, environmental impacts that are considered significant or felt as significant by the stakeholders will be taken into account. Experienced environmental impact assessment experts will perform the assessment.

The environmental impact assessment takes into account the environmental impacts in the research area as well as those that extend outside the area. In this context, ‘assessment area’ refers to the area defined for each type of impact in which the environmental impact in question is examined and assessed. The aim is to determine an assessment area so large that significant environmental impacts cannot be expected to occur outside the area. However, if it becomes apparent during the assessment work that a specific environmental impact has a respective affected area larger than estimated, the scope of the observed and affected areas will, in that connection, be redefined for the impact in question. Thus, the actual definition of affected areas will be carried out in the environmental impact assessment report as a result of the assessment work.

The chapters below describe the environmental impact assessment methods and the related assumptions. The table below (Table 7-1) includes a summary of the studied environmental impacts and the methods used in the assessment. The research area in Eurajoki will be determined and the current status data will be specified for the selected research area before the impact assessment (see Chapter 2.4.1).

**Table 7-1. Summary of the studied environmental impacts and the methods used in the assessment.**

| ASSESSMENT AREA | IMPACT ASSESSMENT AND THE METHODS USED |
|---|---|
| Land use and built environment | An expert assessment of the project's relationship with current and planned regional structure, infrastructure, land use, and land use objectives. Inconsistencies in land use and needs for change will be assessed. In addition, distances from objects in the built environment will be studied with the help of maps. |
| People and communities | An expert assessment of the project's impact on people's well-being and living conditions based on quantitative and qualitative assessments utilizing other studies and research. Subjective experiences of the effects will also be taken into account. Health impacts will be assessed in compliance with instructions by the Finnish Radiation and Nuclear Safety Authority. In addition, impacts on business, employment, and the regional economy will be assessed based on separate surveys.<br><br>The following will be completed for the impact assessment:<br>• Survey of the population living within a five-kilometer and a twenty-kilometer radius from the site<br>• Resident survey<br>• Small group events and interviews<br>• Analysis of current socioeconomic status<br>• Survey of impact on the public image of local municipalities |
| Landscape and cultural environment | An expert assessment of the project's relationship with the landscape in a broader sense, the local landscape and cityscape, and views towards the research area. The project's impact on the built cultural environment and archaeological cultural heritage sites will also be assessed. Photomontages will be prepared to support the assessment, and inventories of historical monuments will be completed, if necessary. |
| Soil, bedrock and groundwater | A preliminary assessment of the applicability of the bedrock for final disposal operations will be made based on geological surveys and interpretations and modeling made based on the geological surveys. The EIA report will also include an assessment of the project's impact on the soil, bedrock, and groundwater.<br><br>The conditions of the area's bedrock and soil, as well as hydrological and hydrogeochemical conditions will be determined with several studies and modeling, such as:<br>• Studies of the soil surface<br>• Studies in boreholes at a depth of around 500–1,000 m<br>• Research excavations and supplementary structural geology surveys and geophysical measurements (seismic reflection, electromagnetic probing, electric probing, gravity measurements, etc.)<br>• Preliminary 3-D model of structural geology and hydrogeology.<br>• Special geophysical measurements (in situ thermal conductivity, tomography, mise-a-la-masse, etc.) and any necessary additional drilling |
| Flora, fauna, and protection sites | An expert assessment of the project's impact on flora, fauna, habitat types, and targets with importance for the concervation of nature, as well as on biodiversity and interaction on a wider scale (ecological connections, etc.). At least the following environmental surveys will be implemented to support the assessment:<br>• Vegetation and habitat type surveys<br>• Survey of nesting birds<br>• Necessary surveys of Habitats Directive species (such as Siberian flying squirrel, bat, and moor frog)<br><br>In the case of Natura 2000 areas, it will be assessed whether there will be any impact on the natural values due to which they are protected that require a Natura 2000 assessment as laid down in section 65 of the Nature Conservation Act. |

| ASSESSMENT AREA | IMPACT ASSESSMENT AND THE METHODS USED |
|---|---|
| Water systems | An expert assessment of the project's impact on surface water systems based on available research data and completed studies. Water systems and small water systems in the area will be surveyed, and the limitations of the catchment areas of the small water systems and water discharge directions will be determined. If necessary, surface water depth, sediments, water quality, and aquatic organisms in the research and drilling areas will be studied. |
| Climate and air quality | An expert assessment of the project's emissions into the air. Existing studies and assessments will be utilized in the assessment. The emissions will be compared with the set guideline and limit values. To support the assessment of the climate conditions, a weather station may be installed in the research area to monitor the wind direction and temperature, etc. Snow and frost measurements will be taken within the geological research program.<br>Radioactive emissions generated mainly during exceptional and accident situations will be assessed as described under "Exceptional situations and accidents" below. |
| Transport and traffic | A calculated estimate of the changes caused by the project in current traffic volumes and an expert assessment of the impact of transport on traffic and traffic safety. A separate transport report will be prepared to support the assessment. It will cover transport routes, alternative transport methods, radiation doses to the transport personnel and people living along the transport route, and any related health risks, for example. The transport report will also cover any exceptional or accident situations. |
| Noise | The noise impact assessment will be done by means of noise modeling. Noise caused by the activities performed at the different project phases and related transport activities in the immediate vicinity of the project site (in a radius of approximately two kilometers from the activities) will be studied. In the assessment, the noise caused by the project will be compared to the area's current noise level and guideline noise values. |
| Vibration | An expert assessment of the impact of vibration during excavation of the bedrock and transport during the project. The intensity of the vibration will be assessed in relation to the distance based on available information about the source of vibration and previous experience. |
| Waste and by-products, and their utilization | An expert assessment of the by-products and waste generated during the different project phases, their quantities, properties, and processing options, as well as their impact on the environment. |
| Utilization of natural resources | An expert assessment of the utilization of natural resources, including utilization of the blasted stone generated by the project and the consumption of materials during the project period. |

| ASSESSMENT AREA | IMPACT ASSESSMENT AND THE METHODS USED |
|---|---|
| Exceptional and accident situations | A risk analysis to identify the project's exceptional and accident situations will be prepared to study the potential accident risk types and their probability at the different project phases. The risk of exceptional and accident situations during the transport of spent nuclear fuel will also be separately studied in the transport report to be prepared. The impact of the accidents on human health and the environment will be studied based on safety analyses and the requirements posed for the final disposal operations. Radiation doses caused by accidents and the areas affected by radiation will be assessed. The consequences of exceptional situations will be assessed based on research data on the health and environmental impact of radiation. Instructions by the Radiation and Nuclear Safety Authority will be followed when assessing emissions during exceptional situations and accidents and their impact. |
| Long-term safety | Long-term safety will be modeled with computer software. Issues to be modeled include hydrological, chemical, thermal, mechanical, and biological processes. The EIA report will present the bases for the safety design of the encapsulation plant and final disposal facility and an assessment on compliance with the currently valid safety requirements. The radiation doses to humans and other organisms and radioactive release rates at ground level that were modeled in the environmental impact assessment will be compared to the safety requirements in legislation and YVL Guides of the Radiation and Nuclear Safety Authority. |
| Combined effects with other projects | According to the currently available information, no projects that could have any combined impact with the encapsulation plant and final disposal facility are planned for the immediate vicinity of the research areas. This issue will be examined in more detail in the EIA report. |
| Cross-national effects | Based on the preliminary estimate, the Fennovoima's final disposal project does not have any environmental effects crossing state borders.<br><br>A separate transport report, a risk analysis for exceptional and accident situations, and long-term safety modeling will be completed for the project. One of the issues examined in these studies is whether the effects could extend beyond the borders of Finland. |

## 7.2 Land use and the built environment

The data sources used for the description of current status included in the EIA program include databases of Finnish environmental administration and materials published by the Ministry of the Environment and the municipalities. In studying the current status maps, aerial photos, various registers, GIS data, and other data sources were used. The description of the current status in the EIA report will be updated. Representatives of the land use planning offices of the local municipalities in the research area will be interviewed to ensure that the information and interpretations about current land use and land use status in the assessment are correct.

The project's impact on land use and the built environment will be studied at different levels: whether the realization of the project will have any impact on the regional structure, land use in the neighboring areas, or single sites in the immediate vicinity of the project.

When the project's impact on the infrastructure and land use is being studied, the project's relationship with current and planned regional structure, infrastructure, and land use will be investigated. The project's relationship with national land use objectives will also be studied when assessing its relationship with planned land use. For the assessment, information about the current and planned land use in the research areas as well as all currently valid and pending land use plans will be studied. Any inconsistencies in land use or need to modify the land use plans will be indicated and described. The impacts will be studied within a radius of around five kilometers. If necessary, the assessment area can be expanded at the EIA report phase to as far as the estimated impacts extend. The assessment area also includes all new roads and power lines required by the project.

The assessment will study the distance between the research area and residences, industrial operations, and other important sites in the research area and its immediate vicinity (radius of around 5 km) by determining all permanent residences, holiday homes, and other buildings in the immediate vicinity of the research areas. The changes caused by the project in them will be assessed. The assessed impacts will be described and illustrated with maps in different scales.

## 7.3 People and communities

### 7.3.1 Impact on humans

A human impact assessment (HuIA) is an interactive process where a project's impacts on individuals, communities, or society that may change people's living conditions, comfort, wellbeing, or improvement of wellbeing are studied in advance. A human impact is always either directly or indirectly connected to the other impacts of the project. The HuIA combines a health impact assessment (HIA) and a social impact assessment (SIA) *(National Institute for Health and Welfare 2015, Ministry of Social Affairs and Health 1999).* As part of the human impact assessment, the project's impacts on recreational use of the area, business, and employment will be studied. Furthermore, perceived impacts will be studied, i.e. how people experience concrete changes occurring in their environment. The human impact assessment provides valuable information about the needs of the different stakeholders during the assessment process and during the latter phases of the project. It can also be used as a communication channel.

The assessment is a combination of an analysis of empirical or subjective data and an expert assessment. The assessment methods include results of the other impact assessments completed during the EIA procedure and information obtained from resident surveys and small group events. Other sources of information include literature, maps, information obtained from public events and meetings of the advisory group, opinions about the EIA program, and any pertinent information or discussion in the media about the project. The EIA report will cover the project's general acceptability and fears and concerns of the involved parties. To ensure a high-quality assessment, as large a group as possible consisting of representatives from different stakeholder groups will be allowed to participate in the human impact assessment procedure.

Data sources used for the description of the current status in the EIA program include maps, aerial photos, GIS data, a variety of registers, and municipality-specific information published by municipalities and Statistics Finland. The background data used in the description of the current status includes information about the areas on, for instance, location of residences, holiday homes, recreational areas, and other human activities. Furthermore, vulnerable sites (kindergartens, schools, retirement homes, etc.) in the immediate vicinity of the project site, i.e. sites that are most susceptible to potential adverse impacts, have been surveyed. For the EIA report, the data will be updated and supplemented with additional information obtained from the municipalities, other authorities, and residents.

The project's impacts on people's well-being and living conditions during construction and operation will be assessed with the help of quantitative and qualitative assessments from the other parts of the environmental impact assessment. The assessed impacts will include changes in land use, impacts on the landscape, impacts on traffic, impacts on employment, and noise, among others. Perceived impacts, meaning how the local residents and other parties active in the area experience the above-mentioned impacts, will also be assessed. Furthermore, the local distribution of positive and negative impacts will be studied.

Impacts on health will be assessed by comparing the project's estimated impacts with the health-based guideline value or recommended value of each impact. The maximum theoretical radiation exposure of a local resident due to the final disposal operations will be assessed and compared with both the limit values in the regulatory requirements and natural background radiation. At most, the encapsulation and final disposal operations and related transport will increase the natural radiation dose from the environment with a minuscule amount. The impacts of any exceptional situations will be assessed during the risk analysis. The encapsulation and final disposal activities will be planned in such a manner that an amount of radioactive substance that could have a direct health impact cannot be released even in the case of an accident. Furthermore, the long-term safety modeling will assess the radiation impact and radiation safety of the final disposal facility thousands of years from now in compliance with STUK's YVL Guide D.5 (Disposal of nuclear waste).

Population distribution within a radius of five kilometers and within a radius of twenty kilometers from the research area will be studied. The population distribution will be presented as population density grids on a map. The impacts on humans will be studied up to a distance of around 20 kilometers from the research area. However, the assessment will focus in the immediate surroundings of the research area, because the primary impacts are expected to occur in the immediate vicinity of the site. The impacts of transport during the project period on people (see Chapter 7.9.) in the immediate vicinity of the transport routes will also be taken into account. The assessment area will be larger in the case of the impacts on business and employment with the focus being on the impact of the project on regional employment. Population groups or areas that are affected the most will be identified during the assessment. Available means of eliminating or mitigating any adverse impacts will also be studied.

***Resident survey***

A resident survey will be implemented at the alternative locations to support the assessment. A questionnaire will be sent by regular mail to all households with permanent residents or holiday residents in the immediate area (within a radius of five kilometers from the research area, for example) and to a random sample of people living farther away (within a radius of twenty kilometers from the research area, for example).

The survey will study the general attitudes of different stakeholder groups towards the project and any personal concerns. The survey will shed light on the current use of the area, allow an assessment of the project's potential impacts, and assist in finding means to mitigate the impacts. The empirical data obtained with the survey can be compared with the impacts assessed using the other methods. Furthermore, the survey will be part of the project's communication: it will reach all permanent and holiday residents in the immediate vicinity of the research area. The people replying to the survey will also be able to indicate their willingness to participate in the small group events to be arranged later. The questionnaire will include open ended and structured questions, and the residents will receive a summary of the project and map images with the questionnaire. The survey data will be analyzed with key statistical analysis methods, such as cross tabulation, a variety of correlations, and quantitative data analysis methods to specify the results.

The survey will be implemented for the first time after the submission of the EIA program (in Eurajoki, once the research area has been determined), and the survey will be repeated at the EIA report phase. During the time between the surveys, the organization responsible for the project may also realize other opinion surveys and other surveys whose results can be utilized to support the assessments.

***Small group events***

To identify the impact on humans and obtain a better idea of the data obtained with the other methods, small group interviews and workshops will be arranged at the alternative locations. One of the objectives with the small group events is to ensure that all of the issues pertinent in terms of the project's impacts are taken into account in the environmental impact assessment and further planning of the project. Target groups that may be invited to the small group events include local residents and holiday residents, representatives of businesses, recreational users of the area, associations, organizations, and other stakeholders. The interviews will be implemented with the help of a themed framework. At the beginning of each event, the project and the environmental impact assessment will be presented to the participants, and then the interview themes will be reviewed with the help of a map. The themes involve the current status of the area, current operations, and potential impacts of the project on these. Means to mitigate the impacts will also be sought. The participants will have an opportunity to pose questions about any concerns they have. Results of the small group events will be compiled and analyzed, and the results will be described in the EIA report.

### 7.3.2 Impact on regional economy

Analyses of the current socioeconomic status and structure of the alternative locations will be prepared to study the project's socioeconomic impact. Themes to be studied when describing the project's operating environment include population, population structure, population forecasts, the labor force and employment, the economic structure, and enterprises and their offices.

The assessment will describe the socioeconomic impact mechanisms during construction and operation of the project and assess the project's direct and indirect impacts on employment and business at the alternative locations. In addition, the impact of the project on the development of the economic structure, the planning of operations of society, and the future plans of local enterprises will be studied. The report will primarily study impacts at the alternative locations, but broader impacts of the nuclear facility on employment, population development, construction, infrastructure, and municipal economy will also be taken into account. The different phases of the project will be taken into account when assessing the impacts.

The project's impact on employment is an important part of the project's socioeconomic impacts. The project's impact on tax revenue will be assessed on the basis of the employment impact. The project's direct impacts during the operating phase include the jobs at the facility and the indirect impacts include for example the fact that the project increases the demand of maintenance services, transport services, and other services. At the research and construction phase, direct employment impacts include planning, research, and construction work required by the project and indirect impacts include intermediate products and services, such as subcontracting services, construction materials and supplies, and transport services. Means to promote the positive socioeconomic impacts will also be sought during the impact assessment.

The impact assessment will utilize, among others, regional input-output tables and work input coefficients by Statistics Finland. Authorities and experts will be interviewed to support the assessment.

If necessary, a separate study of the impact on the image of municipalities will be made. In this study, the external image of the municipalities among residents, Finnish consumers at large, and representatives of businesses will be studied. The study can be realized as telephone interviews.

Furthermore, a study of the project's impact on tangible assets, such as the value of properties, in the immediate vicinity of the project area can be made and any expropriation measures at the final disposal site can be presented, as the implementation of the project will cause the need to buy or expropriate real estate (see 4.11).

## 7.4 Landscape and the cultural environment

### *Landscape*

Initial data for the description of the current status of the landscape in the EIA program includes, for example, aerial photos, maps, and GIS data. The current characteristics of the landscape in the research area and its immediate surroundings will be studied in the EIA report by studying the maps and aerial photos again, visiting the site, and utilizing local knowledge. The impacts on the landscape will be illustrated with photomontages.

The landscape impact comprises changes in the structure, characteristics, and quality of the landscape. Visual impacts are one of the subsets of the impact on landscape. Immaterial factors are also linked to the landscape: regional history, human experiences, hopes, appreciation, and attitudes all influence how the landscape is perceived. Assessments of the same landscape or the significance of the landscape impacts caused by a new project can differ noticeably due to the above-mentioned reasons.

The impact assessment describes the project's relationship with the landscape in a broader sense, the local landscape and cityscape, and views of the research area. The assessment area determined for the EIA program phase is around five kilometers from the research area. The assessment area can be revised for the EIA report phase based on feedback on the EIA program, for example.

### *Cultural environment*

The description of the built cultural environment and archaeological cultural heritage in the EIA program is based on existing studies, inventories, and registers (such as the register of historical monuments by the National Board of Antiquities), as well as reviews of maps and aerial photos. For the EIA report, the data will be updated, the research areas will be visited, and an inventory of historical monuments will be performed if necessary.

The impact assessment will describe the project's impacts on the built cultural environment and archaeological cultural heritage sites in the immediate vicinity of the research area (within a radius of around five kilometers). Any historical monuments in the research area will be inventoried and a protection plan will be prepared in cooperation with the National Board of Antiquities, if necessary.

## 7.5 Soil, bedrock and groundwater

The description of the current status of the soil and bedrock is based on studies by the Geological Survey of Finland (on issues like rock types, grain size, exposure, topography, fragmentation, geophysical properties, and ore potential). The description of the current status of groundwater areas is based on geographical information on areas classified as groundwater areas and other suitable water supply areas.

Safety of the final disposal site is mainly based on bedrock conditions favorable to final disposal. A research program of several years is needed to study these conditions. Desired final disposal bedrock properties will be determined before starting the site studies. When determining the target properties, all acts, regulations, and YVL Guides on final disposal must be taken into account. In addition to these safety requirements, requirements on public acceptance and requirements on technical and economic factors of the operator must be specified before selecting the final disposal location. Materials on target properties of final disposal bedrock published by the programs of Posiva and SKB can be utilized when determining the requirements. Results of the location studies will be compared with the target properties, and suitability of the sites for final disposal will be assessed based on the comparison.

A large amount of further geological, geophysical, hydrological, and hydrogeochemical information from each potential site is needed to assess the environmental impact of final disposal, compare the research areas, and select the final disposal site. To enable comparison of the areas with each other, equally comprehensive studies using the same methods must be completed at all the potential sites. The starting point of these studies is finding out whether the properties of the bedrock at each site correspond with the requirements and assumptions set for the bedrock at the research area selection phase. Studying characteristics that influence suitability of the bedrock, such as ore deposits, extensive horizontal or slightly inclined deformation zones, exceptional hydrogeochemistry, or variation of rock types in the horizontal direction, is an especially important issue.

Geological surveys of the research areas presented in a separate research plan *(Paananen et al. 2016)* were preliminary divided into three phases which are naturally linked and will gradually specify the information on the area's bedrock, soil, hydrological conditions, and hydrogeochemical conditions. These phases are described below.

- At the preliminary investigation phase, suitable research areas will be determined based on lineaments, and their geological and environmental properties will be studied.
- The first phase will mostly focus on studying the soil surface. The studies at this phase will be general in nature.
- The second research phase will offer more important information obtained by studying five boreholes that are approximately 500–1,000 meters deep. Additional information about the conditions at the surface will be obtained with, for instance, research excavations, a supplementary structural geology survey, and supplementary geophysical measurements (such as seismic reflection, electromagnetic probing, electric probing, and gravity measurements). The first preliminary 3-D model of structural geology and hydrogeology will be prepared at this phase.
- At the third research phase, any open questions will be studied by means of special measurements (in situ thermal conductivity, tomography, mise-a-la-masse, etc.) and by means of making additional boreholes, if necessary. When the necessary studies where open boreholes are used have been completed, multi-packer equipment will be installed in the holes, and hydrogeological moni-

toring of the plugged holes and hydrogeochemical sampling will begin. An integrated 3-D model of the site's structural geology and hydrogeology will be prepared based on the research data. Important aspects of the soil (including sediments), surface water, and vegetation types will be taken into account at the latest in the integrated models created at the third phase.

– Groundwater monitoring in the area will continue for a period of several years after the research phases have ended.

The research results will be compiled into a separate report and the key results will be included in the environmental impact assessment report. A preliminary assessment of the applicability of the bedrock for final disposal operations will be made based on geological surveys and interpretations and modeling made based on the geological surveys. The EIA report will also include an assessment of the project's impact on the soil, bedrock, and groundwater. The impacts of the project on the soil and bedrock at the site will be assessed based on the landform, the soil and bedrock quality, and the proportions of the area required for the facility and the related structures and underground facilities. The impact of the heat generated by the spent nuclear fuel on the bedrock will be assessed. To assess the impacts on groundwater, the location of the final disposal facility with respect to groundwater areas and any risks imposed on groundwater due to construction and operation, such as lowering of the groundwater table, will be studied. The amount of groundwater that will seep into the underground facilities will be assessed. The assessment area determined for the EIA program phase is the research area plus an area with a radius of approximately five kilometers around the research area. The assessment area will be further specified as the studies progress.

## 7.6 Flora, fauna and protection sites

Data sources used for the description of the current status in the EIA program include map services of the Finnish environmental administration, GIS data and GIS databases, a variety of maps and aerial photos *(National Land Survey of Finland 2015 & 2016, Geological Survey of Finland 2016, Natural Resources Institute Finland 2016b)*, land use plans and their background surveys, and other reports and information available from public sources. The description of the current state of the natural environment from the EIA program will be further specified in the EIA report, and impacts that the project has on flora, fauna, habitats, and targets with importance for nature conservation, as well as on biodiversity and interaction on a wider scale (ecological connections, etc.) will be assessed. The assessment will take into account direct and indirect impacts of the different project phases in the entire affected area.

Thorough environmental studies will be performed at the research areas for the EIA report. At least the following will be included in these studies:

– Vegetation and habitat type studies
– Survey of nesting birds
– Necessary surveys of Habitats Directive species (such as Siberian flying squirrel, bat, and moor frog).

Information obtained from the research programs listed in Chapter 7.5 will also be used. The environmental data collected for the EIA program will be verified and supplemented for the EIA report. Observation data on endangered species will be requested from the Finnish Environment Institute, the Finnish Museum of Natural History, and ELY Centres. Other environmental data from the ELY Centres, regional councils, municipalities, organizations, and nature enthusiasts will also be reviewed. All Natura 2000 areas, nature conservation areas, national nature conservation program sites, and other known valuable national nature sites are presented in the EIA report. All known regionally and locally valuable nature sites are also presented. The natural values due to which the nature conservation areas are protected will be specified in the report. The preliminary assessment area determined for the EIA report phase is around five kilometers from the research area.

The environmental studies and the impact assessment will be completed in compliance with the related guides (*Söderman 2003, Sierla et al. 2004, Ministry of Economic Affairs and Employment 2015*) or in compliance with any more recent surveying or assessment instructions that are available. Special attention will be paid to all impacts on Natura 2000 areas, nature conservation areas, valuable nature sites, endangered habitats, and endangered or otherwise notable species.

The intensity and duration of the impacts, nature conservation values of the nature sites, their susceptibility to changes, and habitat requirements of species will be taken into account when assessing the significance of the impacts. In the case of Natura 2000 areas, it will be assessed whether there will be any impact on the natural values due to which they are protected that require a Natura assessment as laid down in section 65 of the Nature Conservation Act. If necessary, the assessment will be included in the EIA report. Furthermore, the assessment will provide recommendations on how to mitigate and monitor any impacts detrimental to natural assets.

## 7.7 Water systems

The data sources used for the description of current status included in the EIA program include databases of Finnish environmental administration, other maps, GIS data, and aerial photos. For the EIA report, the description of the current status will be updated and the data will be supplemented with any additional information provided by the municipalities. Information obtained from the research programs listed in Chapter 7.5 will also be used. Surface waters in the area will be surveyed in connection with the environmental studies. Water quality will also be analyzed, if necessary.

Water supply arrangements of all the final disposal project phases will be described and impact of the water supply on the environment will be assessed at the EIA report phase. Processing of return water at the research phase, leakage water at the construction phase, and wastewater at the different phases, as well as the environmental loads caused by them will be described. Impact of excavation work, rock crushing, and deposition of rock material during construction of the encapsulation plant and final disposal facility on surface waters will be described. The impacts on the surface waters in the research areas will be assessed based on the available research data. If no research data on surface waters is available, the water quality of the surface waters will be studied to the extent required by the project. The impact assessment will be based on existing research data, results of any separate surveys, and expert assessments. A preliminary assessment of the impact assessment area is around ten kilometers.

## 7.8 Climate and air quality

The descriptions of the current status of the climate and air quality in the EIA program are based on data published by the Finnish Meteorological Institute and publicly available air quality monitoring data. The current climate and air quality data in the EIA program will be updated for the EIA report, and any new air quality monitoring efforts in the neighboring municipalities will be taken into account.

Emissions into the air from transport operations at the different project phases will be assessed in the EIA report. Local dust formation due to excavation work, construction site traffic, and other activities during construction (such as rock crushing and deposition of rock material), exhaust gas emissions from vehicles and working machinery, and their impacts will be assessed by experts. A preliminary assessment of the impact assessment area is around two kilometers.

Radioactive emissions, which could mainly be generated under exceptional situations, will also be assessed. The assessment methods are described in Chapter 7.14.

To support the assessment of the climate conditions, a weather station may be installed in the research area to monitor the wind direction and temperature, etc. Snow and frost measurements will be taken in connection with the geological research program 7.5.

## 7.9 Transport and traffic

The description of the current status of traffic in the EIA program is based on traffic volume data published by the Finnish Transport Agency. The traffic volume data will be updated for the EIA report. The road network in the immediate vicinity of the sites is described in the EIA program based on maps and GIS data. This data will be verified for the EIA report and the assessment area will be expanded as necessary based on the separate transport report.

The traffic impact will be studied by assessing transport volumes, transport methods, and routes at the different project phases. Changes to the current traffic volumes arising from transport and the means of transport to be used will be assessed based on the project's transport needs. Impacts of road, rail, and sea transport along all the routes the project may affect will be studied. All necessary temporary changes to traffic arrangements will be described. The traffic impact will be assessed based on changes to traffic. Special attention will be paid to any vulnerable sites, such as residences, kindergartens, schools, hospitals, and recreational areas, along the transport routes.

The EIA report will include an assessment of the safety of the different spent nuclear fuel transport options and their impacts on the environment. A separate transport report will be prepared to support the assessment. It will cover transport routes, alternative transport methods, and radiation doses to the transport personnel and people living along the transport routes. The transport report will also cover any exceptional situations and accidents (see Chapter 7.14). The assessment area will be the surroundings of the transport routes to such an extent that the entire area affected by the studied environmental impacts will be covered. A preliminary assessment of the impact assessment area is around two kilometers.

## 7.10 Noise

The current noise status has been described in the EIA program by studying all activities in the area. The current status data will be updated for the EIA report and noise measurements will be taken, if necessary.

Noise during the different project phases and noise caused by transport will be studied. The noise impact assessment will be based on the project design data, the transport volumes required during the operations, experience from similar operations, and existing data on the area's current noise level. The noise impact assessment will be done by means of noise modeling. Noise caused by the activities performed at the different project phases and related transport activities in the immediate vicinity of the project site (in a radius of approximately two kilometers from the activities) will be studied. In the assessment, the noise caused by the project will be compared to the area's current noise level and guideline noise values.

## 7.11 Vibration

The current vibration status has been described in the EIA program by studying all activities in the area. The current status data will be updated for the EIA report.

The impact of vibration during excavation of the bedrock and transport during the project period will be studied. The intensity of the vibration will be assessed in relation to the distance based on available information about the source of vibration and previous experience. The assessment will take into account all buildings in the immediate vicinity of the research area and any adverse impacts experienced by people. A preliminary assessment of the impact assessment area is around two kilometers.

## 7.12 Waste and by-products, and their utilization

The environmental impact of the processing of waste and by-products will be studied by studying the by-products and waste generated at the different project phases, their quantities, properties, and processing options.

The EIA report will describe the quantity, quality, and processing of ordinary, hazardous, and radioactive waste generated at the encapsulation plant and final disposal facility and assess the related environmental impacts. Waste and land masses generated during the research and construction phases will also be described. Any sites with contaminated soil in the research area will be studied, if necessary. Actions to minimize the amount of waste and by-products, any opportunities to utilize waste, the processing of waste, and final disposal options will be described. The environmental impact from processing and utilization of waste in the area and transport of waste, if any, will be assessed. The impact from any processing or final disposal outside the area will not be assessed in this connection.

## 7.13 Utilization of natural resources

The EIA report will describe the impact on the utilization of natural resources from the use of natural resources and the inability to use natural resources. For example, utilization and use of crushed rock generated during the project period and consumption of the materials needed for the project (such as copper for the disposal canisters) will be studied.

Fennovoima's *(2014)* nuclear power plant environmental impact assessment report describes the environmental impact of the nuclear fuel production chain, and the impact of the utilization of uranium has been assessed in this connection, for example.

## 7.14 Exceptional situations and accidents

A risk analysis to identify the project's exceptional situations and accidents will be prepared to study the potential accident risk types and their probability at the different project phases. The environmental impacts of exceptional situations and accidents will be assessed and means to eliminate or mitigate them will be sought.

The EIA report will describe any radioactive releases during exceptional situations and accidents and other releases, and assess their impact on the environment and people. The releases during exceptional situations and accidents will be compared to the guideline values, limit values, and current status of the area. The impact of the accidents on human health and the environment will be studied based on safety analyses and the requirements posed for the final disposal operations. Radiation doses caused by accidents and the areas affected by radiation will be assessed. The consequences of exceptional situations will be assessed based on research data on the health and environmental impact of radiation. Instructions by the Radiation and Nuclear Safety Authority will be followed when assessing releases during exceptional situations and accidents and their impact.

The risks posed by exceptional situations and accidents during the transport of spent nuclear fuel will also be studied. An exceptional situation during the transport of spent nuclear fuel could be an interruption due to a technical malfunction in the means of transport or a traffic accident, for example. Potential causes of accidents include for example collisions, external factors (sabotage, lightning strike), and fires. The impact assessment will study the durability of the transport container in the case of all the above-mentioned exceptional situations and accidents and the radiation doses that these exceptional situations and accidents could cause to the transport personnel and any people living along the transport route.

## 7.15 Long-term safety

The safety design bases of the planned final disposal facility as regards the limitation of radioactive releases and environmental impacts will be described. An assessment of the opportunity to comply with the currently valid safety requirements will also be given. The radiation doses to humans and other organisms and radioactive release rates at ground level that will be modeled in the environmental impact assessment will be compared to the safety requirements in legislation and STUK's YVL Guides.

The EIA report will include an assessment of the environmental radiation impact. It will be modeled by simulating the migration of radioactive substances from damaged canisters in the final disposal facility to the ground level and further to the ecosystem. Initial data for the computer modeling will be obtained by studying the evolution of the materials included in the final disposal concept in nature, by utilizing studies of archaeological discoveries, by testing the materials in a laboratory, and by applying other scientific studies. The final result of the modeling will be an estimate of the radiation exposure to humans, flora, and fauna at the final disposal area. This estimate will be compared to the safety requirements and the current state.

At the later licensing phases, the safety of the final disposal solution up to a million years from now must be proven. This is why the term 'long-term safety' is used when referring to final disposal. It covers environmental radiation safety also after closing of the final disposal facility. Since long-term safety cannot be completely verified experimentally due to the long period of time, the assessment will be done with the help of computer modeling. Issues to be modeled include hydrological, chemical, thermal, mechanical, and biological processes. The modeling will take into account a variety of future scenarios, such as damage caused by earthquakes or ice ages to the canisters.

## 7.16 Combined impacts with other projects

Projects currently ongoing at Eurajoki include the construction of the Olkiluoto 3 nuclear power plant by Teollisuuden Voima Oyj and the implementation of a spent nuclear fuel encapsulation plant and final disposal facility by Posiva Oy. Other smaller projects are also ongoing at Eurajoki.

Karhunnevakangas wind farm project of wdp Finland Oy is ongoing at the northern edge of the Sydänneva research area in Pyhäjoki. The proposed wind farm area is around 2,590 hectares in size. The plan is to build 36–40 wind power plants of 3 MW in Karhunnevakangas.

An EIA procedure for construction of a 110 kV power line required to connect the Hanhikivi 1 nuclear power plant to the external grid is currently ongoing close to the Sydänneva research area in Pyhäjoki. Furthermore, a nuclear power plant construction site of Fennovoima is located on the Hanhikivi headland in Pyhäjoki. Construction of plant infrastructure is currently ongoing. No other ongoing or planned projects in or in the immediate vicinity of the Sydänneva research area are currently known.

Data on ongoing and planned projects at the alternative locations will be revised at the EIA report phase, and any new combined impacts will be assessed.

## 7.17 Transboundary environmental impacts

Based on the preliminary estimate, the Fennovoima final disposal project does not have any transboundary environmental impacts. A transport report by Fennovoima (Fennovoima 2009) states that large amounts of radioactive substances cannot spread into the environment in connection with a potential accident involving the transport of spent nuclear fuel. Even in the most severe case, mainly the transport personnel and any people in the immediate vicinity of the accident site could be exposed to elevated radiation levels.

The worst-case scenario for the encapsulation plant is an accident where a canister falls from a canister hoist in such a manner that the fuel rods inside the canister are damaged and the canister itself is also damaged. Such an accident could lead to gaseous and particulate radioactive releases into the encapsulation plant, which would be collected by the filters of the ventilation system. (Rossi & Suolanen 2013) The plant's filtering systems will clearly reduce the amount of releases. According to the statutory requirements, no radioactive releases into the environment that exceed the limit and guideline values may occur at the encapsulation plant.

A separate transport report, a risk analysis for exceptional situations and accidents, and long-term safety modeling will be completed for the project. One of the issues examined in these studies is whether the impacts could extend beyond the borders of Finland. The project's environmental impacts (such as quality, quantity, and affected area) will be studied in more detail in the EIA report. The EIA report will include an estimate as to whether the project will cause any transboundary impacts. Transboundary impacts will also be studied during the international hearing pursuant to the Espoo Convention.

## 7.18 Impact of the zero-option

The EIA report will also include an assessment of the zero-option, i.e. not realizing the project at all. In this option, the spent nuclear fuel would be stored at the nuclear power plant site on the Hanhikivi headland in Pyhäjoki for several decades. However, Finnish nuclear legislation requires that spent nuclear fuel is permanently disposed of, which is why prolonged storage cannot be the final solution for the disposal of spent nuclear fuel.

# 8 PREVENTION OR MITIGATION OF ADVERSE IMPACTS

The possibilities of preventing or mitigating the adverse impacts of the project by means of design or implementation will be investigated during the EIA procedure. A report on the mitigation measures will be presented in the EIA report.

# 9 UNCERTAINTY FACTORS

The available environmental information and impact assessments always include assumptions and generalizations. In addition, the available technical data is still preliminary. The lack of information may cause uncertainties and inaccuracies in the assessment work. Since the EIA procedure takes a long time, information on the current status of the areas will be updated for the EIA report. Furthermore, the project design data will be further specified during the EIA report phase.

Potential uncertainty factors will be identified as comprehensively as possible during the EIA procedure, and their effect on the reliability of the impact assessments will be considered. These issues will be described in the EIA report.

# 10 PROJECT IMPACT MONITORING

A proposal for the content of the environmental impact monitoring program will be prepared in connection with the impact assessment, and the proposal will be presented in the EIA report. The objective of monitoring is to:

- Provide information on the impacts of the project
- Identify which changes have resulted from the implementation of the project
- Investigate how the results of the impact assessment correspond with reality
- Study how the measures for mitigating adverse impacts have succeeded
- Initiate the required measures if significant unforeseen adverse impacts occur.

# TERMS AND ABBREVIATIONS

The following terms and abbreviations are used in this EIA program:

| TERM/ABBREVIATION | EXPLANATION |
|---|---|
| **Access tunnel** | A vehicle route (ramp) in the rock from ground level to the final disposal facility level. |
| **Activity (Bq)** | Activity states the amount of nuclear disintegrations in a radioactive substance per unit of time. The unit of activity is the becquerel (Bq) = one nucleus decays per second. |
| **Alkaline rock** | A type of intrusive rock, such as gabbro or basalt, which includes 45–52% silica ($SiO_2$). |
| **Anomaly** | A deviation, aberration, irregularity, abnormality, exceptionality. |
| **Assessment area** | An area in which the environmental effects are studied. The environmental effects are always studied in the entire affected area. |
| **Barrier** | A barrier is an engineered or natural structure or material that performs a safety function, i.e. prevents radioactive materials from being released into the environment. |
| **Basal till** | A dense, unsorted type of soil that has been generated from material loosened by a glacier and carried at the bottom of the glacier. |
| **Bedrock** | The topmost part of the Earth's crust, which consists of different types of rock and is covered partly by loose soil and partly by water. |
| **Bentonite/bentonite clay** | A type of naturally occurring clay that has been transformed from volcanic ash. A special property of bentonite clay is the fact that it expands when it gets wet. The plan is to use bentonite as a buffer material in between the canisters and the rock, and also as one of the final disposal facility filling materials. |
| **Borehole** | A research hole drilled into the bedrock. |
| **Broadband electromagnetic scanning** | An electromagnetic method where the transmitter is a horizontal loop and the receiver consists of three perpendicular coils. Determines the electrical conductivity range of the ground up to a depth of several hundred meters, or even a maximum of three kilometers, depending on the coil spacing. |
| **Canister** | An engineered barrier for the final disposal of fuel elements, which consists of a copper shell, bottom and covers, and a cast iron interior. |
| **Catchment area** | A catchment area (also called a basin or a precipitation area) is the area from which a surface water system gets its water. A catchment area is limited by watersheds, i.e. boundaries where the direction of the surface water flow changes. |
| **Coordinating authority** | An authority that ensures that an environmental impact assessment procedure is arranged for a project. In this project, the coordinating authority is the Ministry of Economic Affairs and Employment (MEAE). |
| **Corrosion** | A reaction caused by environmental factors that makes a material useless. The damaged material dissolves or reacts in another way with a material present in the environment (air, liquid, soil, etc.). The simplest example of |

| TERM/ABBREVIATION | EXPLANATION |
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| | corrosion is the rusting of iron. |
| **Decision-in-Principle** | The realization of a new nuclear facility project is subject to a Decision-in-Principle issued by the Finnish Government and ratified by the Parliament. Requirements for the Decision-in-Principle include the facility's total benefit for society and a positive attitude towards the project from the municipality in which the facility will be located, as well as a positive preliminary safety assessment by the Radiation and Nuclear Safety Authority. |
| **Decontamination** | Removing radioactive materials from an object or material. |
| **Deep boring** | Drilling a hole that extends several hundred meters into the bedrock. |
| **Deep drilling** | A disposal solution where the disposal canisters are placed into boreholes drilled several kilometers deep in the bedrock. |
| **Deformation** | An event involving the rock and the layers of the Earth's crust where faults, shear zones, joints, folds, and oriented structures are generated in the rock due to compression or stretching forces. |
| **Degree of enrichment** | Describes the proportion of the desired material in the entire volume of materials (such as the proportion of the isotope U-235 in nuclear fuel). |
| **Diabase** | A commonly occurring type of gangue rock, similar to basaltic volcanic rock. |
| **Diorite** | A type of intrusive rock consisting of plagioclase (andesine) and amphibole, often mixed with biotite and/or augite. |
| **Discharge burnup** | Burnup of the spent fuel that is removed from a reactor during refueling. Burnup refers to the total amount of energy generated in the fuel per unit of mass. |
| **Drilling** | A method for making holes in rock for e.g. research purposes. |
| **EIA** | EIA is short for Environmental Impact Assessment. The statutory EIA procedure involves the investigation and assessment of the environmental impact of specific projects and consultation with the authorities and any parties whose conditions or interests may be affected by the project, as well as communities and foundations whose operations may be affected by the project. |
| **EIA program** | A document prepared during the first phase of the EIA procedure that presents a plan for arranging the environmental impact assessment procedure and the required additional studies. |
| **EIA report** | A document prepared during the second phase of the EIA procedure that presents information about the project and its alternatives, as well as a coherent assessment of their environmental effects. |
| **Elevation model** | A model describing the ground level height. |
| **ELY Centre** | Centre for Economic Development, Transport and the Environment. |
| **Encapsulation plant** | The term 'encapsulation plant' refers to a nuclear facility where spent nuclear fuel is packed into disposal canisters. |
| **Encapsulation plant and final disposal facility** | A plant consisting of two nuclear facilities: an encapsulation plant above ground level and a final disposal facility deep in the bedrock. |

| TERM/ABBREVIATION | EXPLANATION |
|---|---|
| **Environmental impact** | The term 'environmental impact' (or 'environmental effects') refers to the direct and indirect effects of a project in and outside of Finland. |
| **Euratom** | The European Atomic Energy Community. Finland is a member of Euratom. |
| **Fault** | A fracture surface (or zone) where the rocks on either side have moved in relation to each other. |
| **Final disposal** | The permanent disposal of nuclear waste in such a manner that the final disposal site does not need to be controlled and the radioactivity does not cause any danger to the environment or people. |
| **Final disposal facility** | The term 'final disposal facility' refers to tunnels for the final disposal of spent nuclear fuel hundreds of meters deep in the bedrock. |
| **Final disposal project** | The spent nuclear fuel final disposal planning, development, construction, and implementation project by Fennovoima. |
| **Final disposal tunnel** | A tunnel excavated into the bedrock where disposal canisters can be placed. |
| **Fortum** | Fortum Power and Heat Oy. |
| **Fracture zone** | A fracture zone that was generated when internal stresses of the bedrock were released. |
| **Fuel assembly** | A fuel assembly consists of fuel rods that contain the uranium that is used as nuclear fuel. |
| **Fuel element** | The smallest basic structural unit that is used in a reactor. Depending on the reactor structure, a fuel element may be a fuel rod, a fuel assembly, or a structure consisting of a fuel assembly and a fuel channel. |
| **Fuel rod** | The uranium that is used as nuclear fuel is placed inside a fuel cladding in fuel rods. |
| **Geological final disposal** | Geological final disposal refers to a solution for the final disposal of spent nuclear fuel where the spent fuel is isolated deep underground so that its effects on the environment are equal to or less than those of naturally occurring radioactivity. |
| **Geophysical properties** | Magnetic, electromagnetic, electric, seismic, and thermal properties of bedrock. |
| **Gneiss** | Oriented, medium-grade or coarse metamorphic rock that mainly consists of quartz, feldspar and micas, and often also contains garnet, cordierite, amphibole or diopside. |
| **Granite** | A type of intrusive rock that consists of potash feldspar, plagioclase, quartz and mica, and often also contains amphibole. |
| **Granodiorite** | A type of intrusive rock that consists of plagioclase, potash feldspar and quartz, as well as dark minerals, such as biotite and/or amphibole. |
| **Greisen** | A type of hydrothermal rock that usually occurs as seams. It mainly consists of quartz and mica, but may also include topaz, tourmaline, fluorite, as well as a variety of tin, tungsten, and lithium minerals. |
| **Groundwater** | In this context, underground bedrock groundwater. |

| TERM/ABBREVIATION | EXPLANATION |
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| **GTK** | The Geological Survey of Finland. |
| **HIRE Seismic Reflection Survey** | A high resolution seismic reflection survey performed at ground level. |
| **Homogeneity** | Uniform quality. |
| **Hydraulic cage** | An alternative final disposal concept that consists of vertical holes and tunnels excavated around a silo that drain groundwater into the surroundings of the disposal area. Spent fuel assemblies are packaged into disposal capsules manufactured from cast iron and steel, and are stored inside holes (also called final disposal tunnels) that have been drilled radially inside the silo. There are vertical holes around a central shaft in the middle of the silo for cooling. The cooling shafts are surrounded by a bentonite-filled shell, which is around five meters thick. The tunnels and boreholes outside the shell create a hydraulic cage that keeps the underground rooms hydrologically, mechanically, and chemically suitable for final disposal. |
| **Hydrogeochemistry** | Water chemistry. |
| **Hydrogeology** | A branch of science that studies water below ground level, its occurrence, its movements, and its relationship with the surrounding geological environment. |
| **Hydrology** | A branch of science that studies the occurrence of surface water, its movements, and its relationship with the surrounding geological environment. |
| **IAEA** | The International Atomic Energy Agency; an organization under the UN that seeks to promote the peaceful use of nuclear energy. The IAEA also promotes radiation safety, nuclear safety, and nuclear disarmament. |
| **IBA and FINIBA** | IBA is short for 'Important Bird Area', a globally important bird area, and FINIBA is short for 'Finnish Important Bird Area'. The parties in charge of mapping these areas are the Finnish Environment Institute and BirdLife Finland. |
| **International hearing** | A hearing procedure that crosses national boundaries for environmental impact assessments in compliance with the Espoo Convention (the Convention on Environmental Impact Assessment in a Transboundary Context). Several target states can participate in the hearing. |
| **Intrusive rock** | Igneous rock that has crystallized from magma deep in the Earth's crust. |
| **Isotope** | Isotopes are different forms of the same element that differ from each other in relation to the number of neutrons in the nucleus and the properties of the nucleus. Almost all elements exist as several isotopes in nature. For instance, hydrogen has three isotopes: hydrogen, deuterium, and tritium, of which tritium is radioactive. |
| **Joint, jointing** | A rectilinear fracture surface in rock where no displacement has occurred. If displacement in relation to the joint has occurred, it is a fault. |
| **KBS-3** | A final disposal solution developed by SKB, the company in charge of nuclear waste management in Sweden. KBS is short for kärnbränslesäkerhet, Swedish for 'nuclear fuel safety'. |
| **KBS-3H** | A final disposal solution that is based on a principle of multiple barriers. The first barrier, the canister, is placed horizontally into the bedrock (H = horizon- |

| TERM/ABBREVIATION | EXPLANATION |
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| | tal). |
| **KBS-3V** | A final disposal solution that is based on a principle of multiple barriers. The first barrier, the canister, is placed vertically into the bedrock (V = vertical). According to Posiva's current plans, the disposal canisters will be placed into vertical holes in the disposal tunnels. |
| **Laser scanning (LiDAR)** | A non-destructive measuring method that provides accurate three-dimensional information about an object with laser beams. |
| **Leakage water** | In this context, leakage water refers to groundwater that gathers in a shaft or tunnel that has been constructed or excavated in the bedrock. |
| **Lineament** | A long, continuous feature (such as a valley) on a map or in the terrain. A lineament may reflect a fracture zone in the bedrock. |
| **Long-term safety** | The term 'long-term safety' refers to the fact that when planning the final disposal of nuclear fuel, all potential events in the disposal facility and its surroundings during the next 100,000–1,000,000 years should be taken into account. The key is making sure that nature's own mechanisms combined with the engineered barriers will prevent the migration of radioactive materials into the living environment under all conditions, even if one of the disposal canisters starts to leak. |
| **Low and intermediate level waste** | The term 'low- and intermediate-level waste' refers to the operational and maintenance waste of a nuclear power plant. Such waste is also generated when a nuclear power plant is decommissioned. Low-level waste can be handled without any radiation protection arrangements because its level of radioactivity is low (max. 1 MBq/kg). Efficient radiation protection arrangements are needed when handling intermediate-level waste (activity 1–10,000 MBq/kg). |
| **Magnetic anomaly** | Any aberration from the normal magnetic field. |
| **MEAE** | The Finnish Ministry of Economic Affairs and Employment (the coordinating authority of the EIA procedure). |
| **Migmatite** | Migmatite is older rock (usually gneiss) into which younger rock (usually granite) has penetrated as magma or in solution, or that has melted and separated in connection with metamorphosis. |
| **Mise-a-la-masse** | An electronic method that can be used to study the position, continuity, and properties of zones in the ground. |
| **Moraine** | A type of soil generated from rock material loosened and transported by a continental glacier. The grain sizes vary from clay to large boulders. |
| **Multibarrier principle** | Realizing final disposal in such a manner that radionuclides have to penetrate several barriers that are independent from each other before they can enter the living nature. |
| **MW** | Megawatt, a unit of power (1 MW = 1,000 kW). |
| **Natura 2000** | A network of nature conservation sites in accordance with the EU Habitats Directive. The goal of the Natura 2000 network is to protect endangered, rare, or characteristic habitats, animals, and plants. |
| **NEA** | The Nuclear Energy Agency, an OECD organization. |
| **Nuclear facility** | A nuclear facility is a facility where nuclear energy is generated (including research reactors), a facility where large-scale disposal of nuclear waste |

| TERM/ABBREVIATION | EXPLANATION |
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| | takes place, or a facility where large-scale manufacture, production, use, handling, or storage of nuclear waste takes place. |
| **Nuclear fuel** | A compound containing uranium or plutonium that is used in the reactors of nuclear power plants. |
| **Nuclear waste** | A common name for the radioactive waste produced during the operation of a nuclear facility. Nuclear waste is low- or intermediate-level operational waste, or high-level spent fuel.<br>Radioactive waste, as spent nuclear fuel or in other forms, which was generated during or as a result of nuclear energy operation, as well as substances, objects, and structures that, during or as a result of nuclear energy operations, have been decommissioned and that, because of the radioactive hazard, require special measures are all considered to be nuclear waste. |
| **Nuclear-use item** | The term ‘nuclear-use item’ refers to nuclear materials and related materials, components, equipment, nuclear information, and agreements. |
| **Nuclide** | A nuclide is the nucleus of an atom with a specific atomic (proton) number (Z) and neutron number (N). |
| **OECD** | The Organization for Economic Cooperation and Development. Finland is a member of the OECD. |
| **Olivine diabase** | A commonly occurring type of gangue rock, similar to basaltic volcanic rock. The main mineral is usually olivine. |
| **ONKALO** | Posiva Oy’s underground rock research facility of the spent nuclear fuel final disposal facility. |
| **Operational waste** | A common name for the low- and intermediate-level waste produced during the operation of a nuclear power plant. |
| **Organization responsible for the project** | The operator or the party that carries the responsibility for the preparation and implementation of the project for which the EIA procedure is being completed. |
| **Outcrop** | An area of bare bedrock or bedrock very close to the surface, often slightly elevated when compared to the rest of the environment. |
| **Participation** | Interaction between the organization responsible for the project, the coordinating authority, other authorities, parties whose conditions or interests may be affected by the project, and communities and foundations whose operations may be affected by the project during an environmental impact assessment. |
| **Pegmatite** | Very coarse-grained igneous rock that is usually found as seams. |
| **Petrographic survey** | A method of describing and systematically classifying types of rock based on their mineral composition, texture, and structure. |
| **Petrologic and structural analysis** | The survey of rocks based on rock type, structure, and exposure. |
| **Petrology** | The branch of science concerned with the origin, structure, and composition of rocks. |
| **Petrophysical survey** | Studying of the physical properties of rock. |

| TERM/ABBREVIATION | EXPLANATION |
|---|---|
| **Phenocryst** | A sizeable mineral grain in a rock, larger than the surrounding grains (see ‘Porphyritic rock’). |
| **Plagioclase circle** | A circle consisting of plagioclase around a roundish grain of potash feldspar. A structure often found in a rapakivi granite transformation called wiborgite. |
| **Porphyritic rock** | Igneous rock that contains grains that are larger than the rock type’s usual grain size (phenocrysts). |
| **Porphyroblast** | A mineral grain that has grown due to metamorphosis and is larger than the other rock grains. Metamorphosis is a geological event where the structure or mineral composition, or both, of a rock change due to movements or changes in temperature or pressure. |
| **Project area** | The area that houses the project’s underground facilities, the facilities above ground level, and other project infrastructure, such as roads and soil dumping areas. |
| **Pyterlite** | A type of rapakivi granite that does not usually include the circles consisting of plagioclase around the roundish grains of potash feldspar. |
| **Radiation** | Radiation is either electromagnetic wave motion or particle radiation. |
| **Radiation dose** | Radiation dose is a variable used to describe the harmful effects of radiation on humans. The unit of radiation dose is the sievert (Sv). |
| **Radioactive** | A radioactive material contains atom nuclei that can spontaneously transform or decay, creating new nuclei. Ionizing radiation (such as alpha, beta, or gamma radiation) is usually released during such decay. See Radioactivity. |
| **Radioactivity** | Radioactive materials spontaneously decay into lighter elements or isotopes of the same element that have less bonding energy. The process releases ionizing radiation, which is either electromagnetic radiation or particle radiation. |
| **Radionuclide** | The nucleus of an element that spontaneously transforms into another nucleus while emitting ionizing radiation. |
| **Rapakivi massif** | A large and uniform intrusive rock formation consisting of rapakivi granite. |
| **Reprocessing** | Separating useful nuclides from spent nuclear fuel, leaving behind fission products and some transuranic elements. |
| **Research area** | An area that could, based on its size and properties, be an area suited for further studies and final disposal. A target area may consists of several research areas (see Target area). |
| **Research area border** | The border of a research area is the edge of the research area. |
| **Research facility** | A research tunnel or shaft that has been excavated in order to study the bedrock. |
| **Return water** | Return water is tap water used during drilling mixed with the groundwater in the bedrock. |
| **RKY** | The national inventory of built cultural environment of national importance (RKY) was an inventory realized by the National Board of Antiquities. By virtue of a Government decision dated 22 December 2009, the inventory was based on the national land use objectives as laid down in the Land Use and |

| TERM/ABBREVIATION | EXPLANATION |
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| | Building Act, and it started at the beginning of 2010. |
| **SAC area** | An area included in the Natura 2000 network based on the Habitats Directive. |
| **Satellite massif** | A formation that is part of a large and uniform intrusive rock formation, but is slightly separate from it. |
| **Schistosity** | A planar structure in stone, created by deformation. |
| **Seam** | A type of rock occurring as a distinct layer within another type of rock. A seam can be created when magma enters a joint in the bedrock, for example. |
| **Sediment** | A layer of gravel, sand, clay, or peat that has been gathered on the ground by geological processes (such as weathering, erosion, transport, and deposition). Sediment may be clastic, chemical, or organic. |
| **Segment** | A rock area delimited by fracture zones. |
| **Seismic reflection** | Seismic reflection sounding. A geophysical method that is based on percussion waves. |
| **SKB** | Svensk Kärnbränslehantering AB, a Swedish nuclear waste management company. |
| **Soil** | The layer of soil on top of the bedrock. |
| **SPA area** | An area included in the Natura 2000 network based on the Birds Directive. |
| **Spent nuclear fuel** | Nuclear fuel is spent when it has been removed from the reactor. Spent nuclear fuel usually emits high levels of radiation. |
| **Structural and morphological analysis** | Determining segments with low elevation changes based on satellite images. |
| **STUK** | The Radiation and Nuclear Safety Authority. |
| **Surface water** | The water on the ground and in the soil. |
| **Svecofennian** | Dating back to the formation of a mountain range in Finland and Sweden around 1,900 million years ago. |
| **Target area** | A target area is an area that has been deemed applicable for final disposal based on a preliminary study of the rock fracture zones. A target area may consists of several research areas. |
| **Tomography** | A research method (electric or seismic, for example) that usually provides information on a two-dimensional plane between boreholes or the ground below a surveying line. The method is based on inversion calculation. |
| **Tonalite** | A type of intrusive rock; a granitoid that contains only small amounts of potash feldspar. |
| **Tons of uranium** | The amount of uranium in fresh fuel (tU). |
| **Topography** | Detailed description of the topography of the ground. |
| **Transport cask** | A radiation shielded container manufactured for transporting spent nuclear fuel and storing it for a short period of time. In addition to providing radiation |

| TERM/ABBREVIATION | EXPLANATION |
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| | protection, the cask provides mechanical and thermal protection during the transport, handling, and storage of spent nuclear fuel. The term 'transfer cask' can also be used. |
| **TVO** | Teollisuuden Voima Oyj. |
| **Uranium** | An element with the chemical symbol U. An average of 0.0004% of all the material in the Earth's crust (four grams per ton) is uranium. All isotopes of uranium are radioactive. The majority of natural uranium is isotope U-238, the half-life of which is 4.5 billion years. Around 0.71% of natural uranium is in the form of isotope U-235, which can be used as a nuclear fuel. |
| **YVL Guides** | Nuclear power plant guides published by the Radiation and Nuclear Safety Authority that describe detailed radiation and nuclear safety requirements. Detailed safety requirements pertaining to the use of nuclear energy are described in the YVL Guides. |

# LITERATURE

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