FENNOVOIMA

Update to the construction license application for the Hanhikivi 1 nuclear power plant pursuant to section 18 of the Nuclear Energy Act (990/1987)

APRIL 2021

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Content

Update to the construction license application for the Hanhikivi 1 nuclear power plant

Appendices

1. Supplementary account of the environmental impact of the construction and operation of the nuclear power plant, as well as of measures to prevent or mitigate adverse impacts (Original Appendix 3A of the Construction License Application submitted to the Ministry of Economic Affairs and Employment in June 2015)

2. Supplementary account of the environmental impact of the nuclear power plant on the marine environment and fishery during operation (Original Appendix 3B of the Construction License Application submitted to the Ministry of Economic Affairs and Employment in June 2015)

Updating the application

On 30 June 2015, Fennovoima submitted to the Government an application on the con-struction of a new nuclear power plant on the Hanhikivi peninsula in Pyhäjoki. Since then, the project has progressed and the boundary conditions affecting it have changed. These changes do not change the basis of the project from the decision-in-principle phase, but they do supplement the information presented in the construction license application submitted on 30 June 2015. Based on discussions with the Ministry of Economic Affairs and Employment (MEAE), Fennovoima has prepared an update covering all changes essential for the processing of the application, and Fennovoima requests that the supplement be taken into account when processing the original application submitted on 30 June 2015. Appendices 3A, “Account of the environmental impact of the construction and operation of the nuclear power plant, as well as of measures to prevent or mitigate adverse impacts” and 3B, “Additional surveys required by the Ministry of Economic Affairs and Employment on the impact of the nuclear power plant on the marine environment and fishery during operation”, have been updated and are presented in Appendices 1 and 2 to this supplement.

Below, the supplemented information has been grouped in accordance with the original application in such a manner that the notable changes presented in the application’s ap-pendices will be processed in connection with the main chapter in question.

Applicant

Fennovoima Oy is a Finnish limited liability company with the business identity code of 2125678-5. There have been no changes since 2015 to the applicant’s details presented in the original application submitted on 30 June 2015, including the extract from the Trade Register, the articles of association, and the shareholder list in Appendix 1A and the com-pany’s ownership base described in Appendix 1B.

Project

There have been no changes to the premises of Fennovoima’s project since the submission of the construction license application. The plan is to build one nuclear power plant unit with a thermal power of 3,220 MW and an electrical power output of 1,200 MW, as well as other nuclear facilities required for the operation of the power plant unit, including nuclear facilities for the storage of fresh nuclear fuel, the interim storage of spent nuclear fuel, and the storage and processing of low and intermediate level operational waste at the plant site on the Hanhikivi peninsula in Pyhäjoki.

The development and specifications to the Hanhikivi 1 project since 2015 are presented below in this supplement to the construction license application.

Decisions-in-principle

In its decisions-in-principle in 2010 and 2014, the Finnish Government stated that the construction of the new nuclear power plant and the other nuclear facilities required for its operation at the plant site on the Hanhikivi peninsula in Pyhäjoki is, in terms of the key op-erating principles and solutions to ensure safety in the manner as presented by Fennovoi-ma in its applications and in the manner stated in the above-mentioned decisions-in-principle, in line with the overall good of society. Both decision-in-principles included conditions regarding the validity of the decision-in-principles, nuclear waste management, and the company’s ownership base.

Fennovoima met the validity requirement in the 2010 decision-in-principle by submitting an application on the construction of the Hanhikivi 1 nuclear power plant to the Government by the set deadline of 30 June 2015, presenting its specified plans on the nuclear waste management arrangements at the same time.

With regard to the final disposal of spent nuclear fuel, Fennovoima submitted to the coordinating authority (MEAE) an environmental impact assessment procedure compliant with the Act on Environmental Impact Assessment Procedure (EIA, 468/1994) for its own disposal facility for spent nuclear fuel by the specified deadline of 30 June 2016. Furthermore, Fennovoima signed a service agreement with Posiva Solutions Oy in compliance within the same schedule.

In the 2014 decision-in-principle, the Government stated that a minimum of 60% of Fennovoima's ownership must be held by operators domiciled within the EU or the EFTA. Since 2015, more than 60% of Fennovoima's ownership has been continuously held by operators who have committed to further equity financing of the project, and who are domiciled within the EU or EFTA. The prerequisite set by the Government for the granting of a con-struction license regarding Fennovoima's ownership base is thus met.

The development of and specifications to the project since the submission of the construction license application do not change the plant's key operating principles or the solutions pertaining to safety in any other respect, either. The changes made in plant design further improve the plant's safety.

Plant site

Information and grounds pertaining to the plant site at the Hanhikivi peninsula in Pyhäjoki were presented in the construction license application submitted on 30 June 2015 and its Appendices 3A–3C.

Concerning the plant site, the construction license application states that there are no features at the Pyhäjoki site that would prevent the construction of the new nuclear power plant and the related nuclear facilities referred to in the application for a decision-in-principle in compliance with the safety requirements. Since the submission of the construction license application, the plant supplier and Fennovoima have prepared further surveys regarding the specific plant location, the properties of the bedrock, the design of the plant foundations, and the monitoring of ageing during operation. The results of these surveys are still being processed by Fennovoima and the Radiation and Nuclear Safety Authority (STUK).

The environmental impact assessment (EIA report) implemented during 2013–2014 has been found to describe the project's environmental impact and the possibilities to mitigate the environmental impact to a sufficient extent. Measures to manage the environmental impact during the construction and operation of the nuclear power plant, updated to cor-respond to the situation in 2021, are presented in Appendix 1 to this document.

In June 2016, the Regional State Administrative Agency of Northern Finland granted an environmental and water permit to Fennovoima's Hanhikivi 1 nuclear power plant. Pursuant to a decision made by the Supreme Administrative Court of Finland in April 2019, the permit is legally valid. The decision by the Supreme Administrative Court also states that the above-mentioned EIA report covers all the matters laid down in section 10, subsections 3 and 5 of the Government Decree on Environmental Impact Assessment Procedure to the required extent and is free from material deficiencies. These sections of the Government Decree concern the project's key characteristics and solutions over the course of the project lifecycle (section 3) and a survey of the environment and an assessment of the environmental impact of the project and the available options (section 5).

In its statement on the EIA report, issued as the coordinating authority of the EIA procedure, the Ministry of Economic Affairs and Employment required Fennovoima to carry out additional surveys to investigate the power plant's impact on the marine environment and fishery during operation. The results of these additional surveys are presented, updated to the correspond to the situation in 2021, in Appendix 2 to this application.

Land use at the Hanhikivi peninsula is prescribed by the Hanhikivi regional land use plan for nuclear power and the Raahe and Pyhäjoki local master plans and local detailed plans for the nuclear power plant area. The land use planning required for the nuclear power plant project is legally valid at all three levels of land use planning, and no changes have taken place in the land use planning for the project site area since the submission of the construction license application in 2015.

Since the submission of the construction license application, Fennovoima has acquired land and water areas through voluntary real estate transactions so that it now owns a total of 567 hectares, covering all the areas required for the nuclear power plant and its support functions.

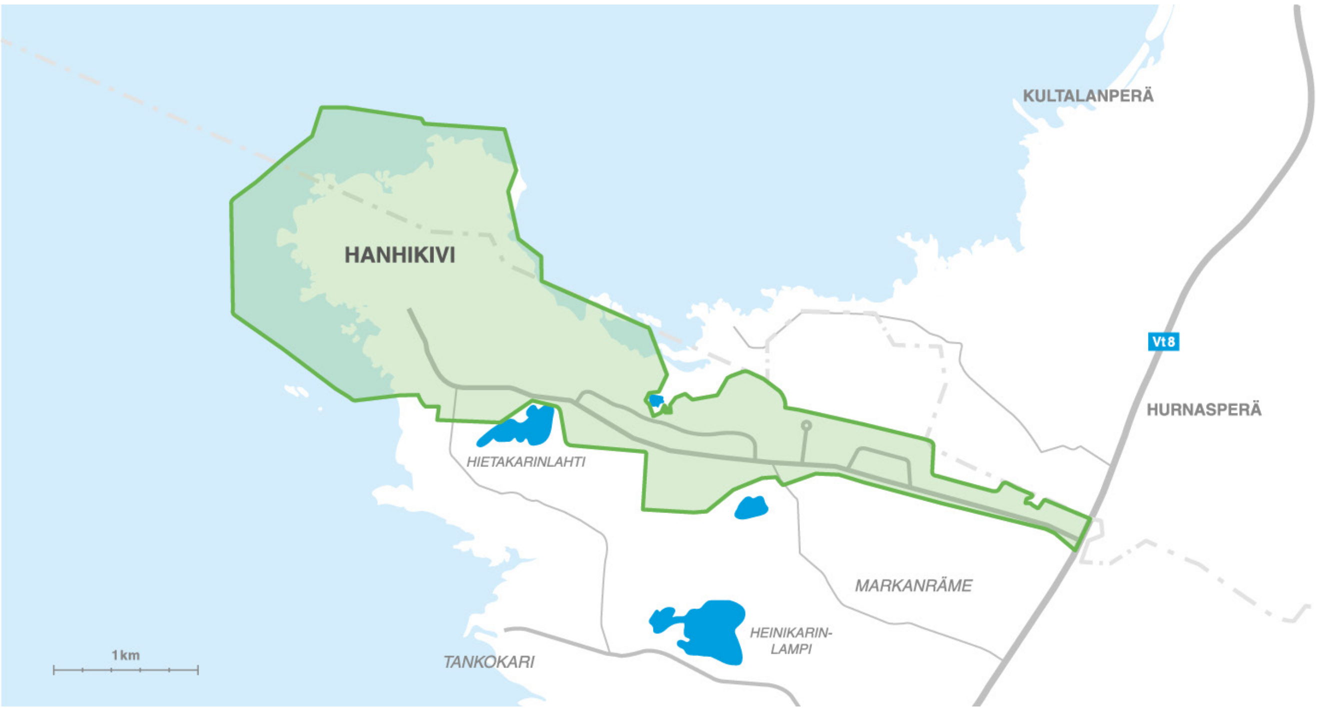

Figure 1. Land and water areas owned by Fennovoima on the Hanhikivi peninsula in Pyhäjoki.

Schedule and manner of implementation

The Fennovoima nuclear power plant project at the Hanhikivi peninsula in Pyhäjoki will be implemented in accordance with the principles and procedures described in the 2015 application and its Appendix 2A, i.e. the delivery will be based on a turnkey delivery model which is to be carried out by one main supplier, excluding the parts included in Fennovoima's scope of work, mainly the construction of infrastructure and administrative buildings, as well as the construction of the interim storage facility for spent nuclear fuel at a later point in time.

In terms of the construction work included in Fennovoima's scope of work, the project has proceeded according to the original plans. The civil engineering elements, power lines, training building and gate buildings required by the construction site, as well as the first nuclear structure, a weather mast related to the measurements required for the power plant's emergency preparedness operations, have been built and commissioned at the plant site. The construction of a permanent office building started in 2020. Licensing documentation for the interim storage facility for spent nuclear fuel that are required for the nuclear power plant construction license phase have been prepared and submitted for review to the Radiation and Nuclear Safety Authority (STUK). The documentation will be updated based on feedback from STUK.

Ensuring compliance of the nuclear power plant design and licensing material with the Finnish requirements has caused some delays in the start of construction. On the other hand, the delay at the licensing phase has enabled better preparation for the transition to the construction phase, which is expected to reduce the cost, quality and schedule risks at the construction phase. The delay of approximately five years experienced at the licensing phase is expected to remain unchanged after the transition to the operational phase, however.

Organization and expertise

The Fennovoima organization is being developed in the manner described in the 2015 ap-plication and its Appendices 2A and 2B to comply with the needs of the buyer of the nucle-ar power plant and later the needs of the operational activities of the plant. The current es-timates on the size of the company's organization during construction and operation of the plant comply with those presented in 2015. The nuclear industry experience and expertise at Fennovoima's disposal have significantly increased from 2015 both through recruitment and the experience gained by employees working in the Fennovoima project. Annual em-ployee turnover has been around 10% in the past few years, and replacement recruitments have been carried out without any major problems.

Toni Hemminki, who was Fennovoima's CEO since 2014, left the company in late 2019. He stayed on as a management consultant until the end of 2019. Timo Okkonen, the compa-ny's COO, was the acting CEO until June 2020, at which time Joachim Specht started his work as the CEO. Specht joined Fennovoima from Preussen Elektra (former E.ON Kern-kraft), where he served as Senior Vice President and Head of Nuclear Engineering and Con-sultancy. Specht holds a master's degree in metallurgy and materials science, and has an almost thirty years of experience from the nuclear industry. He has worked in different po-sitions in Preussen Elektra, Areva, Framatome and Siemens/KWU. Specht has extensive ex-perience from the industry in new build projects, operation and maintenance, as well as services, engineering, and consulting. Fennovoima has named the responsible manager re-quired for the plant construction phase pursuant to section 7 of the Nuclear Energy Act. The named manager has been approved by the Radiation and Nuclear Safety Authority. The regulatory review of the security arrangements, emergency preparedness arrange-ments, and the naming of persons responsible for nuclear safeguards required by the said section of law is currently ongoing.

Due to the difficulties in the preparation of design and licensing documentation compliant with the Finnish requirements, Fennovoima has adopted a more supportive role in the in-teraction with the plant supplier RAOS Project Oy. To develop its own operations, Fenno-voima launched an extensive development program called FV 2.0 in 2019. The program en-tailed modifying the company's organization and management system to better corre-spond to the needs at the licensing and construction phases. Planning of the organization and operating methods at the future operational phase was started at the same time. All the key functions described in the 2015 application are still present in both the construction phase and the operational phase organization, however.

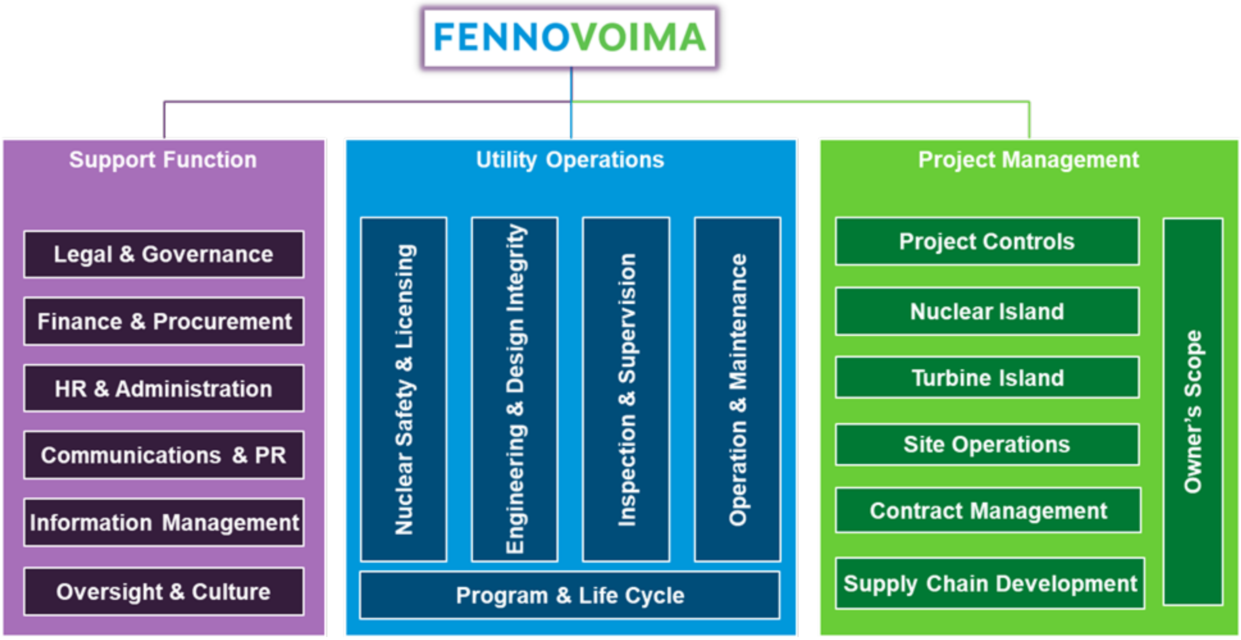

Figure 2. Fennovoima's organization, April 2021. The company's main functions are Sup-port Functions, Utility Operations and Project Management.

Financial resources

Appendix 1C to the 2015 construction license application presented the financial resources required from Fennovoima to realize the nuclear power plant project described in the application. The conclusion given at that time and the justification for the conclusion have not changed. Specifications pertaining to the project cost estimate, the sources of financing, and financial risks and uncertainties are presented below.

Cost estimate

At present, the total investment costs of the Hanhikivi 1 project are estimated at approxi-mately EUR 7–7.5 billion (previously EUR 6.5–7 billion), mainly due to the five-year delay in obtaining the construction license and, to a lesser extent, changes in the project's scope of supply. As the plant supply contract with RAOS Project Oy is a fixed-priced contract, the ex-cess costs are due to expenses from Fennovoima's own operations, expenses from the Fennovoima organization, in particular. A compensation for the delay from the plant sup-plier would decrease the project's currently estimated total price.

Sources of financing

There have been no changes in Fennovoima's owners and their commitment in the capital investments. The capital investments total around EUR 1.7 billion. The timing of the capital investments has been slightly postponed due to the delays in the project. The investments will be made in full by the commissioning of the plant for commercial operation.

JSC Rusatom Energy International (REIN, former JSC Rusatom Overseas) has granted a shareholder loan with a nominal value of EUR 2.4 billion, of which Fennovoima withdrew the first instalment in 2015. REIN is also committed to procure and/or have third party fi-nanciers procure the debt financing facilities in the amounts necessary to cover the total fi-nancing needs of the project. The owners' capital investments and the REIN shareholder loan cover some 50% of the estimated investment costs. Preparations and negotiations on the rest of the financing are ongoing to ensure that the sources of financing will be deter-mined by the start of the nuclear power plant's construction.

Provisions for financial risks and uncertainties

Large and complex investment projects like the Hanhikivi 1 project always involve risks and uncertainties. Some of the risks involving delays and increased costs have already been materialized during the project.

The plant supplier has confirmed the postponement of the planned starting date of commercial operation from 2024 to 2028. This means that the total costs from Fennovoima's own organization during the project will be higher than originally estimated. To a lesser extent, costs have increased due to changes in the content of the project. Any additional delays will increase the total expenses from Fennovoima's own operations, while the nuclear power plant supply contract signed with RAOS Project Oy is a fixed-price contract.

There are uncertainties involving the availability and price of the capital required for the construction of the nuclear power plant. Delays in obtaining the missing part of the investment financing could delay the start of construction. REIN is committed to procure and/or have third party financiers procure the debt financing facilities in the amounts necessary to cover the total financing needs of the project.Fennovoima's Hanhikivi 1 project is a large project with parties from several countries. Due to the international nature of the project, there are risks pertaining to international affairs. Further deterioration of political and commercial relations between the EU, the USA and Russia could lead to more sanctions between the parties. Such deteriorated international affairs and sanctions could influence the project's schedule and financing, in particular.

The ability of Fennovoima, the plant supplier, and the entire supply chain to finalize plant design and the safety assessment, as well as their preparedness to start construction as planned, and ability to ensure compliance with the Finnish requirements at the construc-tion phase, are the most important risks pertaining to possible future delays. Fennovoima estimates that Fennovoima would be able to obtain the construction license by summer 2022. Fennovoima also estimates that the construction would start in summer 2023 and the commercial use of the power plant in 2029. Should the first startup of the plant be delayed from the agreed date due to reasons attributable to the plant supplier, the plant supplier is obliged to pay liquidated damages for the delay.

Any delays in Fennovoima's own preparations for the operation of the plant could influence the commissioning date of the plant. Fennovoima minimizes the risks by means of a strategy and long-term planning that cover the preparedness for the operation of the plant.

Nuclear power plant type

As stated in the 2015 construction license application, the reactor type AES-2006 selected by Fennovoima represents technology developed by the Rosatom Group, which is well-known in terms of the key operating principles and solutions to ensure safety and is equipped with features representing more modern technology. These principles and their application to the Hanhikivi 1 nuclear power plant have not changed since 2015. The work pertaining to the plant's technical safety solutions has focused on ensuring compliance of specific technical solutions and the documentation describing the plant with the Finnish requirements. In addition, analyses required to demonstrate safety have been developed significantly in the past few years to ensure compliance with the Finnish requirements and the Hanhikivi 1 nuclear power plant.

Appendices 4A and 4B to the construction license application include reports on the type of the nuclear power plant to be constructed, its technical operating principles, suppliers of the plant's key components, and the safety principles to be followed at the nuclear power plant. Design modifications and specifications to be made during the design of the plant will be included in the licensing documentation to be submitted to the Radiation and Nuclear Safety Authority at the construction license phase pursuant to section 35 of the Nuclear Energy Decree, and the preliminary safety analysis report in particular. Below is a list of changes and specifications to the information given in Appendices 4A and 4B which are minor but worth noting.

Changes to the supply chain (Appendix 4A, Summary)

- Turbine island supplier: GE Steam Power Systems, which is the French subsidiary of American General Electric; The turbine island is still based on the Alstom-Arabelle technology (name change caused by corporate restructuring)
- Management of I&C delivery as a whole: Russian JSC Rusatom Automated Control Systems (JSC RASU)
- Supplier of safety-classified I&C: French Framatome SAS
- Supplier of operational I&C: German Siemens Energy Global GmbH & Co. KG

Status of the reference plant (Appendix 4A, History)

- The reference plant LAES II-1 in Sosnovyi Bor was commissioned for commercial operation in October 2018. Its sister unit LAES II-2 has also been commissioned for commercial operation, in March 2021.

Reactor pressure vessel (Appendix 4A, Basic technology, reactor pressure vessel and primary circuit)

- The section of the application refers at a general level to empirical and prevailing procedures for the management of radiation embrittlement in the reactor pressure vessels of VVER plants. In the case of the Hanhikivi 1 plant, radiation embrittlement and the available means to manage it have been studied since 2015. A program to manage the phenomenon with ageing tests to be performed prior to the commissioning of the plant has been approved by the Radiation and Nuclear Safety Authority.
- The plant's reactor coolant line and pressurizer connecting line will be designed and manufactured to comply with the leak-before-break principle.

Preparation for severe reactor accidents (Appendix 4A, Management of severe reactor accidents)

- The strategy for the management of severe reactor accidents and the design of related technical systems have been updated to comply with regulatory changes since 2015.

Large commercial airplane crash (Appendix 4A, Safety systems)

- Reviews pertaining to large commercial airplane crashes will demonstrate, in accordance with the requirements, that no significant releases into the environment result from the crash and that the most important safety functions can be activated and maintained with sufficient assurance to bring the nuclear facility to a safe state. The finalization of the surveys and the regulatory review process with STUK are ongoing.

Development of nuclear industry regulations (Appendix 4B, Safety)

- Changes have been made to the nuclear industry regulations since 2015. They also regulate the design, licensing, construction, and subsequent operation of Fennovoima's nuclear power plant. The Nuclear Energy Act and Nuclear Energy Decree have been amended since 2015, particularly in terms of administrative requirements pertaining to nuclear waste management and security arrangements. The above-mentioned themes are discussed in more detail in sections "Nuclear waste management" and "Security and emergency preparedness arrangements" of this update. There are regulations on the licensing of the decommissioning of a nuclear power plant in section 7g of the Nuclear Energy Act, which are further specified by the regulations of section 33a of the Nuclear Energy Decree and requirements elsewhere in the Decree. These amendments do not apply to the construction license phase. The Government Decrees that were in force in 2015 have subsequently been replaced with regulations issued by the Radiation and Nuclear Safety Authority, which have the same names and mostly the same content, and they do not cause any need to update the submitted construction license application. A large number of amendments have also been made to the regulatory guides on nuclear safety published by STUK (also referred to as (YVL Guides)). Fennovoima participated in the preparation of the changes by issuing its statement on the effectiveness of the amendments in each guide and ensuring, by means of requirement management, that the plant supplier took into account the specifications of the YVL Guides in the plant design.
- On the basis of the above, the nuclear power plant to be constructed on the Hanhikivi peninsula will be realized in the manner required by the currently valid legislation and other related regulations.

Radiation exposure reference value

- Since the submission of the construction license application, the aver-age radiation exposure in Finland according to the Radiation and Nuclear Safety Authority data was 5.9 mSv in 2018. The difference from the average annual estimate of 3.2 mSv presented in the construction license application is due to an adjusted estimate of the impact of radon in indoor air. Reference: https://www.stuk.fi/web/en/topics/what-is-radiation/the-average-radiation-dose-in-finland

Plant decommissioning (Appendix 4B, Decommissioning)

- Fennovoima has prepared and submitted to the Radiation and Nuclear Safety Authority a plan on the decommissioning of the nuclear power plant required pursuant to section 35 of the Nuclear Energy Decree. At a later stage, Fennovoima will have to take into account an amendment of the Nuclear Energy Act that entered into force in 2018 on the licensing of decommissioning.

Since 2015, Fennovoima has reviewed the plant's technical design documentation as a whole and presented all the identified correction needs to the plant supplier. Deliveries of the documentation laid down in section 35 of the Nuclear Energy Decree and the related regulatory review are ongoing, and the plan is to deliver the last documents pertaining to preparedness for the construction license to the Radiation and Nuclear Safety Authority by the end of 2021.

Security and emergency preparedness arrangements

Since the submission of the construction license application, Fennovoima has acquired sufficient areas on the Hanhikivi peninsula to implement the security and emergency preparedness arrangements. A movement restriction has been imposed on the Hanhikivi peninsula with Decree 480/2018 of the Ministry of the Interior. Furthermore, an aviation ban pursuant to section 4 of Government Decree 930/2014 was imposed on the Hanhikivi peninsula in 2016, excluding any aviation related to the maintenance of the plant or any other activities and operations at the plant site. The above-mentioned actions already provide good prerequisites for the management of the site area during the construction of the plant.

Relating to the construction of the nuclear power plant, extensive structural, technical, operational, and administrative security arrangements have been realized for the site area. These will be utilized later in the security arrangements for the plant's operational phase. Design and licensing documentation pertaining to the security arrangements and preparedness will be developed in cooperation with the plant supplier and the authorities.

The Radiation and Nuclear Safety Authority approved the preliminary emergency plan pursuant to section 35 of the Nuclear Energy Decree in 2017. It has been agreed in discussions with inspectors of the Radiation and Nuclear Safety Authority that Fennovoima will update the preliminary emergency plan to comply with the current design of the plant and the related facilities and takes into account amendments of the regulatory guides.

The plan is to name the responsible persons for the security and emergency preparedness arrangements and safeguards of nuclear material pursuant to section 7i of the Nuclear Energy Act during the ongoing regulatory review in spring 2021.

Nuclear fuel management

The nuclear fuel for Fennovoima's nuclear power plant will be acquired as a turnkey delivery from ROSATOM TVEL, which is part of Rosatom Group. The nuclear fuel management procedures were described in detail in Appendix 5C to the construction license application, and there have been no changes since 2015.

An update of the source references at the end of Appendix 5C:

- World Nuclear Association (WNA) December 2020: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx
- World Nuclear Association (WNA) June 2020: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/uranium-markets.aspx

Nuclear waste management

A summary of the nuclear waste management plans was presented in Appendix 5B to construction license application. This section discusses the most important actions and specifications pertaining to nuclear waste management since 2015.

Interim storage of spent nuclear fuel

Before final disposal, spent nuclear fuel will be stored at the plant site in an interim spent fuel storage. The interim storage period is necessary to reduce the residual heat power and radiation level of the spent nuclear fuel to the level required for final disposal. According to the current plans, the interim storage of spent nuclear fuel will be realized in a water pool storage facility based on Finnish references and experience. Fennovoima has submitted to the Radiation and Nuclear Safety Authority descriptions of the technical principles of the interim storage facility and its safety justification, as well as a plan on how the final design documents for the interim storage facility will be submitted for a regulatory review closer to the construction time of the facility.

Final disposal of spent nuclear fuel

In accordance with the 2014 decision-in-principle, Fennovoima submitted in June 2016 to the Ministry of Economic Affairs and Employment an environmental impact assessment program for the final disposal facility for spent nuclear fuel. It started an environmental impact assessment procedure for the final disposal project and the suitability of the optional final disposal locations for final disposal in accordance with the Act on Environmental Impact Assessment Procedure (468/1994). The purpose of the final disposal project is to manage the spent nuclear fuel that will be generated during the operation of Fennovoima's Hanhikivi 1 nuclear power plant. As the project's coordinating authority, the Ministry of Economic Affairs and Employment issued a statement on the EIA program in December 2016.

In 2016, Fennovoima and Posiva Solutions Oy signed a service agreement on cooperation for the next ten years in order to make Posiva's experience and expertise available to Fennovoima's nuclear waste management projects.

The EIA procedure will end with a statement issued by the coordinating authority on the environmental impact assessment report, which will not be complete until several decades from now. Due to the length of the EIA procedure, the Ministry of Economic Affairs and Employment required in its statement on the EIA program that Fennovoima submits reports on the progress of the final disposal project to the ministry during the course of the EIA procedure. In the first report submitted in January

2018, Fennovoima presented three related reports to be prepared pursuant to a service agreement signed with Posiva Oy. The reports were prepared in 2018–2020, and all of them have been separately submitted to the Ministry of Economic Affairs and Employment for information.

The first report determines the desired final disposal bedrock properties to ensure compliance with the safety functions of the KBS-3V final disposal facility. Experience obtained from previous site selection surveys performed in Finland and Sweden and current knowledge of the significance of the bedrock for the long-term safety of final disposal were taken into account in the work. When combined with construction aspects, the desired properties determine the bedrock properties that need to be investigated during the site surveys.

The second survey, completed in 2019, investigates factors influencing the acceptability of final disposal from the perspective of the Fennovoima project. The prerequisites for acceptability and changes in these prerequisites are studied throughout the history of Finnish nuclear waste management, from the 1980s to the current day. One of the conclusions is that the local population's knowledge of final disposal should be further increased to develop the acceptability of final disposal. In addition, the Radiation and Nuclear Safety Authority is deemed to play a major role in the accomplishment of the acceptability of final disposal. According to opinion polls, the majority of citizens will trust in the final disposal, provided that STUK finds the project safe.

The third report, completed in 2020, reviews the current legislative requirements, schedule aspects, the optional final disposal options, potential future development paths, and innovations Fennovoima needs to take into account when making decisions concerning final disposal.

Final disposal of the spent nuclear fuel from Fennovoima's plant is estimated to begin no earlier than in the 2090s.

Estimate of nuclear waste accrual

According to current estimates, approximately 6,300 m³ of very low level, low level and intermediate level waste will be generated during the operation of the nuclear power plant. The volume of decommissioning waste is estimated at approximately 20,000 m³. The esti-mates on the accrual of spent nuclear fuel have remained at the level presented in 2015, 1,200–1,800 metric tons of uranium. According to the current knowledge, the final disposal of low and intermediate level waste at the Hanhikivi peninsula based on a separate licens-ing procedure to be realized later will start in the late 2030s.

Other changes to the nuclear waste management plans have mainly involved the nuclear waste accrual and schedules.

Submitting construction license application documentation to the Radiation and Nuclear Safety Authority

Pursuant to section 35 of the Nuclear Energy Decree, when applying for a construction license, the applicant must submit to the Radiation and Nuclear Safety Authority the documentation listed in the section to the extent presented in the regulations and guides of the Radiation and Nuclear Safety Authority.

At the beginning of 2021, the documents, pursuant to section 35 of the Nuclear Energy Decree, are being submitted in phases to the Radiation and Nuclear Safety Authority for re-view. The plan is to deliver all the required documentation to the Radiation and Nuclear Safety Authority in phases during 2021.

Helsinki, 28 April 2021

Yours faithfully,
Fennovoima Oy

Esa Härmälä
Chairman of the Board

Joachim Specht
Chief Executive Officer

Nuclear power plant site

Appendix 1

Supplementary account of the environmental impact of the construction and operation of the nuclear power plant, as well as of measures to prevent or mitigate adverse impacts

Summary

This appendix (Appendix 3A of the original construction license application submitted to the Ministry of Economic Affairs and Employment of Finland in June 2015) includes a description pursuant to section 32, subsection 7 of the Nuclear Energy Decree (161/1988), of the nuclear facility's environmental impact and the design basis adopted by the applicant to avoid environmental accidents and to restrict the burden on the environment. The information provided in this description is mainly based on information presented in Fennovoima's environmental impact assessment report, published in February 2014, and in the environmental permit application for the nuclear power plant, submitted in December 2014. The description was updated in March 2021, taking into account such factors as construction work completed at the Hanhikivi peninsula thus far and the changes the construction has caused to the environment in the area. The construction work at the Hanhikivi peninsula started in 2015, and thus far, infrastructure and auxiliary buildings have been constructed at the plant site and water construction works pertaining to the cooling water intake and discharge structures have taken place in the sea area. The update also takes into account the environmental permit granted for Fennovoima's nuclear power plant in June 2016, which is legally valid.

The nuclear power plant will be built at a highly visible location in the central and northern parts of the Hanhikivi peninsula reaching out into the open sea, and the construction of the plant will change the landscape considerably. Some of the forests and seashores on the Hanhikivi peninsula have already become built areas, which means that some of the flora and fauna in the area has disappeared or changed. Protected seashore meadows and habitats of endangered plants on the peninsula are located outside the construction areas. The construction has not compromised the preservation of the moor frog among the species of the peninsula; moor frogs can still be found at several locations on the peninsula. During the water construction works, fishing in the immediate area has not been possible, and the work temporarily drives fish away from the area. The environmental impact from construction is temporary and local.

The most significant environmental impact occurring during the operation of the power plant will be the spread of warm cooling water to the surrounding sea area, and the consequences of this for the water system and the fishing industry. The heat load will lead to a slight increase in the production of phytoplankton in the area. Charophyte meadows found on the eastern coast of the peninsula may suffer from the increased temperature of the seawater. Warming of the sea water and the lack of ice may, over the long term, accelerate the overgrowing of seashore meadows on the eastern coast of the peninsula, deteriorating the habitats of the Siberian primrose that grows in these meadows. The overgrowing of the seashore meadows can, however, be prevented through maintenance measures. The heat load discharged into the sea will be decreased by designing the plant to operate in an energy-efficient manner. The objective is to maximize power production and to minimize the waste heat to be discharged.

The warm cooling water will have adverse effects on commercial and recreational fishing in the areas near the power plant. Fishing will be prevented or rendered difficult, and changes will take place in the species distribution and fry production. The impact will be strongest in the immediate vicinity of the cooling water discharge channel, and gradually decrease as the distance from the Hanhikivi peninsula increases. The adverse effects will be compensated for by paying compensation to professional fishermen and by complying with the fishery obligation.

Radioactive substances will be generated during the operation of the nuclear power plant. These substances will be isolated from the living environment using several successive barriers. Very low levels of radioactive substances will be able to reach the environment via the ventilation channels, for example. All potential emission routes will be monitored, and they can be closed and the radioactive emissions recovered. The radiation dose from radioactive emissions will be only a fraction of the dose from natural background radiation, and the emissions will have no impact on nature, even on the Hanhikivi peninsula.

Other environmental releases resulting from the operation of the nuclear power plant will be low, and their environmental impact has been assessed as minor.

Construction and operation of the nuclear power plant and the nuclear facilities required for its operation are not expected to have any significant adverse effects on the habitats or species that form the conservation criteria of the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area, or on the integrity of the area.

The environmental impact from the construction and operation of the nuclear power plant and the nuclear facilities required for its operation have been carefully assessed and are well known. The construction and operation will have no adverse environmental impact of a magnitude that would be unacceptable or could not be mitigated to an acceptable level.

Supplementary account of the environmental impact of the construction and operation of the nuclear power plant, as well as of measures to prevent or mitigate adverse impacts

Environmental management system

Fennovoima is committed to continuous improvement of environmental management and has defined clear environmental objectives and targets for its operations, as well as action plans. In addition, Fennovoima has prepared an environmental management system for the construction phase of the nuclear power plant to ensure that the environmental impact at the construction phase will be properly managed and remain as low as possible. The environmental management system has been continuously developed to correspond to the changes in conditions at the plant site. The environmental management system complies with ISO 14001 and is part of the company's management system. The environmental management system for the construction phase was certified in 2018. The most important environmental objectives are:

1. proactive prevention and mitigation of the environmental impact;
2. functional and timely communication with the environmental authorities and other external stakeholders;
3. verifying the preservation of the nature conservation areas and Natura 2000 areas on the Hanhikivi peninsula and protected species;
4. compliance with permits and statutory requirements; and
5. ensuring efficient management of construction waste.

There are indicators for all of these objectives, and the indicators are regularly monitored. The environmental management system will be developed as the project proceeds. In addition, the system will be updated to cover all the different project stages and ultimately extended to cover the operation of the future nuclear power plant.

Fennovoima also commits to continuous improvement of energy efficiency. Fennovoima will integrate an energy efficiency system into its environmental management system and join the national energy efficiency agreement scheme before the start of electricity production at the nuclear power plant. In its energy efficiency system, the company will commit to developing the efficiency of the energy conversion process, reducing auxiliary power, promoting overall energy efficiency, and fostering right attitude towards energy efficiency.

Environmental impact assessment

Fennovoima carried out an environmental impact assessment (EIA) procedure in 2013–2014 to investigate the environmental impact from the construction and operation of a nuclear power plant with an approximate power output of 1,200 MW. The plant site is on the Hanhikivi peninsula in the municipality of Pyhäjoki. The coordinating authority, the Ministry of Economic Affairs and Employment, issued a statement on the EIA report on June 2, 2014 to conclude the EIA procedure. In its statement, the Ministry of Economic Affairs and Employment found that the EIA report meets the requirements laid down in the EIA legislation, and that the statement issued by the coordinating authority regarding the EIA program had been taken into account in the report.

The coordinating authority also included in its EIA statement the requirement that Fennovoima carry out additional surveys of the marine environment and fishery and enclose their results with the construction license application. The additional surveys are included in Appendix 2 to this application.

Furthermore, Fennovoima realized in 2015 and 2016 in cooperation with Fingrid Oyj an EIA procedure on the transmission lines required to connect the Hanhikivi 1 nuclear power plant to the main grid. An EIA procedure for the encapsulation plant and disposal facility for spent nuclear fuel was started in 2016.

Environmental and water permits

Permits pursuant to the Environmental Protection Act

On June 15, 2016, the Regional State Administrative Agency of Northern Finland granted Fennovoima a permit pursuant to the Environmental Protection Act (527/2014) for the operation of a nuclear power plant (decision number 91/2016/1). The permit applies to the production of energy with a nuclear power plant, auxiliary steam boilers, and diesel generators, cooling water discharge structures, and the discharge of cooling water into the Bothnian Bay. The Regional State Administrative Agency simultaneously granted Fennovoima a permit pursuant to the Water Act (587/2011) for cooling water intake from the sea during the operation of the Hanhikivi 1 nuclear power plant. The environmental and water permit became legally valid based on a decision of the Supreme Administrative Court on April 17, 2019. The environmental and water permit of a nuclear power plant includes several permit conditions involving, among others, the water supply, releases into the water and air, noise, the processing of waste, chemicals and chemical releases, as well as the monitoring of the environmental impact. The permit conditions will be taken into account in the design, implementation, and operation of the nuclear power plant.

Permits pursuant to the Environmental Protection Act have been granted for the operations on the Hanhikivi peninsula during the construction phase, such as the operation of a concrete mixing plant, stone crushing, and the deposition of uncontaminated spoil.

Permits pursuant to the Water Act

On July 10, 2015, the Regional State Administrative Agency of Northern Finland granted Fennovoima permits pursuant to the Water Act for the construction of a harbor area, cooling water intake structures, and a navigation channel (decision number 54/2015/2) and the deposition of dredging masses in the marine spoil area (decision number 56/2015/2). Appeals regarding the water permits were lodged with the Vaasa Administrative Court, but on December 23, 2015, the Vaasa Administrative Court decided not to investigate the appeals. The decision was not appealed to the Supreme Administrative Court and the water management permits thus became legally valid.

Current state of the environment

The Hanhikivi peninsula area is low-lying land-uplift coast, the typical features of which include seaside meadows and overgrowing shallow bays. The natural forest succession series of the land uplift coast is the dominating habitat type on the peninsula, but without the most mature forests.

There are several small gloe lakes and one flada on the northwestern shore of the peninsula (Fig. 1-1). A gloe lake is a pond that has been separated from the sea due to land-uplift and no longer has a regular connection to the sea. A flada is a low-lying lagoon separated from the sea by a threshold or other barrier that prevents water flow. Both of these habitat types are endangered and included in the habitat types protected by the Water Act. There is also a small pond in the eastern part of the peninsula.

There are several nature conservation areas on private land and habitat types protected by the Nature Conservation Act on the Hanhikivi peninsula. The Hietakarinlahti-Takaranta area in the eastern part of the peninsula is one of Finland's important bird habitats (FINIBA). The two-part Natura 2000 area of Parhalahti–Syölätinlahti and Heinikarinlampi is located approximately two kilometers to the south of the project site, on the south side of the peninsula. It is a bird habitat of national significance that is included in the Finnish national waterfowl habitat protection program. Most parts of the bird habitat area are nature conservation areas (Fig. 1-1).

Five endangered or otherwise notable species of vascular plants have been observed on the Hanhikivi peninsula. These include the Siberian primrose, a species included in Annex IV (b) to the Habitats Directive, with several occurrences especially in the Takaranta seashore meadow area. The species is protected in the whole of Finland. It was previously classified as endangered, but in the most recent assessment (from 2019) it was classified as near threatened. Another notable species is the yellow iris, which is protected in the provinces of North Ostrobothnia, Kainuu, and Lapland. It is prevalent especially in the Siikalahti Bay area. The moor frog, which is one of the species listed in Annex IV (a) to the Habitats Directive, is also found on the peninsula. No endangered plants grow in the areas where construction will take place, nor have any bat or Siberian flying squirrel nesting or resting sites been found there.

Due to its varied habitats, Hanhikivi peninsula has a wide range of nesting bird species and large bird populations. A wide variety of wetland birds nest in the area. Species of the meadow and reed bed habitats, as well as those of rough shores and beaches, are also found in the area. The areas with the widest range of bird species are located outside the construction area, in the Takaranta, Heinikarinlampi, Hietakarinlahti, Parhalahti, and Syölätinlahti areas.

The loose soil layer of the Hanhikivi peninsula mainly consists of moraine. The bedrock is mainly metaconglomerate. The Hanhikivi peninsula area has been classified as a nationally valuable area in terms of natural and landscape conservation, and it is also a geologically important bedrock area. The nearest classified groundwater catchment area is approximately ten kilometers from the peninsula. In the northern parts of the peninsula, there is the Hanhikivi border stone, which is of historical importance. The stone is a fixed historical monument protected by the Antiquities Act (295/63) and an object of national value.

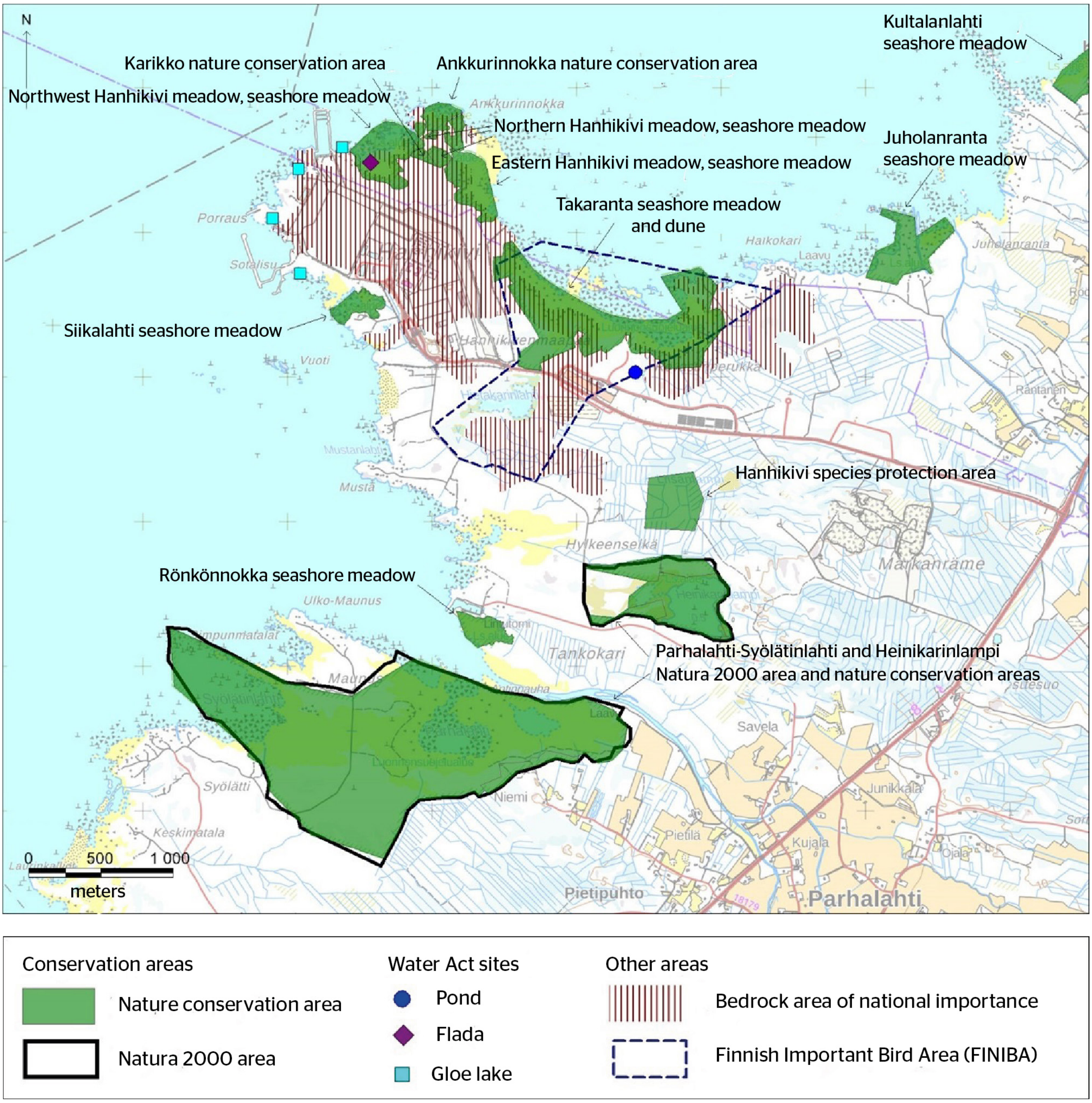

Figure 1-1. Natura 2000 areas, nature conservation areas, and other noteworthy areas on the Hanhikivi peninsula and in the surrounding areas.

The coastline around the Hanhikivi peninsula is very open and windy, and water turnover in the area is thus efficient. The depth of the water slowly increases towards the open sea, by approximately one meter in the first one hundred meters. The area off the coast of the Hanhikivi peninsula is part of a body of water called Vaaranlahti-Pyhäjoki-Siniluoto (4_Ps_003 Coast), which is part of the inner coastal waters of the Bothnian Bay. In the classification for the third season, the ecological status of the body of water is satisfactory (Table 1-1; Finnish Environment Institute 2020). Water quality off the coast of the Hanhikivi peninsula depends on the general status of the Bothnian Bay and diffuse load (nutrients, solids and organic carbon) from the rivers emptying into the Bothnian Bay from the catchment area (Yppärinjoki, Pyhäjoki, Liminkaoja, and Piehinginjoki). Most of the diffuse load originates from agriculture. Some loads may also come to the area from the body of water called Rahja-Kalajoki-Yppäri (4_Ps_002) with currents running along the coast. The ecological status of this body of water is also satisfactory. The outer sea area is included in category good.

Table 1-1. The ecological status of the body of water Vaaranlahti-Pyhäjoki-Sinisalo (4_Ps_003) in the third season classification.

	Third season classification		
	Numerical value	Calc. /infl. score	**Assessment**
Vaaranlahti-Pyhäjoki-Sinisalo (4_Ps_003)			
Biological		Good	
Phytoplankton	0.63	Good	
Chlorophyll a	3.2 µg/l	Good	Good
Physico-chemical conditions			Adequate
Total phosphorus (µg/l)	18.83 µg/l	Adequate	
Total nitrogen (µg/l)	401.67 µg/l	Adequate	
Visibility depth	1.88 m	Satisfactory	
Hydrological & morphological conditions		2	Good
Overall status classification: Satisfactory			

The shores of the Hanhikivi peninsula are gently sloping and open to waves. The most sheltered areas with the most diverse aquatic vegetation are found in the shallow coves of Takaranta and Kultalanlahti. Five endangered underwater Baltic Sea habitat types are found on the shores of the Hanhikivi peninsula and in the waters around it. Charophyte meadow is the most important one. In the new assessment of the conservation status of habitat types, the said habitat type is divided into open and sheltered charophyte bottoms (Kontula & Raunio 2018). The former is vulnerable in the whole of Finland (VU, Vulnerable) and the latter is endangered (EN, Endangered). Charophyte meadows have been found on the east coast of the peninsula and, in particular, at the base of the peninsula on the Kultalanlahti side. Charophytes observed in the area include rough stonewort, fragile stonewort, delicate stonewort, bird's nest stonewort, and other Characeae species. A total of 33 species of plants and algae were found in surveys, of which 20 were species of aquatic vegetation. No endangered species of aquatic flora or algae have been found in the peninsula area. For a more detailed description of the aquatic vegetation in the area, see Appendix 2 to this application. The Habitats Directive habitat types found in the immediate vicinity of the project area include reefs, estuaries, and large shallow bays.

The sea off the coast of the Hanhikivi peninsula is significant both in terms of the fish stock and in terms of fishery. The fish species typically found in the area are those typically found in the whole of the Bothnian Bay. Species of economic significance include the sea-spawning whitefish, common (migrating) whitefish, perch, Baltic herring, vendace, sea trout, salmon, and pike. Spawning river lampreys can also be caught in the rivers emptying into the area. Grayling, a critically endangered species, can also be found in the sea area. The surroundings of the Hanhikivi peninsula are an important spawning area for sea-spawning whitefish, Baltic herring, and vendace. Migration routes of whitefish and salmon exist in the peninsula area, but based on interviews with commercial fishermen, the main migration routes to the rivers in the north are located fairly far away from the shoreline, in waters at least ten meters deep. Appendix 2 to this application includes a more detailed description of the fish stocks and fishing industry in the area, as well as migrating fish and their routes.

Environmental impact of the construction phase and the prevention and mitigation of adverse impacts

Environmental impact during construction has been assessed in the project's EIA procedure and the permit procedures for the project pursuant to the Environmental Protection Act and the Water Act. The construction work at the Hanhikivi peninsula started in 2015, and thus far, infrastructure and auxiliary buildings have been constructed at the plant site and water construction works pertaining to the cooling water intake and discharge structures have taken place in the sea area. This section describes both the results of the previous EIA and the results of monitoring activities during construction.

Management of the environmental impact from the construction site is based on proactive identification of environmental risks. All contractors working in the project area comply with a comprehensive risk assessment and risk management procedure. Fennovoima, the plant supplier, and the main contractor have prepared an environmental management procedure for the construction site to ensure that the adverse impacts from the construction phase are as minimal as possible. Fennovoima monitors the progress of the contracts and guides the management of environmental matters in collaboration with the plant supplier and the main contractor through weekly site walkthroughs and targeted environmental inspections, among other things.

During the construction phase, construction site areas are marked off with fences and signs. Access to the plant site's seashore areas and other construction site areas including protected species or habitats is prevented with fences and signs. Employees are provided with training and information on the restrictions that are in force with regard to activities in the natural environment and in nature conservation areas.

Bedrock, groundwater, and surface waters

Excavation of the bedrock reduces the geological value of the Hanhikivi peninsula, which has been classified as valuable. However, most of the bedrock of geological value will remain untouched, as excavation of the bedrock will mainly take place at the power plant site. As indicated by the land use plans, representative parts of the bedrock will be left exposed. So far, excavation has only taken place in the cooling water intake and discharge structure area. The bedrock that has been classified as valuable will not be excavated for the temporary structures used during the construction phase. The adverse impacts from the vibration generated by the excavation work are mitigated by properly planning the excavation work and by using appropriate working methods.

The level and pressure of groundwater may decrease during construction, and groundwater quality may temporarily deteriorate as the result of blasting and grouting of the bedrock. Any changes will be limited to the construction area by using solutions such as watertight support structures and sealing of bedrock. The impact on groundwater will remain local and minor. Monitoring of the groundwater level and quality during the construction phase started in late 2019.

Drainage water (rainwater) will be collected from the construction site in a controlled manner, purified appropriately, and discharged into the sea. Drainage water is not expected to deteriorate the quality of the seawater. Quality of the collected drainage water will be managed using both centralized structures (retention basins) and distributed structures (catch basins). Oil sumps and other water treatment structures will be constructed as necessary. The condition and functionality of drainage water basins and structures will be monitored in accordance with a maintenance program. At present, four sedimentation basins are in use at the construction site to discharge drainage water into the sea. There are sand and oil traps between two of the sedimentation basins and the sea. The quality and volume of water is being monitored in accordance with the requirements. The environmental permits include monitoring requirements pertaining to drainage water from the concrete mixing plant, water drained to keep the plant excavation pit dry, as well as runoff and seepage water from the spoil deposition area, for example.

Flora, fauna, and nature conservation areas

The nuclear power plant will be built at a highly visible location in the central and northern parts of the Hanhikivi peninsula reaching out into the open sea. The plant will stand out from the environment in terms of size and character and will bring about significant changes to the landscape. The role of the Takaranta seashore meadow, which is of regional importance, in the landscape will change, as will the role of the historic Hanhikivi border stone, which is of national importance. Access to the Hanhikivi border stone will be arranged for visitors during the operation of the nuclear power plant.

Some of the forests and seashores on the Hanhikivi peninsula have already become built areas, which means that some of the flora and fauna in the area has disappeared or changed. The natural forest succession series of the land uplift coast habitat type represented by the peninsula has been partially fragmented, but a significant part of the habitat type has remained outside the areas reserved for construction. Nearly all of the seashore meadows are protected nature conservation areas and are therefore excluded from the construction site.

There are some objects of natural environment indicated as items of importance for biodiversity in the site area that have been partially covered by built structures. Parts of the meadows have been covered by the harbor structures and the cooling water intake and discharge structures at the tip of the peninsula. Furthermore, a gloe lake that was located in the cooling water intake area was destroyed on the basis of an exceptional permit pursuant to the Water Act. This impact cannot be considered significant, as similar, more representative, and larger sites can be found in other parts of the Hanhikivi peninsula.

The habitats of endangered flora and the species of flora listed in Annex IV(b) to the Habitats Directive found in the Hanhikivi peninsula are located outside the construction areas and will not be subjected to any direct impact. Legally valid permits have been granted for the transfer of batches of yellow iris, which is among the species protected in North Ostrobothnia. The transfers of yellow iris at the Hanhikivi peninsula took place in 2015 and 2016. Monitoring has revealed that the yellow irises have settled well in the new habitats: the transferred shoots have sprouted new growth, and the number of sprouts in the new habitas has increased (Sitowise Oy 2020a).

Moor frog, which is listed as a species under strict protection in Annex IV(a) of the Habitats Directive, can be found on the Hanhikivi peninsula. A moor frog habitat in the dock area was destroyed in 2016 based on an exceptional permit pursuant to the Water Act. The most important moor frog spawning sites are located outside the plant site area, and the operation of the power plant will have no impact on these sites. The construction activities have not compromised the retention of the moor frog in the flora and fauna of the peninsula: according to the most recent monitoring results, some moor frogs can still be found at several locations on the peninsula, and a population at Heinikarinlampi pond, located in the inner part of the peninsula, is very large (Sitowise Oy 2020b).

The nuclear power plant and other construction activities related to it are mainly located in the inner parts of the Hanhikivi peninsula. A woodland bird population has been eradicated from this area as the result of the removal of trees and other already completed construction activities. The shore areas at the harbor and the cooling water intake and discharge areas are not particularly valuable bird habitats, which means that their impact on bird populations during the construction phase will remain minor. Noise from construction activities may temporarily disturb birds close to the power plant construction site and the access road leading to the power plant site.

According to a Natura assessment performed in 2009, the construction activities are not expected to have any significant adverse effects on the habitats or species that form the conservation criteria of the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area, or on the integrity of the area (Pöyry Environment Oy 2009). The impact from construction has been monitored during the already completed construction activities: for example, the noise and turbidity of sea water caused by water construction works have been monitored by means of continuous measurements. The construction activities completed so far have not been observed to cause any adverse impact on the Natura 2000 area.

Water systems and the fishing industry

Dredging during the construction of the navigation channel, the harbor area, an auxiliary cooling water inlet channel, and the cooling water discharge area, as well as the construction of protective embankments, will cause temporary turbidity of seawater. The seabed in the area to be dredged mainly consists of quickly settling rough-grained materials, such as sand and gravel. When such rough-grained materials are dredged, the turbidity spreads to approximately 10–100 meters from the dredging site or marine spoil area, while the dredging of more fine-grained materials may cause turbidity of the water in an area extending up to two kilometers from the site. The dredging is not expected to cause any releases of nutrients or contaminants into the sea. There are charophyte meadows in the cooling water discharge structure area. These meadows will be lost as a result of the construction activities. The area that will be changed by the construction activities is small, however.

The turbidity will be controlled or limited by utilizing continuously operating measuring buoys to gather data about turbidity levels and the prevailing water flows. Continuously operating measuring buoys will also be used to monitor turbidity resulting from the disposal of dredging spoil into the marine spoil area. Based on the water quality monitoring during construction so far, the total phosphorus and solids concentrations and turbidity have remained elevated for short periods of time due to the water construction works (dredging and marine spoil disposal). However, no changes caused by water construction works have been detected in the average concentration of total nutrients at the monitoring points (mean value for the entire year or the summer season).

According to the impact assessment, the water construction works may drive away fish from a larger area and may influence the migration routes of fish. Excavation, in particular, will cause powerful underwater noise that may drive away fish from an extensive area. The impact will most likely be significant in an area extending at least one kilometer around the blasting sites. The construction activities in the sea will destroy some spawning areas of sea-spawning whitefish and Baltic herrings found in the dredging areas. The fishing activities in the area mainly focus on whitefish that come to the area to feed on Baltic herring spawn during the herring's spawning season. Thus, construction activities may have an adverse impact on the fishing of whitefish in the immediate vicinity of the peninsula. Fishing in the water construction areas and in their immediate vicinity will not be possible during construction.

Impact of the construction phase activities on fishery and fish stocks has been monitored in accordance with the fisheries monitoring program that has been agreed with the responsible authority. Disadvantages caused to commercial fishermen will be compensated on a case-by-case basis.

On the basis of the monitoring results so far, the impact on the fish stock has been lower than anticipated: the results of test net fishing indicate that the water construction works, which were ongoing at the time of the test fishing, did not drive away fish from the immediate vicinity of the work sites. No changes in the structure of the fish stock that were clearly caused by the water construction works could be detected. However, the water construction works did have a noticeable impact on commercial fishing during the open water periods in 2016–2019. The impact could be seen in many ways, such as in the volume of caught migrating fish, as a deteriorated opportunity to utilize fishing sites, and as the soiling of fishing tackle. There have also been some reports on fishing tackle being damaged due to maritime traffic (e.g. Vatanen et al. 2020).

Releases into the air, noise, waste, and wastewater

Excavation works, construction site traffic, and activities such as rock crushing generate dust during the construction of the power plant. The dust affects air quality mainly at the construction site. The spreading of dust outside the construction site area is monitored with dust collectors that have been placed particularly in the immediate vicinity of nature conservation areas. No increased dust volumes outside the construction site area have been detected during the monitoring. The volume of dust can be reduced by building asphalt roads or wetting the roads in the area, as well as by carefully planning and executing the rock crushing and excavation works.

Traffic emissions will significantly increase at the construction phase, particularly during the period of the busiest construction activities. Traffic emissions are reduced by establishing speed limits and by arranging shared transportation to the site. Construction-related traffic emissions will not have any significant impact on air quality in the area.

Work that causes noise during construction includes water construction works, excavation, and rock crushing, among others. Construction site traffic also causes noise. The spreading of noise was assessed in connection with the power plant's EIA procedure by means of noise modeling. According to the modeling results, during the noisiest construction phase, i.e. when excavation and rock crushing work is underway, the average daytime noise level remains below the reference value of 45 dB(A) defined for holiday residences. The noise level in the closest protected seashore meadows (a meadow in the northwestern corner of the Hanhikivi peninsula and the Siikalahti seashore meadow) may be approximately 50–53 dB(A). During the busiest construction phase, the traffic noise of 55 dB(A) and 50 dB(A) from the access road leading to the Hanhikivi peninsula will spread to fairly narrow zones, in which there are no residences. The zone where the noise level will be some 45 dB(A) extends a short distance into a protected seashore meadow and an important bird area adjacent to the road connection. The noise is not, however, estimated to significantly disturb the birdlife.

Noise is monitored by means of continuous measurements during construction. At present, noise is being monitored at seven measuring points in the immediate vicinity of the construction site. The measuring point closest to residential properties is approximately one kilometer from the closest home. The guideline values for ambient noise have at times been exceeded at the measuring points when construction work causing noise has been ongoing. For example, the average noise level when pile driving was taking place at the cooling water discharge area in 2019 varied from 30 to 69 dB between the measuring points.

The impact of noise on people or the environment is being mitigated and prevented by proper planning of the location of noisy activities. Noise from traffic is reduced by means of traffic control, scheduling, and speed limits.

The handling of regular or hazardous waste at the construction site does not give rise to any environmental impact. A waste management plan has been prepared for the construction site, and waste sorting and processing instructions are given to all persons working at the site. Waste is sorted at the place where it is generated, and most of it will be reused or recycled as material or energy.

Excavation, quarrying, and dredging masses have been used to construct breakwaters and embankments in the harbor area and at the cooling water discharge area. On land, masses have been used to fill out and level construction areas. The handling, storage, and transportation of hazardous waste has been arranged in accordance with the regulations.

Sanitary wastewater is drained from the site to a municipal wastewater treatment plant via a sewer network. The volume and quality of sanitary wastewater is monitored in accordance with the agreement signed with the municipal sanitary services.

Environmental impact during the operation phase and the prevention and mitigation of adverse impacts

Environmental impact during construction has been assessed during the EIA procedure and the permit procedure for the project pursuant to the Environmental Protection Act. An environmental permit was granted for Fennovoima's nuclear power plant in June 2016, and the permit is legally valid. The environmental permit applies to activities during the operation of the nuclear power plant. This section takes into account the requirements of the environmental permit regarding, for example, the prevention and mitigation of the environmental impact and adverse effects.

According to section 8 of the Environmental Protection Act (527/2014), the operator must prevent pollution of the environment by ensuring that best available techniques (BAT) are used. Fennovoima uses this principle in the design and operation of the nuclear power plant. In accordance with the environmental permit granted for the Fennovoima nuclear power plant, planning of the operations and the processes, the selection of related management systems and components, as well as maintenance and monitoring are implemented in such a manner that the operations as a whole will reach as good an energy efficiency level as possible when taking into account the plant safety requirements laid down in the Nuclear Energy Act. During the operation of the nuclear power plant, reports on the energy efficiency measures and the energy efficiency of key electric motors and pumps purchased for the operations are submitted in connection with the annual environmental protection summaries.

Cooling water

The nuclear power plant will be designed for maximum power production efficiency and minimum discharge of waste heat into the sea with the cooling water. Appropriate technical solutions and correct dimensioning of the turbine plant will have a major impact on the plant's energy efficiency and the amount of waste heat discharged. Turbine extraction steam will be used for heating the power plant and other buildings at the plant site. In the case there is demand for the production of district heat in the vicinity of Pyhäjoki in the future, heat pumps will enable the recovery of waste heat.

In accordance with the environmental permit granted for the power plant, Fennovoima will determine sites where the waste heat produced by the plant can be utilized and monitor the development of technology available for the utilization of the heat in the cooling water for heating or as electrical energy. Related information and reports, as well as any proposals on the utilization of waste heat, will be submitted every three years during the operation of the nuclear power plant, in connection with the annual environmental protection summary, to the Centre for Economic Development, Transport and the Environment and to the Energy Authority for information.

Thermal load from cooling water

The nuclear power plant will use cooling water at an approximate rate of 45 m³/s. The cooling water will be taken from the harbor basin located on the western shore of the Hanhikivi peninsula using an onshore intake system and discharged at the northern part of the peninsula. The temperature of the water will rise by 10–12°C during this process.

The cooling water used at the power plant that is discharged into the sea will increase the temperature of the seawater close to the discharge location. The extent and direction of the spreading of warm cooling water has been investigated with the help of a three-dimensional flow model (Lauri 2013). Based on the modeling, the temperature of the seawater will increase by more than 5°C in an area of approximately 0.7 km² in the immediate vicinity of the cooling water discharge location, and by 1°C in an area of approximately 15 km². The thermal impact will be higher in the surface water (0–1 meters below the surface) and decrease at greater depths (Figure 1-2). According to the modeling results, no temperature increase will occur at a depth of more than four meters.

The spreading of the cooling water in the surface waters (0–1 m) in different years has been surveyed during a period between July 15 and August 15 in 2009–2013, at which time the seawater is at its annual peak temperature and the impact of the cooling water will be at the highest level reached in the summer season. The largest increase in temperature (more than 9°C) takes place within a limited area of 0.09–0.19 km² in the immediate vicinity of the cooling water discharge location. An increase of five degrees in the surface water temperature is limited to an area of 0.54–0.82 km², and an increase of one degree to an area of 8.0–13 km². An average surface water temperature increase of more than two degrees is limited to a distance of 2–3 km from the cooling water discharge location in all situations. Brief periods may occur when the warm cooling water will be carried significantly further than under the average conditions presented here.

Under typical south-westerly winds, the thermal emission will tend to accumulate in the Kultalanlahti Bay to the north of the Hanhikivi peninsula. Warm water will, however, mix reasonably well with the current that flows along the coast. When temperature layers exist in the seawater and northerly winds prevail, upwelling will occur as the wind pushes warm surface water to the open sea and cold water rises from the bottom to the surface layer. Under these conditions, the power plant's thermal emissions will be efficiently diluted in the rising cold water.

In the winter, the thermal load from the cooling water will keep the discharge area unfrozen and cause the ice to be thinner, mainly to the north and east of the Hanhikivi peninsula. During the early winter, the extent of the open water area and the area where the ice is thinner will largely depend on the prevailing temperatures. According to the modeling results, the annual differences in the thickness of the ice will even out further into the winter months as the ice becomes thicker overall, and the open water area will be 2.4–4.5 km² by February–March. At this time of the year, the open water area will extend approximately 2–5 km from the discharge location and the area with thinner ice approximately 0.5–2 km further.

Continuously operating meters will be used to monitor the temperature of the cooling water in the intake and discharge area. Several measuring sensors will be installed in the sea area at several depths in an area extending up to two kilometers from the cooling water discharge channel. The measuring of the cooling water intake and discharge temperature will begin before the start of the nuclear power plant's operation, and the temperature of the sea area will be continuously monitored during the operation of the plant. According to the environmental permit granted for the operation of the nuclear power plant, the temperature of the cooling water discharged from the plant into the sea must not exceed 40°C at the mouth of the cooling water discharge channel, calculated as a moving weekly average. A detailed monitoring plan will be submitted to the Regional State Administrative Agency of Northern Finland in due time, at the latest a year prior to the startup of the plant.

In the winter, the thermal load from the cooling water will keep the discharge area unfrozen and cause the ice to be thinner, mainly to the north and east of the Hanhikivi peninsula. Ice conditions in the discharge area (thickness and extent of the unfrozen area) will be monitored at intervals of 1–3 weeks, depending on the conditions. Warnings of thin ice as a result of cooling water discharge will be given on warning boards along the roads to the area, for example.

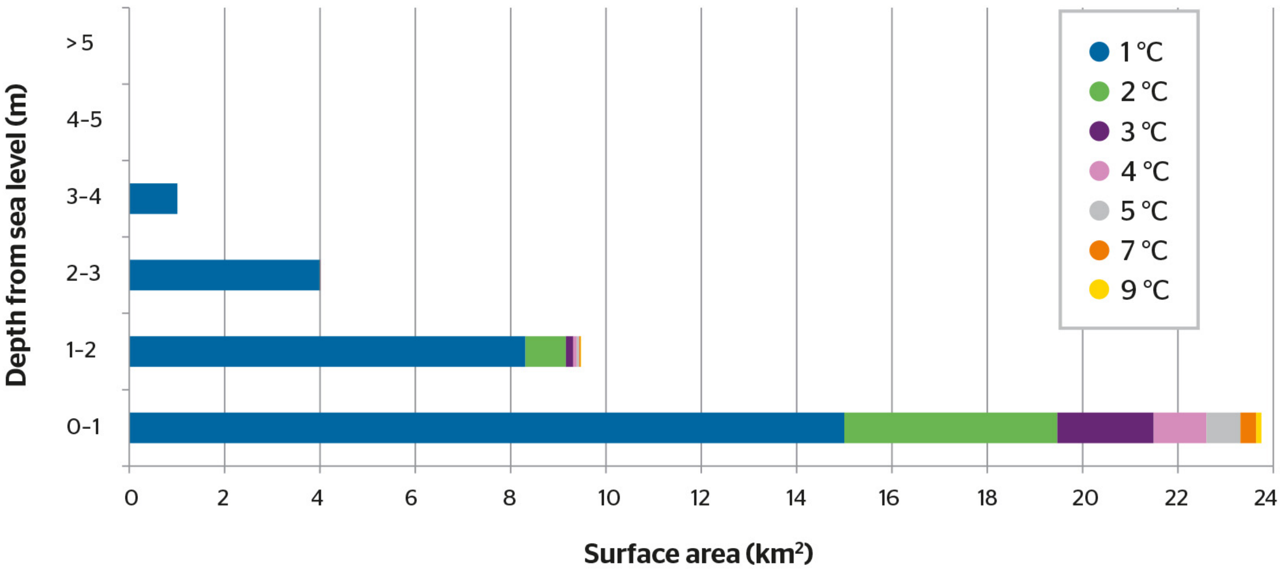

Figure 1-2. Surface areas in which the temperature increase exceeds 1, 2, 3, 4, 5, 7, and 9 degrees Celsius in the June 2012 average temperature field.

Impact on water systems

Apart from the increase in temperature, the quality of the cooling water will not change as it flows through the power plant. The operation of the power plant is not estimated to have any impact on the oxygen conditions in the sea area, as there are no depressions susceptible to oxygen depletion near Hanhikivi. Based on measurements and a water analysis, the oxygen conditions in the Hanhikivi sea area have also been found to be good even in deeper water layers; the area has no particular load of organic materials which could, together with the warm cooling water, lead to oxygen depletion.

In the Bothnian Bay, the production of phytoplankton is limited particularly by the short open sea period. The warm cooling water will extend the open sea period and therefore the growth period. The summer season chlorophyll content and biomass measured in phytoplankton samples reflect the typically low nutrient levels of the Hanhikivi sea area. The thermal load from cooling water is estimated to lead to some increase in the production of phytoplankton in the discharge area. There may also be changes in species distribution, also between seasons. The operation of the power plant is not estimated to have any detrimental impacts on zooplankton.

Blooming of cyanobacteria typically occurs in eutrophic sea areas, particularly in late summer when nitrogen is the limiting nutrient. In the Hanhikivi sea area, phosphorus is the primary limiting nutrient for primary production, making cyanobacteria blooms fairly unlikely. Benthic fauna in the Hanhikivi sea area mainly consists of species which are able to live on hard surfaces. The potential impacts of cooling water on benthic fauna are mainly indirect and mostly due to changes in primary plankton production. Since no major changes to the primary production levels are expected and the amount of organic matter accumulated on the seabed is expected to remain low, the temperature increase is not expected to cause any major impact on the benthic fauna, and any impacts that occur will remain local.

Charophyte meadows found on the eastern coast of the Hanhikivi peninsula and in the Kultalanlahti Bay may suffer from the temperature increase. Decreased growth is most likely to take place on the eastern coast of the peninsula, and the impact is expected to be more subdued in Kultalanlahti. It has been estimated that the conditions required by bottom dominated by submerged macrophytes may even improve around the Hanhikivi peninsula, but the species distribution in this habitat type may change. A more detailed description of the effects of cooling water discharge on aquatic vegetation is included in Appendix 2 to this application.

Plenty of surveys and monitoring data on the water quality and current status of water fauna in the power plant's impact area are already available. Furthermore, in accordance with the power plant's environmental permit, comprehensive advance monitoring will be realized before the operation of the plant begins, and detailed impact monitoring plan for the operational phase, prepared on the basis of the monitoring results, will be submitted to the North Ostrobothnia Centre for Economic Development, Transport and the Environment for approval. The monitoring will include, among others, the monitoring of water quality, phytoplankton, primary production, aquatic vegetation, and benthic fauna. Furthermore, impacts on seashore meadows, the generation of mist, aquatic bird species, invasive species, and the natural state of the gloe lakes in the affected area will be monitored.

Impact on fishery

The operation of the nuclear power plant will have an adverse impact on commercial and recreational fishing in the area where the warm cooling water spreads. Fishing will be prevented or rendered difficult, and changes will take place in the species distribution and fry production. The impact will be strongest in the immediate vicinity of the cooling water discharge channel, and gradually decrease as the distance from the Hanhikivi peninsula increases. The impact on fishing will mainly be negative, but positive effects, such as improved growth of the fish, will also occur. Ice fishing is expected to end in the ice fishing area around the Hanhikivi peninsula and in the Kultalanlahti Bay. In more distant areas, the thinning of ice will prevent ice fishing from time to time.

Most of the fish pulled into the cooling water intake channel will be small, young individuals and small species moving in schools. Newly hatched fry drifting with water columns are particularly susceptible to ending up in the water intake channel. The impact of the lost fry on the fish stocks and catch in the area is expected to remain minor and local. To mitigate the adverse impacts, there is a preliminary plan to implement an escape pipe for fish, which is intended to set free some of the fish that end up in the cooling water intake channel back to the sea A more detailed description of the impact of cooling water intake and discharge on the fish stocks and fishery as well as migration routes is included in Appendix 2B to this application.

Plenty of surveys and monitoring data on the current status of the fish stock and fishing in the power plant's impact area are already available. Furthermore, a one-time advance fishery monitoring project will be realized in compliance with the environmental permit prior to the start of the nuclear power plant operation. A detailed plan on fishery monitoring during the operation of the power plant, based on the advance monitoring results, will be submitted to the Lapland Centre for Economic Development, Transport and the Environment for approval. The monitoring will include, among others, the monitoring of fishing (professional and leisure fishing), the monitoring of species distribution and growth, and the monitoring of fry production. The number of fish ending up in the nuclear power plant's water intake system will also be monitored by species, size class, and age.

The adverse impacts from the operation of the power plant to professional fishermen will be compensated on a case-by-case basis, and Fennovoima will attempt to agree on the compensation to the professional fishermen already before the start of the power plant operation. The environmental permit for the power plant also includes a fishery obligation according to which sea trout and common whitefish fry will be planted in the sea area during the operation of the nuclear power plant.

Furthermore, separate grayling surveys will be implemented in compliance with the environmental permit prior to the start of the nuclear power plant operation. The environmental permit includes an obligation to investigate any breeding, migration, and feeding areas of grayling spawning in the sea and anadromous grayling in the area affected by the operation. The report must include an assessment of the size and fry production volume of the grayling population spawning in the sea and the anadromous grayling population, the impact of the operation on these populations, any changes to the required compensatory measures or additional compensatory measures, and monitoring measures. The report and a proposal on measures to mitigate the impact on grayling, any proposed changes to the required compensatory measures or additional compensatory measures, and a monitoring proposal must be submitted to the Regional State Administrative Agency of Northern Finland in the form of an application.

Impact on nature conservation sites and birdlife

Under typical south-westerly winds, the warm cooling water will tend to gather in the Kultalanlahti Bay to the north of the Hanhikivi peninsula, off the coast of the Takaranta seashore meadow. According to the water system simulation, the average water temperature will increase by more than two degrees

Celsius in front of the seashore meadows in the northeastern and eastern parts of the Hanhikivi peninsula, which are protected habitat types under the Nature Conservation Act. The warming of the seawater and the lack of ice may lead to a local increase of primary production and thus the growing over of seashore meadows over the long term. The lack of ice may also accelerate overgrowth as ice will no longer cause erosion at the shoreline. Overgrowth of seashore meadows in the eastern Hanhikivi meadow and at Takaranta may deteriorate habitats of the Siberian primrose. Seashore meadows will experience natural overgrowth due to the lack of traditional use as pasture and moving of hay. Should the overgrowth of the meadows accelerate, their conservation value will deteriorate faster than currently, unless maintenance actions are carried out.

The impacts of the warm cooling water on the seashore meadows will be monitored as part of the impact monitoring during the operation of the nuclear power plant (see Impact on water systems above). Based on the monitoring results, maintenance of the meadows will take place according to a separate plan as necessary. Primary maintenance measures will include mowing and using the meadows as pastures, both of which generally improve the condition of seashore meadows.

Migrating waterfowl may use the unfrozen area in front of the cooling water discharge location as a resting and feeding site. Some of the migrating birds may stay in the unfrozen area longer than usual or return earlier in the spring. The moving of the edge of the ice further away from the shore may shift the early spring migration of gulls to the outer sea. This is not, however, estimated to have a significant impact on the migration behavior of gulls. Species that feed on fish, such as the common tern and the Arctic tern, may have better feeding opportunities, and waterfowl and birds that nest on the shore may begin their nesting period earlier. However, the timing of the nesting season will also depend on other environmental conditions.

A Natura assessment pursuant to section 65 of the Nature Conservation Act on the impact of the construction and operation of the nuclear power plant (including transmission lines) on the impact on the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area was performed in 2009 (Pöyry Environment Oy 2009). In its opinions (PPO-2009-L-683-255, POPELY/15/07.04/2010), the North Ostrobothnia Centre for Economic Development, Transport and the Environment stated that the project does not appear to have any significant direct adverse impacts on any habitat types or species. According to the opinions, any long-term risks of the project are such that their potential impact cannot be completely excluded. The opinions referred to the long-term impact on the Siberian primrose and the bird populations, as well as the possible reflection of hydrological changes in the sea around the Hanhikivi peninsula on the state of the Natura area.

An investigation on the need for a Natura assessment performed in 2014 (Sito Oy 2014) covered potential long-term effects of the power plant's cooling water on the Takaranta area, not included in the Natura area, and the potential impact of these effects on the natural values based on which the Natura area has been protected, as well as a consideration of the significance of hydrological effects on Heinikarinlampi. The conclusion of these investigations was that the operation of the nuclear power plant will have no significant deteriorating impact on the Natura area over the short or the long term. The operation of the nuclear power plant is not expected to have any indirect adverse impacts on the habitat types or the bird life. The cooling water would only have minor adverse impacts on the Siberian primrose population of the Natura area, even over the long term, if the populations were to disappear from the Takaranta area. Monitoring of the Takaranta seashore meadows and active maintenance when necessary will secure the preservation of the Siberian primrose in the Takaranta and Hanhikivi areas. No adverse hydrological effects on the development of Heinikarinlampi or any other part of the Natura area could be found either.

An opinion by the North Ostrobothnia Centre for Economic Development, Transport and the Environment (POPELY/2670/2014) finds that "based on the investigations, it can be concluded that the project is not likely to cause any significant adverse impacts or indirect long-term impacts on the natural values based on which the area has been defined as a Natura area." The Centre for Economic Development, Transport and the Environment also states that such effects will be prevented by the monitoring and maintenance measures presented in the report as mitigating actions.

In 2016 in connection with an EIA procedure required for the transmission lines to connect the Hanhikivi 1 nuclear power plant to the external grid, an update of the Natura assessment was prepared. It supplemented the 2009 Natura assessment on the risk of birds colliding with the transmission lines (FCG Suunnittelu ja Tekniikka Oy 2016). A key object of assessment was the risk of birds colliding with the transmission lines, which is included among the conservation criteria for the Parhalahti-Syölätinlahti and Heinikarinlampi Natura area, and the long-term effects of such collisions on the birdlife. In its opinion issued on December 5, 2016 (POPELY/1408/2016), the North Ostrobothnia Centre for Economic Development, Transport and the Environment stated that the transmission line project could deteriorate the ecological values based on which the Natura area was included in the Natura 2000 network, but that based on the assessment, the adverse impacts of the project on the birdlife that is included in the conservation criteria or the Natura area's habitat types cannot be considered significant.

Wastewater, drainage water, and groundwater

Wastewater

The nuclear power plant will generate approximately 50,000–70,000 m³ of purified process water and wastewater per year. Of this annual volume, 80–90% will be generated during the annual outage. The phosphorus load to the sea from the process water and wastewater (annual maximum of 15 kg) will be very low when compared to the phosphorus load reaching the sea via rivers, for example. After treatment, the plant's process water and wastewater will be discharged into the sea via the cooling water discharge tunnel. The process water and wastewater will mix with the cooling water and flow into the open sea. Even with the seawater temperature increase in the discharge area caused by the cooling water, the wastewater load from the power plant is not estimated to cause detectable or harmful changes to the eutrophication levels, oxygen saturation, vegetation, or fishery.

The boron carried into the sea with the wastewater (approximately 100 kg annually) will be effectively diluted in the immediate vicinity of the discharge channel. The addition to the boron content of seawater will be too low to have any impact on the seawater quality or water fauna. Process water also contains salts generated in the neutralization process. These salts are naturally found in the seawater and will have no detrimental impact on the marine ecosystem.

The acidic and alkaline wastewater generated in circulating water production (demineralization) will be drained into a neutralizing tank. After neutralization, the water will be drained into the cooling water discharge channel. The liquid waste treatment plant will process the controlled area wastewater that may contain radioactive substances. Different types of wastewater will be drained and treated separately, and the treatment method will depend on the quality and radioactivity of the wastewater. Possible treatment methods include separators, ion exchangers, distillation, and, when required, evaporation. One of the purposes of the treatment of water that contains radioactive substances is to concentrate the radioactivity in a smaller volume. The total volume of treated process wastewater and the concentrations of radioactive substances will be measured in the liquid waste treatment system before the cooling water is drained into the discharge channel.

Non-radioactive wastewater generated at the nuclear power plant will be kept separate and treated in the appropriate manner. Water and preserving solutions coming from the conventional auxiliary systems and the filter rinsing and decantation water will be chemically processed, i.e. hydrogen peroxide and a catalyst will be mixed into the wastewater. Wastewater containing chemicals will also be treated at the liquid waste treatment plant and the non-radioactive wastewater treatment system, depending on whether the wastewater has been generated within or outside the controlled area of the power plant.

Water from floor drains and washing water will be drained into the sewage system via oil separators. Any solids in the water will be separated. When necessary, the wastewater to be pumped out will be neutralized with sodium hydroxide or sulfuric acid. After treatment, the wastewater will be drained into the cooling water discharge channel.

The power plant's sanitary wastewater (water from restrooms and showers, as well as wastewater from the cafeteria and kitchens in office spaces) will be drained from the power plant site via the sewer network to be treated at the wastewater treatment plant of the municipal water utility (Pyhäjokisuun Vesi Oy). The sanitary wastewater will be monitored in accordance with an agreement signed with the municipal water utility.

Algae, fish, and other solids entering the facility with the cooling water will be removed using screens and filters and treated as biowaste. Solids attached to the cleaning equipment will be rinsed off with seawater and drained into the treatment plant where the solids will be separated from the water. The water will then be returned to the sea via the cooling water discharge channel.

Drainage water

Drainage water (rainwater) will be collected from the plant site in a controlled manner, purified using the appropriate structures, and discharged into the sea. The drainage water is not estimated to cause any contamination of groundwater or the soil. The quality of the drainage water collected will be managed using both centralized and distributed structures. As centralized management structures, retention basins will be built in the plant area. Retention basins will balance overflow and reduce the risk of erosion in the discharge routes. In addition, solids in drainage water will sediment in the retention basins. As distributed drainage water management structures, catch basins will be built in the plant area to gather solids from the drainage water. In addition, structures to separate floating litter will be built. Oil sumps and other water treatment structures will be constructed as necessary.

The condition and functionality of drainage water basins and structures will be monitored in accordance with a maintenance program. After the separation of sand and oil, the drainage water will not contain any contaminants that would require chemical monitoring.

Groundwater

The formation of groundwater will decrease as a result of watertight surfaces and the drainage water being discharged into the sea. This may lower the surface level or pressure of groundwater in the peninsula area. The Hanhikivi peninsula is not classified as a groundwater area, and the lowered surface level or pressure of groundwater will have no impact on the water supply in the region. There is no groundwater abstraction in the impact area and no biotic communities dependent on the groundwater have been identified in the area.

A lower groundwater level may lead to changes in the direction of the groundwater flow in such a manner that seawater will be able to mix with the groundwater, which will alter the chemical composition of the groundwater. Studies have found mixing of groundwater and seawater locally in the Hanhikivi peninsula area even before the construction work began. The concrete structures that come into contact with the groundwater in the soil or bedrock may also increase the pH value of the groundwater. The impact will, however, be limited to the immediate vicinity of the structures, and the changes in the chemical composition of the groundwater will not be significant.

Chemicals and flammable substances

The majority of the chemicals used at the nuclear power plant will be various acids and bases used in the production of the power plant's process water and the control of acidity and chemical reactions in the plant's water circulation systems. Chemicals will also be used for to clean steam circulation equipment and pipelines and to prevent corrosion.

The emergency diesel generators and auxiliary steam boilers will be fueled with light fuel oil. Gases to be used include hydrogen used for cooling the turbine plant generator and nitrogen used as the fuel in specific pieces of equipment. Lubricating oils will be used to lubricate rotating machines (including the turbine and generator bearings and pumps). Furthermore, the transformer will contain a large amount of oil for cooling purposes.

Sodium hypochlorite will be used to prevent organic growth in the cooling water system. The power plant's environmental permit includes specifications and reporting obligations pertaining to sodium hypochlorite.

Storage of chemicals, fuels, and oils is not estimated to cause any contamination of the groundwater or the soil. The prevention of a variety of leaks and accidents will be taken into account in the design of the chemical and fuel systems. Risk analyses will be carried out to support the design. The chemical offloading locations, storage tanks and facilities, and the chemical dosing systems will be constructed in accordance with legislation governing the safe storage and handling of hazardous chemicals and fuels, guidelines of the Finnish Safety and Chemicals Agency (Tukes) based on the legislation, and SFS standards. In the event of leaks, all premises that contain chemical tanks or storage facilities will be drained to shielding pools, sludge and oil separation wells, and to the neutralizing tank. The volume of the shielding pools for flammable liquid storage containers will be a minimum of 110% of the volume of the storage container. The chemical and fuel offloading locations will also be equipped with pools. In

December 2020, Tukes granted Fennovoima a chemical license for the operation of the nuclear power plant, which enables the storage and handling of hazardous chemicals at the Hanhikivi 1 plant.

Releases into the air, noise, and vibration

Releases into the air

Conventional releases into the air during the operation of a nuclear power plant originate from the production of emergency power and from the handling of process waters. The annual emissions to air are normally very small and have no impact on the air quality at the plant site.

The primary purpose of the emergency diesel generators is to guarantee power supply to the functions critical to nuclear safety under all operating conditions, such as if the connection to the external power grid is lost. During normal operation, the operation of the emergency diesel generators will be limited to monthly test runs. The maximum operating time of each emergency diesel generator will be 50 hours per year. Auxiliary steam boilers are normally only used during the startup and shutdown of the nuclear power plant. When the nuclear power plant is in the production phase after commissioning, the auxiliary steam boilers will be in operation for a maximum of 500 hours per year. Two boilers will be used simultaneously, with the third one, which acts as a back-up boiler.

The emergency diesel generators and auxiliary steam boilers are fueled with low-sulfur light fuel oil. Other releases into the air will be controlled with combustion technology. Under normal circumstances, the annual emissions from back-up power generation are very low and have no impact on air quality at the plant site.

Noise and vibration

According to the noise modeling, the noise from the operation of the nuclear power plant will remain below the guideline values set for residential areas and areas including holiday residences in Government decision on noise level guideline values (993/1992). The average sound level at the closest holiday residences will remain below 30 dB(A). The maximum noise level at the Siikalahti seashore meadow and the northwest Hanhikivi meadow will be 35–40 dB(A). According to the noise simulation, the guideline values for noise will not be exceeded in the closest nature conservation area (Ankkurinnokka).

The noise from road traffic to the plant will remain below the guideline values for day and night (55 dB(A) at 50 dB(A), respectively) at the nearest residences. In the area between Hietakarinlahti and Takaranta seashore meadow, the maximum noise level in the vicinity of the road will be approximately 45 dB(A). The noise is not estimated to cause any significant harm to birds during the operation of the nuclear power plant.

The primary sources of noise at the power plant will include the turbine, the generator, pumps, compressors, coolers, and fans. They will make a steady, low humming noise. The noise will be reduced by covering the noise sources and installing sound-absorbing wall structures. Traffic noise will be reduced by establishing a speed limit for the access road leading to the plant, for example.

According to the power plant's environmental permit, the plant must not cause, under normal operation, any ambient noise that exceeds the equivalent sound level (LAeq) of 45 dB in the closest nature conservation areas. After the start of the nuclear power plant operation, the equivalent sound level in the immediate vicinity of the plant, such as the nature conservation area subjected to the most noise, will be measured. The measurements will be taken in a manner approved by the North Ostrobothnia Centre for Economic Development, Transport and the Environment. Furthermore, the noise levels of fixed sources of sound that clearly influence the ambient noise level will be measured and the noise spreading model will be updated if any components are replaced.

The operation of the nuclear power plant will cause no significant vibration. Traffic to the power plant will mostly consist of passenger traffic that will only cause minor vibration limited to the immediate vicinity of the access road. There will be no permanent sources of vibration at the nuclear power plant.

Radioactive substances

Radioactive substances are found at natural low concentrations everywhere in our surroundings. Most of the radioactive substances in the environment originate from natural sources, such as uranium found in the soil or cosmic radiation, and less than one per cent originate from man-made sources. The radioactivity found in Finnish nature that originates from man-made sources mainly comes from nuclear weapons testing and the Chernobyl nuclear disaster.

The nuclei of atoms of a radioactive substance decay into lighter nuclei, releasing ionizing radiation. Depending on the method of decay, this radiation can be either particle radiation or electromagnetic radiation. The health effects of radiation are illustrated using the concept of radiation dose, measured in sieverts (Sv). The sievert is a large unit, and in practical applications, millisieverts (one thousandth of a sievert, mSv) or microsieverts (one millionth, µSv) are nearly always used.

According to calculations by the Radiation and Nuclear Safety Authority (STUK 2018), the average annual radiation dose of a person living in Finland is approximately 5.9 mSv. The most significant source of this radiation dose is radon found in indoor air, which accounts for nearly two-thirds of the annual radiation dose, while man-made radioactive substances in the environment only account for 0.01 mSv. The factors contributing to the annual average radiation dose are presented in Figure 1-3.

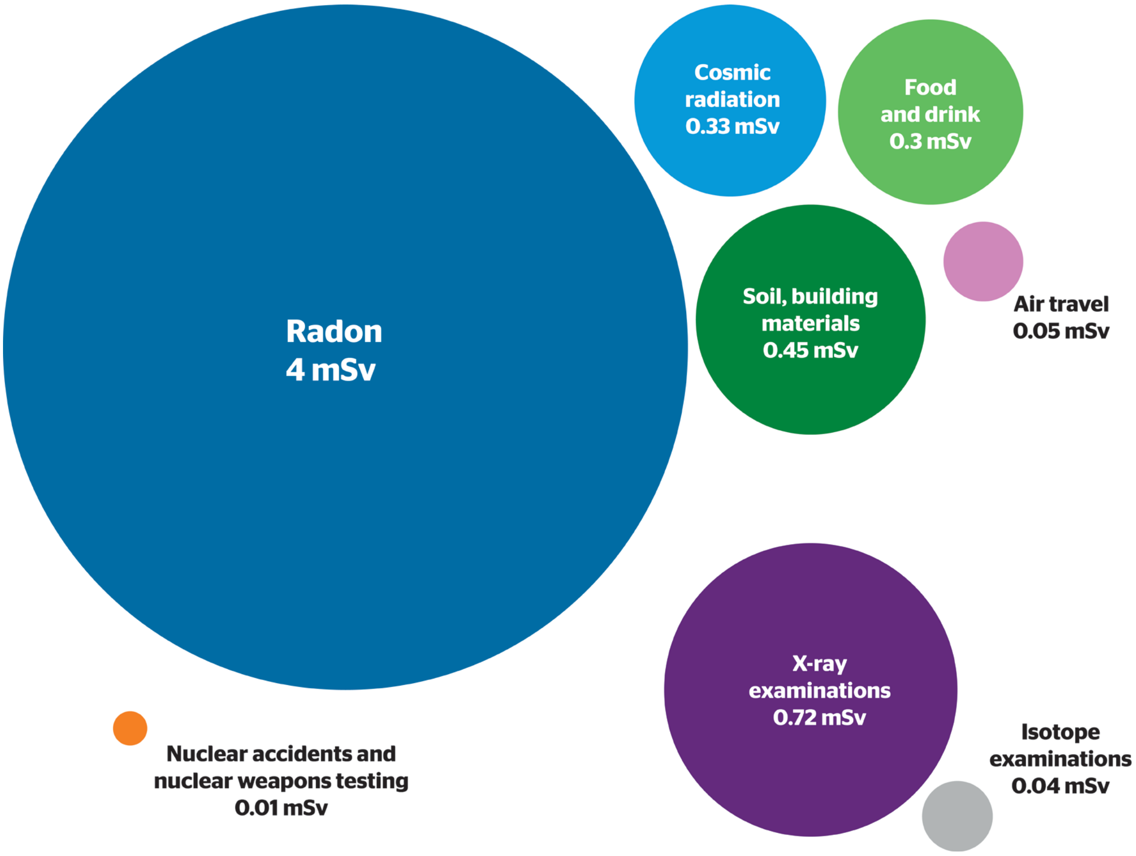

Figure 1-3. The average annual radiation dose for a person living in Finland is approximately 5.9 mSv (STUK 2018).

Radioactivity at a nuclear power plant

The majority of the radioactive substances at a nuclear power plant are found in the spent nuclear fuel. Fresh fuel is uranium dioxide (UO_2), which consists of oxygen and uranium. In addition, a small quantity of gadolinium has been added to some fuels. Gadolinium, like oxygen, is a stable element. The uranium in the fresh fuel is only weakly radioactive and causes no radiation hazard.

In a nuclear reactor, heat is generated by nuclear reactions that take place within the fuel. Neutrons collide with uranium nuclei and split them into lighter elements, generally called fission products. Instead of splitting in two, some uranium nuclei capture the neutron to create transuranic elements, which are heavier than uranium. The majority of fission products and all transuranic elements are radioactive. Therefore, spent fuel is highly radioactive and must be handled with particular care. The most important safety requirement in the entire nuclear power process is to keep the radioactive substances from the spent fuel isolated from the living environment.

A considerably lower portion of the radioactivity found in a nuclear power plant is located in the primary circuit of the reactor, and other systems connected to it, such as the purification systems. Small amounts of radioactivity may also be released from the fuel elements into the cooling water. The water in the primary circuit is continuously purified, and radioactive substances are captured by the ion exchange resin used in the purification systems. The ion exchange resin will be treated as radioactive reactor waste, processed appropriately, and safely disposed of in the final disposal facility for low- and intermediate-level operational waste at the Hanhikivi peninsula.

Radiation exposure limit values from the operation of the nuclear power plant

The licensee of a nuclear power plant is obligated to set radioactive substance emission limits that ensure that the limit for the dose of an individual in the population, laid down in the Government Decree on the Safety of Nuclear Power Plants (717/2013), will not be exceeded. According to the Decree, the annual dose for an individual in the population arising from the normal operation of a nuclear power plant must not exceed 0.1 mSv; furthermore, an anticipated operational occurrence must not cause an addition to the annual dose of an individual in the population that exceeds 0.1 mSv.

Nuclear power plant accidents are divided into three categories, and limits for the annual dose for an individual in the population have been defined for each of these. The limit is 1 mSv for Class 1 accidents, 5 mSv for Class 2 accidents, and 20 mSv for a design extension condition, i.e. the less likely the accident, the higher the dose. The probability of accidents is discussed in more detail in Appendix 4B to the construction license application that was originally submitted to the Ministry of Economic Affairs and Employment in June 2015. The dose arising from an accident may be compared to a chest X-ray, which will typically cause a dose of 0.1 mSv, or a CT scan of the abdomen, which will cause a dose of 7 mSv.

The Hanhikivi 1 nuclear power plant will be designed so that the dose to the population will remain below the limits with certainty. In addition, Fennovoima will define emission targets for radioactive substances in accordance with the ALARA (As Low As Reasonably Achievable) principle. These emission targets will be considerably lower than those defined in the Government Decree. Current radioactive emissions from Finnish nuclear power plants are typically less than one percent of the limits set in the Government Decree. Fennovoima aims to limit radioactive emissions from the Hanhikivi 1 nuclear power plant to the level of the nuclear power plants currently in operation in Finland, or lower. Emission levels can be influenced by plant design and through various measures during operation.

The strict limits and monitoring of emissions will keep radioactive emissions very low, and the impact of the radiation on the environment will be very low when compared to the impact of natural radioactive substances found in the environment.

Containment of radioactivity

Containment of radioactive substances is based on the functional and structural implementation of the defense-in-depth principle, including several successive and redundant structures and functions. The structural defense-in-depth principle refers to four successive barriers that are able to reliably isolate the radioactivity of the fuel from the environment. These barriers are the ceramic fuel, the fuel cladding, the primary circuit, and the containment.

1. The nuclear fuel is the first level of the structural defense-in-depth principle. The fuel consists of a solid ceramic material which releases strongly radioactive substances at a slow rate. Thus, only a minor portion of the radioactive substances are conveyed out of the fuel material. During normal operation, the fuel mainly releases gaseous and volatile fission products, such as inert gases, iodine, and cesium inside the cladding.
2. The fuel cladding is the second level of the structural defense-in-depth principle. The fuel is packed into a gastight one-millimeter-thick cladding manufactured from zirconium and niobium. A fuel rod is approximately four meters long with a diameter of one centimeter. The reactor has an approximate total of 50,000 fuel rods. Despite strict quality requirements, minor leaks may

occur in individual fuel rods. Measures will be planned to manage leaking rods to prevent the spreading radioactivity from causing any harm.

3. The third level consists of the primary circuit designed to contain any radioactive substances found in the coolant. The primary circuit consists of the reactor pressure vessel, the pressurizer, and four separate cooling circuits, each equipped with a steam generator and a reactor coolant pump, as well as a pipeline connecting all of these. Steam generators are heat exchangers in which heat is transferred from the primary circuit to the secondary circuit with no mixing of the water of the circuits. This prevents radioactive substances from reaching the water in the secondary circuit.
4. The outermost level is the double-shell containment, which contains nearly all radioactivity found at the facility: the reactor core, the entire primary circuit, and the spent fuel storage pools. The inner shell of the containment consists of a pre-tensioned reinforced concrete structure with a gas-tight steel lining that functions as a release barrier. The outer shell of the containment is a massive reinforced concrete structure designed to withstand a large passenger aircraft crash. The containment has efficient pressure relief and heat removal systems that will ensure the integrity of the containment even in accident conditions.

Limiting and controlling emissions

The controlled area of a nuclear power plant includes the parts of the plant in which radioactivity may exist in systems or rooms. The release routes in the controlled area (ventilation, wastewater, waste, equipment, tools, and employees) are continuously monitored to ensure that any releases into the environment remain negligible. If activity levels above normal are observed, emissions can be limited using systems designed for the purpose.

Gases that contain radioactive substances are led into a cleaning system where radioactive substances are removed from the gas using, for example, activated carbon filters. The purified gases will be released into the atmosphere via the vent stack. Radioactive releases into the air will be monitored and measured at several stages in the gas treatment systems, and finally at the vent stack.

Radioactive liquids from the controlled area will be led to the liquid waste treatment systems, where they will be treated so that their activity level falls well below the limit values set for emissions before they are released into the sea. The level of radioactivity in the water to be discharged into the sea will be determined by taking a sample before the discharge on the basis of which a discharge permit is issued. The results are reported to the Radiation and Nuclear Safety Authority based on a representative sample from the release. Furthermore, the size of the release will be monitored by conducting measurements at the discharge line before the cooling water is drained into the discharge channel. The goal is to minimize the volume of emissions by, for example, recycling the process water and pool water and by minimizing the generation of wastewater. Best available technology will be used to limit both gaseous and liquid emissions. All tools and equipment leaving the controlled area will be inspected for radioactivity and cleaned when necessary. People leaving the controlled area will also be subjected to personal monitoring measurements to ensure that no radioactive substances are present on the employees' clothes or skin. Any radioactive substances found in the inspections, such as contaminated working clothes, will be cleaned or separated from the release flow and permanently disposed of in the final disposal facility for low- and intermediate-level operational waste to be constructed in the site area. The procedure ensures reliable isolation of waste from the living environment until the radioactivity has reduced to a negligible level.

Environmental radiation monitoring

The radioactivity levels in the surroundings of the nuclear power plant will be monitored to reveal any changes during the entire operating life of the power plant from the design phase to the decommissioning. Fennovoima has already begun surveying the basic condition of the natural environment at the plant site and the naturally occurring radioactivity in accordance with a program approved by the Radiation and Nuclear Safety Authority to facilitate reliable observation of any changes brought about by the power plant and its construction activities.

During the operation of the plant, radiation levels will be measured precisely and comprehensively in the immediate vicinity of the plant using systems such as an automatic radiation monitoring network that will extend approximately ten kilometers from the plant. The plant's impact on the level of background radiation will be too low to be reliably observed using external radiation meters. The most important method of environmental monitoring will be the determination of levels of radioactive substances found in samples gathered from the environment. Samples will be taken to cover various migration routes and stages of food chains. Samples will be taken from plants, fungi, animals, drainage water, and air, for example.

Emissions under exceptional conditions

The Hanhikivi 1 nuclear power plant will not, even during a severe reactor accident, release a quantity of emissions that would require civil defense measures outside the areas close to the plant, or long-term restrictions on the use of extensive land and water areas. The actual analyses to prove that emissions from the plant will be, in all accident conditions, lower than the limits defined in the Government Decree on the Safety of Nuclear Power Plants will be submitted to the Radiation and Nuclear Safety Authority STUK as part of the construction license application documentation.

Emergency preparedness arrangements will be prepared for accident situations to ensure that the plant can be brought to a safe state and to minimize any consequences to people from any radioactive releases. These consequences can be mitigated by, for example, seeking shelter indoors, evacuating the area, and taking iodine tablets. Regular drills will be organized to improve cooperation between Fennovoima's personnel and the authorities. In accordance with the Nuclear Liability Act (484/1972), Fennovoima will also be responsible for the post-processing of a potential accident.

Waste

Reactor waste and spent nuclear fuel

The estimated volumes of reactor waste and spent nuclear fuel, as well as the plans and procedures related to their handling, processing, storage, and final disposal, were originally presented in Appendix 5B to the construction license application that was submitted to the Ministry of Economic Affairs and Employment in June 2015. The procedures and plans on the handling, storage and final disposal of waste have remained largely unchanged since then, but according to the current estimate, approximately 6,300 m^3 of very low level, low level and intermediate level waste will be generated during the operation of the nuclear power plant and the volume of decommissioning waste is estimated at approximately 20,000 m^3. The estimates on the accrual of spent nuclear fuel have remained at the level presented in 2015, 1,200–1,800 metric tons of uranium. The estimated volumes of reactor waste and spent nuclear fuel, as well as the plans and procedures related to their handling, processing, storage, and final disposal, are presented in Appendix 5B to the construction license application that was submitted to the Ministry of Economic Affairs and Employment in June 2015. The treatment and storage of reactor waste will be carried out in the treatment and storage facilities located in connection with the power plant. The facilities will be equipped with systems that allow safe processing and transfer of the waste, as well as monitoring of the quantity and quality of radioactive substances. The processing and storage of the waste will cause no risks to the environment. The final disposal of reactor waste will be carried out in a manner which ensures that the radioactive waste will be isolated from the living environment, so that the safety of the environment will not compromized at any stage of the process.

The air conditioning and filtering systems in the spent fuel processing and interim storage facilities will prevent any radioactive releases in exceptional situations from escaping into the environment. Under normal conditions, the processing and storage of spent nuclear fuel will not have any impact on the environment, and the statutory limits will not be exceeded.

In accordance with the prerequisites laid down in the Government decision-in-principle M 6/2014, Fennovoima submitted in June 2016 to the Ministry of Economic Affairs and Employment an environmental impact assessment (EIA) program for the final disposal facility for spent nuclear fuel (Fennovoima 2016). This started an environmental impact assessment procedure for the final disposal project and the suitability of the optional final disposal locations for final disposal in accordance with the Act on Environmental Impact Assessment Procedure (468/1994). The purpose of the final disposal project is to manage the spent nuclear fuel that will be generated during the operation of Fennovoima's Hanhikivi 1 nuclear power plant. As the project's coordinating authority, the Ministry of Economic Affairs and Employment issued an opinion on the EIA program in December 2016. Due to the exceptionally long duration of the EIA procedure, the Ministry of Economic Affairs and Employment required in its opinion (Ministry of Economic Affairs and Employment 2016) that Fennovoima submit reports on the progress of the final disposal project during the said EIA procedure. In the first report submitted in January 2018 (Fennovoima 2018), Fennovoima further specified the schedule for selecting the optional final disposal locations and described three related reports to be prepared pursuant to a service agreement signed with Posiva Oy.

Furthermore, in October 2020, Fennovoima submitted to the Radiation and Nuclear Safety Authority a general nuclear waste management plan for Hanhikivi 1 power plant together with the sections on nuclear waste management and related systems from the plant's preliminary safety analysis report (Chapter 11).

Conventional waste and hazardous waste

Similarly to other energy production plants or industrial facilities, a nuclear power plant generates both conventional waste and hazardous waste. The primary objective of waste management at a power plant is to generate as little waste as possible. The sorting and gathering of waste will be carried out in accordance with the waste management guidelines, and the quality, volume, and treatment of waste will be continuously recorded, as required by the Waste Act. Conventional waste will be utilized as far as possible. The objective is to utilize and recycle 90% of all waste. There will be no landfill at the plant site.

Waste volumes will vary year to year, depending on factors such as the length of the annual outage and the maintenance measures included in it. Conventional waste generated at the plant will include scrap iron and metal, wood, paper, and cardboard waste, biowaste, and energy waste (combustible waste). Hazardous waste will consist of, for example, waste oil and oil-contaminated waste, fluorescent tubes, solvents and chemical waste, as well as discarded electrical and electronic equipment. The estimated annual volumes of conventional waste and hazardous waste are 400 tons and 40 tons, respectively.

Solid matter will enter the plant with the cooling water, generating solid screenings that will be separated at a specific treatment facility. The solid screenings will be pre-processed to reduce their volume and to make interim storage easier. The processing of the screenings is not expected to generate any disturbing odors or other harm. After pre-processing, the screenings will be packed and transported from the power plant site to be processed as biowaste. The total annual volume of solid screenings is estimated at 5–15 tons.

Minor quantities of ash will be generated by the emergency diesel generators that burn light fuel oil, and chimney cleaning waste will be generated during boiler maintenance. The ash and cleaning waste will be stored at the power plant in closed containers to prevent the spreading of dust. The volume of ash generated will mostly depend on the ash content of the fuel. The ash content of light fuel oil is low. Hazardous waste, such as oily waste, will be collected in separate containers and stored in a hazardous waste storage facility. Ash, chimney cleaning waste, and hazardous waste will be delivered to appropriately licensed operators for further processing and final disposal.

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Nuclear power plant site

Appendix 2

Additional surveys on the impact of the nuclear power plant on the marine environment and fishery during operation

Summary

In 2013–2014, Fennovoima carried out an environmental impact assessment (EIA) procedure concerning a 1,200 MW nuclear power plant to be constructed on the Hanhikivi peninsula located in the municipality of Pyhäjoki. The coordinating authority, the Ministry of Economic Affairs and Employment, issued a statement on the EIA report on June 2, 2014 (TEM/1965/08.04.01/2013), which concluded the EIA procedure. The Ministry of Economic Affairs and Employment included in its EIA statement the requirement that Fennovoima carry out additional surveys of the marine environment and fishery and enclose the survey results with the construction license application. This appendix 2 (Appendix 3A of the original construction license application submitted to the Ministry of Economic Affairs and Employment of Finland in June 2015) includes the additional surveys required by the Ministry of Economic Affairs and Employment pursuant to section 32, subsection 15 of the Nuclear Energy Decree (161/1988).

This appendix was last updated in February 2021, at which time the descriptions of the current status of the fish stock, fishing, invasive species, underwater nature and habitats, the occurrence of seals, as well as the marine area plan and underwater marine nature areas of ecological significance (the abbreviation in Finnish is EMMA) were updated. The update was based on the available monitoring data and other available information (such as data from The Finnish Inventory Programme for the Underwater Marine Environment - VELMU). A separate report on invasive species was prepared. It also covered the risks caused by other animal species in the project area and the impact of climate change on the presence and spreading of invasive species. In the case of the description of the current status, updated information included information on the grayling, a fish species present in the area, and the impact of the construction and operation of the power plant on the grayling, as well as an update of the habitat type data (incl. charophyte meadows and bottom dominated by submerged macrophytes) and an assessment of the impact on these habitat types.

The additional surveys aimed to assess the impact of the operation of the nuclear power plant on the spread of invasive species, the migration of seals and their staying in the Pyhäjoki sea area, fishery and migrating fish species, and the habitat types of bottom dominated by submerged macrophytes, and of charophyte meadows. In addition, the survey report presents the objectives of the marine management plan that have the greatest significance for the nuclear power plant, and the impact of the operation of the power plant on these objectives.

Invasive species are not expected to spread as a result of the operation of the nuclear power plant. However, the increase in the temperature of the seawater may assist new fish species in adapting to the region. The overall impact of the unfrozen sea area at the cooling water discharge location on seal populations and the reproductive process of seals is estimated to remain low.

Fishing in the vicinity of the Hanhikivi peninsula is estimated to be prevented or rendered more difficult due to the impact of the warm cooling water to be discharged. The detrimental effect on fishing will be most pronounced in the immediate vicinity of the warm cooling water discharge channel and will gradually reduce as the distance from the Hanhikivi peninsula increases. Changes are likely to take place in the fish stocks and the species distribution. Local changes may be high, but in terms of the entire Bothnian Bay, the impact is estimated to remain very low. The operations are not expected to have a significant impact on the routes of migrating fish or their access to spawning rivers.

Charophyte meadows on the eastern coast of the Hanhikivi peninsula may suffer from the increased seawater temperature, but bottom dominated by submerged macrophytes may even benefit from the change.

The operation of the Hanhikivi 1 nuclear power plant is not estimated to compromise the general objective of the marine management plan to “protect, preserve and, when necessary, restore the Baltic Sea so that it is biologically diverse, dynamic, clean, healthy, and productive”.

Additional surveys on the impact of the nuclear power plant on the marine environment and fishery during operation

Survival and spreading of invasive species in the Pyhäjoki marine area

The occurrence of invasive species and the impact caused by them are discussed in more detail in a separate survey (AFRY 2020). In general, invasive species are not expected to spread as a result of the operation of the Hanhikivi 1 nuclear power plant, but local growth in populations of specific species that spread into the project area may occur. The impact of climate change may also promote the spreading of several invasive species and intensify their harmful effects.

Invasive species that cause harmful effects to the operation of nuclear power plants include, in particular, fouling organisms. The freshwater hydroid and the zebra mussel are fouling organisms occurring in the Bothnian Bay. The zebra mussel is not established in the Bothnian Bay or in the immediate vicinity of the project area yet, unlike the freshwater hydroid, which is likely to cause fouling as it becomes more common in the area.

Other fouling organisms that may spread into the area include the acorn barnacle, the Harris mud crab, and the dark false mussel. Of species that have not been observed in Finnish waters as of yet, harmful fouling organisms include the Asian clam and the quagga mussel, a related species of the zebra mussel. All of the above-mentioned species can potentially spread into the area, but the risk of this occurring in the near future is estimated as low. Of native species, *Electra crustulenta* may also cause fouling if it spreads into the area.

Species ending up in the cooling water intake system may also cause harm to the operation of the nuclear power plant. An example of such species is the fishhook waterflea. It occurs in the Bothnian Bay and benefits from the warming caused by the cooling water and the impact of climate change, which can lead to mass occurrences of the species. Similar species that may have a negative impact on cooling water intake include the Black Sea jellyfish, among others, but only irregular vagrants of it have been observed in the Finnish waters. The species may become more common as the result of climate change, however. Of the native species, specific algae may cause harm to cooling water intake if they occur in large quantities.

It has been estimated that there are several species that can become locally more common due to the impact of the cooling water. The most likely of these is the round goby, which already occurs in the waters near Hanhikivi peninsula. The negative impact from the round goby, which has been discovered to be a highly aggressive competitor, can be significant, as it is capable of replacing other fish species and strongly changing the delicate ecosystem of the Bothnian Bay, also at a broader scale if it becomes more common. Other species that may become locally more common include the Canadian waterweed, among others. The above-mentioned species will not constitute a direct threat to the operation of the nuclear power plant, however.

Populations and migration of seals

Seal populations

Information on the occurrence of seals, i.e. the ringed seal and the grey seal, in the immediate vicinity of Hanhikivi peninsula has been obtained from local professional fishermen, commercial fishing surveys, the Natural Resources Institute of Finland and, on the Swedish side, from the Swedish Museum of Natural History, which is responsible for seal population counts.

There is a year-round population of ringed seal in the Bothnian Bay. The ringed seal is able to live in areas covered by fast ice by maintaining a network of breathing holes. Gray seals do not make breathing holes like ringed seals do, and they must migrate as ice conditions change. When the sea is covered with ice, gray seals move towards the south where there is no ice, or further away from the coast to the open sea. In the early 1900s, the ringed seal population of the Baltic Sea comprised several hundred thousand specimens. The populations collapsed as the result of hunting rewards and the difficulty of reproduction due to high levels of environmental toxins. Currently, the ringed seal population in the Bothnian Bay is estimated at around 20,000 specimens.

Ringed seal mothers and pups are typically found in the Hanhikivi peninsula sea area immediately after the ice has broken. They move to other regions for the summer, only to return in September to winter and nest in the area. The ringed seal populations in the Hanhikivi peninsula sea area are abundant; for example, approximately 20 ringed seals get caught in the fyke nets of a local commercial fisherman each year. Up to 40 ringed seals have been counted on a single floe. However, they do not usually favor areas close to the shore where the water is shallow and land carnivores are close by.

The counted population of the gray seal, or the number of gray seals sighted in surveys, has increased from the 10,000 found in the early 2000s to the current number of nearly 40,000 seals. The result is expected to be between 60% and 80% of the overall population, which would thus be some 50,000–67,000 individuals. The results of the counts in both the Bothnian Bay and the Bothnian Sea have been around 2,000, which puts the total population estimates at 2,500–3,400. During the season when the gray seals grow new fur, their core habitat remains at the northern edge of the main body of the Baltic Sea, in the archipelago of central Sweden and the southwest Finnish archipelago. The counted population in the archipelago of central Sweden has shown steady growth in the 21st century so far, while the increase halted in Finland in the middle of the last decade (information provided by Markus Ahola from the Swedish Museum of Natural History).

Gray seals migrate to the north in the spring as the edge of the ice retreats, but do not yet come to the shores of Hanhikivi peninsula at that time. Hunting of the gray seal takes place in late winter out in the sea that is still frozen. Gray seals typically come to the shore near Hanhikivi peninsula in September or October and leave the area when the sea freezes. The movements of the seals and the period they stay in the area depend on the development of the ice conditions. Gray seals mostly nest on floes at the edge of fast ice, and sometimes on land. There are no gray seals nesting near the Hanhikivi peninsula. Gray seal populations in the Hanhikivi peninsula sea area are fairly abundant; for example, approximately 10 gray seals get caught in the fyke nets of a local commercial fisherman each year. There have been some observations of seals and the increased number of seals having caused negative impact on fishing in surveys on commercial fishing in the past few years (e.g. Vatanen et al 2020).

Impact on the migration and staying of seals

The sea area kept unfrozen by the cooling water will extend at most to a distance of a few kilometers from the Hanhikivi peninsula, and its overall impact on seal populations is estimated to remain low. Ringed seals cannot nest in the unfrozen area. The ringed seal has adapted to living in frozen seas during the winter, so the unfrozen area is not expected to particularly attract ringed seals. Ringed seals may, however, use the unfrozen area as a feeding ground in the winter.

The better availability of food may attract gray seals into the area, influenced by the warm cooling waters. Signs of this have been observed in the cooling water discharge area of the Olkiluoto nuclear power plant, at the mouth of the Eurajoki river (Lehtonen et al. 2012). As the sea freezes, gray seals migrate towards the south. In practice, the period in which gray seals stay in the Hanhikivi peninsula region depends on the rate at which fast ice forms. Gray seals swim great distances every day, sensing the progress of the edge of fast ice, and will leave the region by the time the sea south of Hanhikivi peninsula freezes. Gray seals are not expected to remain in the unfrozen area to winter. The unfrozen area will have no impact on the reproduction of gray seals.

Fish and fishing industry

The sea area in front of the Hanhikivi peninsula is a significant area for fish stocks and the fishing industry, and fish species typical to the Bothnian Bay are common there. This section presents research results concerning the fish stocks and spawning areas as well as commercial and recreational fishing activities in the sea area around the Hanhikivi peninsula. The section also contains an assessment of the impact of the nuclear power plant's cooling water intake and discharge on the fish stocks and fishery in the area.

Current fish stocks and fishing activities

Fish stock

Fish stocks and fishing activities in the Hanhikivi peninsula sea area have been surveyed in recent years by fishing with nets, catching fry, and conducting fishing surveys in connection with the monitoring of water construction works and the project area's environment baseline studies (Vatanen et al. 2016, Karppinen et al. 2016, Karppinen et al. 2018, Karppinen et al. 2019, Vatanen et al. 2020, Happo et al. 2021).

Various methods have yielded catches with an approximate total of 30 different fish species. Based on net fishing in 2014–2019, perch, ruffe and Baltic herring are the most abundant catches in the area. Fish were caught in three different areas (1. observation area, 2. area B, and 3. reference area) during the monitoring of the water construction works in 2017–2019 (Fig. 2-1). No construction works took place in 2014 and 2016, but the catching areas were partially the same. Annual variation was observed mainly in the proportion of Cyprinidae: the catch sizes increased (Fig. 2-2). Catches by net included relatively many whitefish, and the whitefish catch sizes increased towards 2019. The endangered grayling also occurs in the area.

Based on fry surveys, the Hanhikivi peninsula area has significance for the fry production of sea-spawning whitefish, vendace, and Baltic herring. The sea-spawning whitefish and vendace spawn in the shallows in October and November. The Baltic herring mainly spawns between the middle of June and the middle of July. Reproduction of the grayling is discussed in more detail in chapter "Routes of migrating fish and the access of fish into spawning rivers".

According to professional fishermen, most important spawning areas of sea-spawning whitefish and Baltic herring can be found on the northern side of the Hanhikivi peninsula very close to the peninsula, as well as in the Maanahkiainen and Lipinä shallows located some 7–9 kilometers to the north of Hanhikivi peninsula (Fig. 2-3). In the outer sea, significant spawning areas of the Baltic herring and the sea-spawning whitefish include the shallows of Matti and Sumu, as well as Ulkonahkiainen. The vendace also spawns in the same shallows as the sea-spawning whitefish and the Baltic herring. It seems that there is very high annual variation in the spawning of the Baltic herring in the Hanhikivi peninsula sea area. Goby, perch, and three-spined stickleback fry have also been caught (Happo et al. 2021).

Table 2-1 presents the fish species found in the sea area of the Hanhikivi peninsula and estimates of their reproduction, as well as the fry and fish counts in the cooling water intake area. The estimate is based on data from 2014 to 2019.

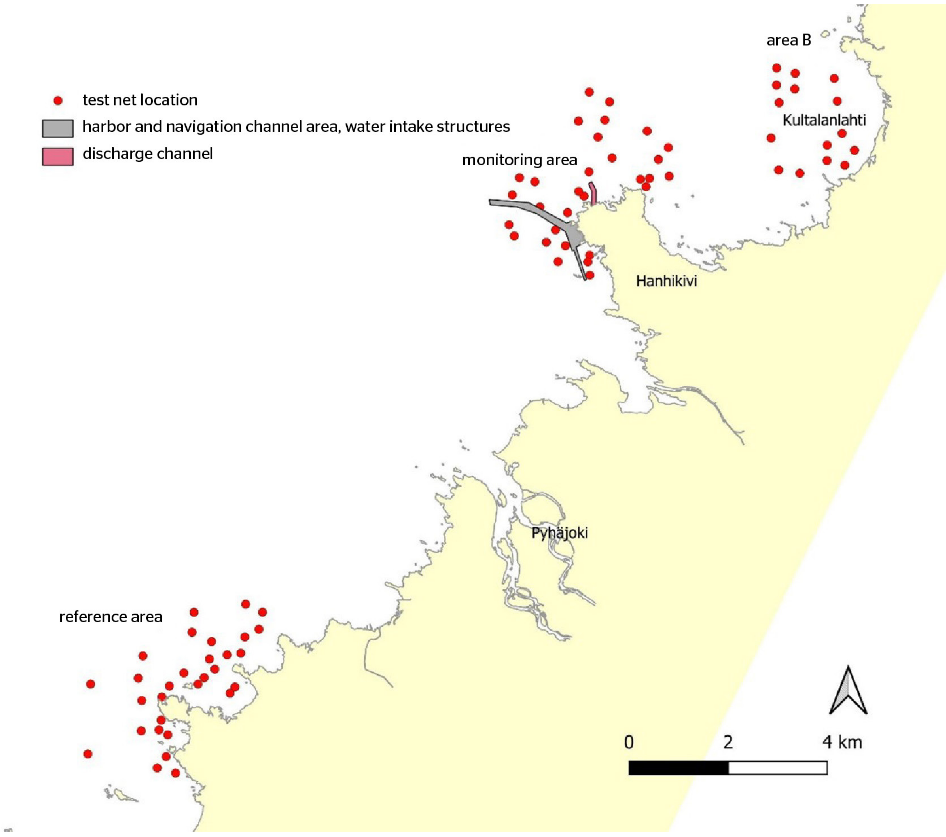

Figure 2-1. Coastal test net fishing catching areas during early monitoring of the Hanhikivi 1 project's water construction works (Vatanen et al. 2020).

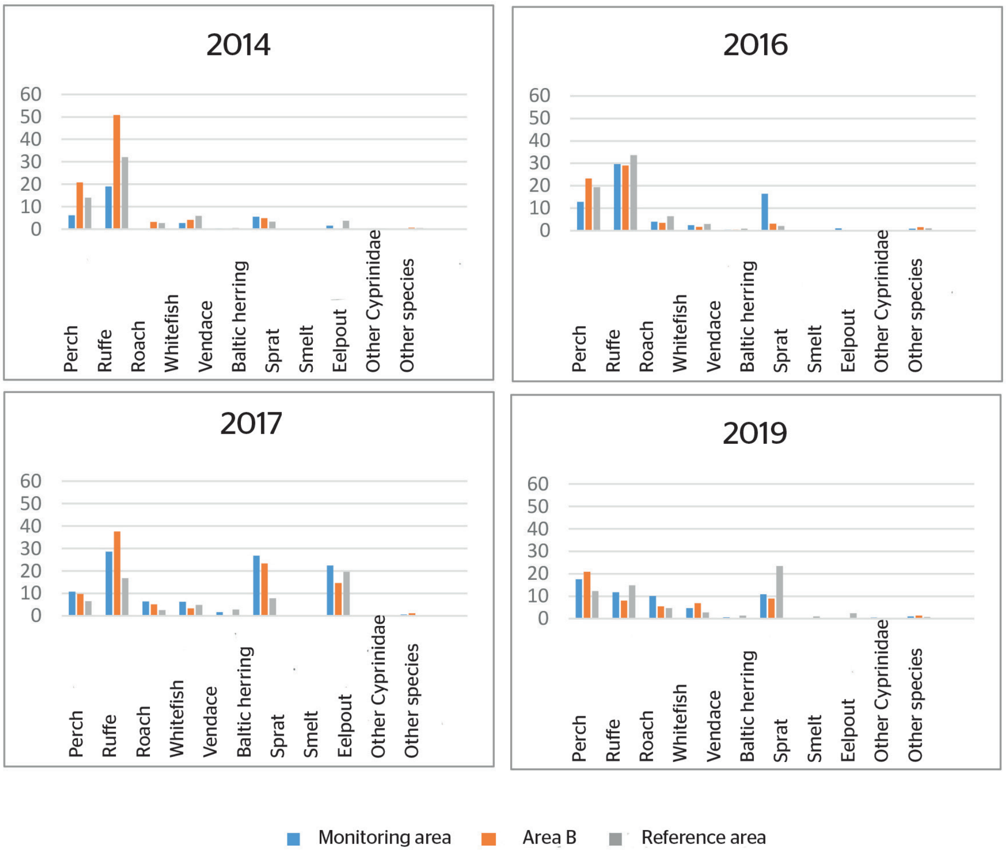

Figure 2-2. Annual fish catches (pcs/net) of the most common species and groups of species by area. The group "Other Cyprinidae" includes carp bream, bleak, ide, and dace. The group "Other species" includes bullhead, three-spined stickleback, pike-perch, salmon, burbot, trout, round goby, river lamprey, grayling, and fourhorn sculpin (Vatanen et al. 2020).

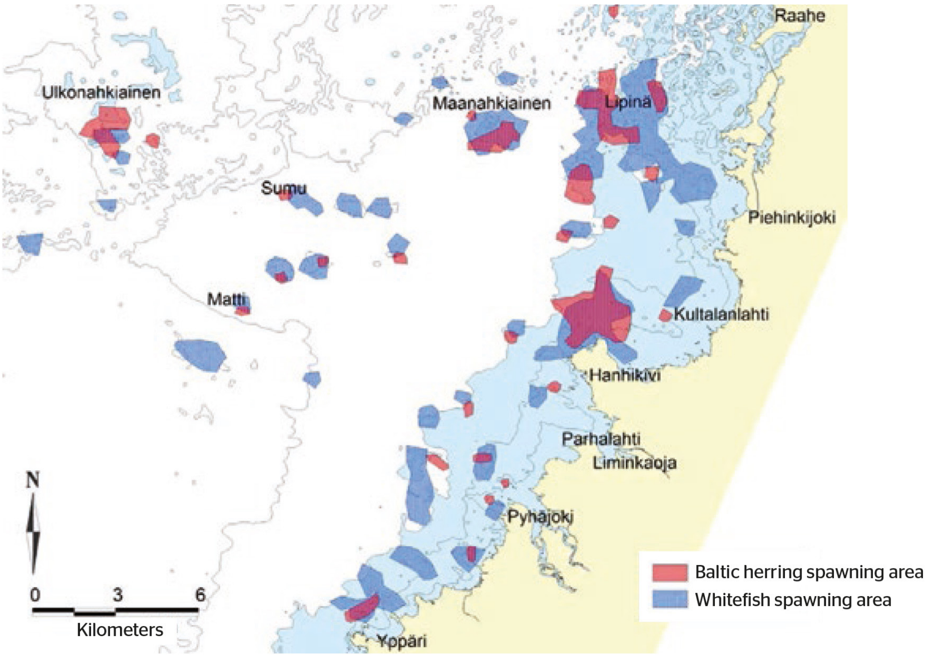

Figure 2-3. Spawning areas of sea-spawning whitefish and Baltic herring as reported by commercial fishermen (Karppinen and Vatanen 2014).

Table 2-1. Prevalence of fish species off the Hanhikivi peninsula at different life stages. The estimate of the prevalence of the fish species is based on data collected in 2009–2020. The data on grayling is also presented in Table 2-3.

Species	Spawning period	Populations in the vicinity of the project site			
		Spawning in the area	Fry stage	Juvenile stage	Aged one year or more
Perch	May–June	not significant		abundant	abundant
Pike	May	not significant		probably not	abundant
Grayling	May–June	different types of populations			observed in the area
Fourhorn sculpin	December–January	probably, inadequate data			observed in the area
Eelpout	August–September	probably, inadequate data			observed in the area
Bullhead	May–June	probably, inadequate data			observed in the area
Ruffe	May–July	probably		abundant	abundant
Pike-perch	May–June	unlikely			rarely observed
Sprat	June–August	no		not observed	sporadic
Ninespine stickle-back and three-spined stickle-back	June–July	commonly		abundant	abundant
Smelt	May	probably not			abundant
Burbot	January–February	spawns in rivers	inadequate data		common
Minnow	June–July	commonly		abundant	abundant
Lesser sand eel	May–July	probably, inadequate data		abundant	abundant
Whitefish and vendace	October–November	commonly	abundant	abundant	abundant
Baltic herring	May–July	commonly	abundant	abundant	abundant
Fall-spawning Baltic herring	inadequate data		observed in the area		
Cyprinidae	May–July	not significant		abundant	abundant
Gobies	May–July	commonly			abundant

Commercial fishing

According to a survey concerning the year 2019, a total of 17 commercial fisherman households operate in the surveyed area (Karppinen et al. 2020). The survey, realized by regular mail, included all fishermen listed in classes 1 and 2 in a commercial fishing register maintained by the Lapland Centre for Economic Development, Transport and the Environment (a total of 29 households). The most frequently used fishing tackle in the sea area of Pyhäjoki and Raahe was a bottom-set net with a mesh size of less than 45 mm. A total of 49,988 of such nets were used in the area in 2019. Bottom-set nets with a mesh size over 45 mm were also popular, with approximately 32,000 units in use. Other tackle used included fyke nets designed for whitefish or salmon, hooks for burbot and pike, as well as vendace/herring nets, which were not used much when compared to bottom-set nets. Trawling does not take place in the area (Karppinen et al. 2020.) In the surveyed area, fishing took place all year round, but was considerably more intense between June and October. Fishing with nets took place throughout nearly the entire surveyed area, mostly close to the coastline and near shallows in the outer sea, also in winter (Figure 2-4). Fishing with nets was very frequent in the spawning areas of whitefish and Baltic herring.

Fyke nets were used in four areas: Lipinä, Kultalanlahti, the Hanhikivi peninsula, and the area between Pyhäjoki and Yppäri (Fig. 2-5). Winter fishing is concentrated in areas near the coastline, and mostly takes place to the north of the Hanhikivi peninsula. In 2019, the total catch of the commercial fishermen in the surveyed area was approximately 16,500 kg (Table 2-2). Whitefish accounted for nearly 53% of this volume, and most of the whitefish was of the sea-spawning variety (45%). Perch catches (23%) were also fairly abundant. Other species of commercial significance were the Baltic herring, vendace, sea trout, and salmon.

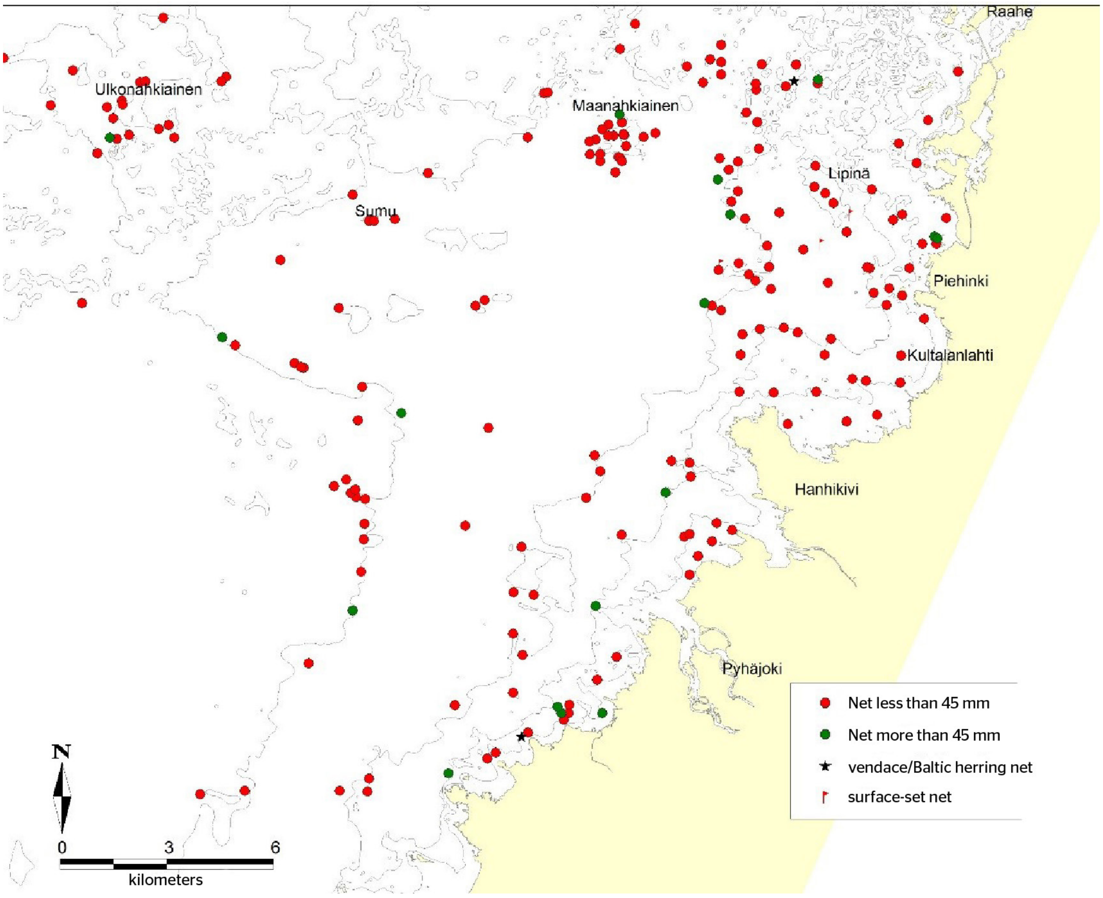

Figure 2-4. Most common net fishing areas of the commercial fishermen (Vatanen et al. 2020).

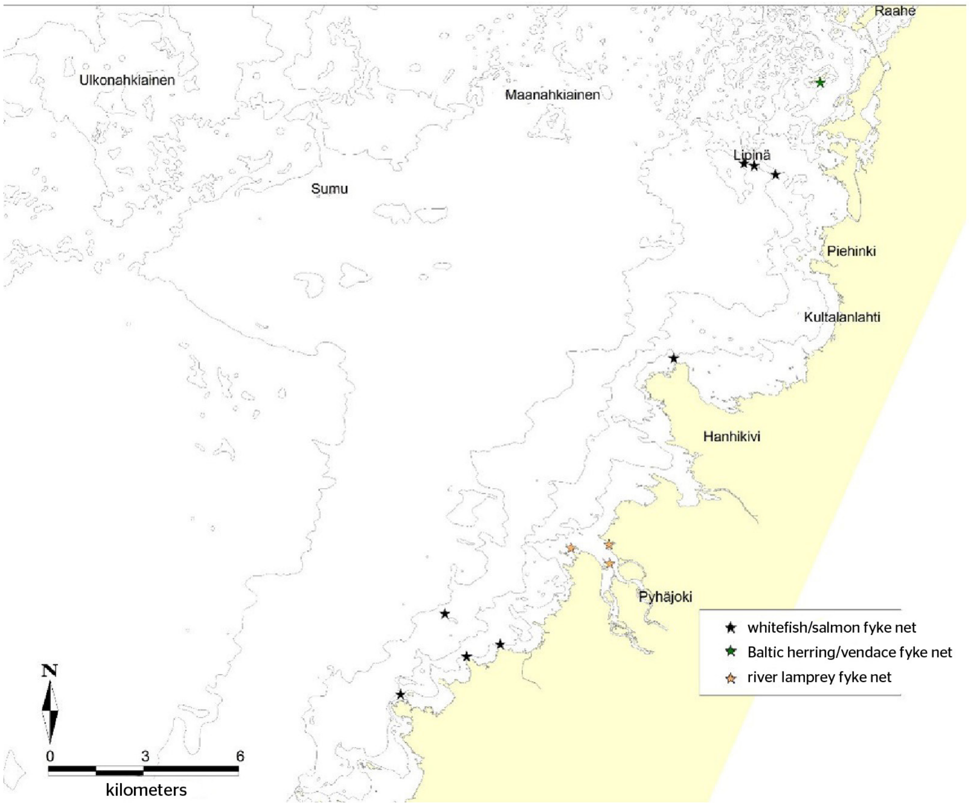

Figure 2-5. Fyke net fishing areas of the commercial fishermen in the sea area off Pyhäjoki and Raahe in 2019 (Vatanen et al. 2020).

Table 2-2. Catches reported by the commercial fishermen in 2019 (Vatanen et al. 2020).

	Month of catching													
Catch	1	2	3	4	5	6	7	8	9	10	11	12	**Total**	**%**
Perch	223	19	21	80	303	567	617	350	350	178	6	0	**3 861**	**23.5**
Pike	19	23	23	10	10	15	15	10	30	0	0	0	**155**	**0.9**
Pike-perch	0	0	0	0	0	0	4	2	4	0	0	0	**10**	**0.1**
Burbot	24	83	5	5	10	0	0	0	10	33	10	0	**197**	**1.2**
Baltic herring	0	3	8	12	15	70	20	20	56	14	9	0	**537**	**3.3**
Vendace	0	0	0	0	0	0	0	0	10	0	0	0	**190**	**1.2**
Salmon	0	0	0	0	1	71	41	86	0	0	0	0	**199**	**1.2**
Sea trout	3	0	0	10	0	9	0	0	0	50	0	0	**102**	**0.6**
Sea-spawning whitefish	43	263	144	20	315	1026	970	634	653	1273	100	0	**7 455**	**45.3**
Common whitefish	0	0	0	0	85	110	110	280	279	230	30	0	**1 384**	**8.4**
Grayling	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Carp bream	0	0	0	12	48	290	160	110	3	5	0	0	**1 278**	**7.8**
Roach	0	9	11	35	0	20	30	0	10	8	12	0	**693**	**4.2**
River lamprey	0	0	0	0	0	0	0	50	150	100	0	0	**300**	**1.8**
Other	0	70	20	0	0	0	0	0	0	0	0	0	**90**	**0.5**
Total	312	470	232	184	187	2178	1967	1542	1555	1891	167	0	**16 451**	**100.0**

Fishing for domestic use and recreational fishing

Fishing for domestic use and recreational fishing in the sea areas off Pyhäjoki and Raahe were last surveyed in 2016 (Haikonen et al. 2017). The survey was carried out as three contact rounds of interviews based on census register data. According to the survey results, approximately 896 households engage in fishing in the area. Of these, 91% reported that they had caught fish. The average size of a fishing household was three persons, of whom two participated in the fishing activities.

A total of 27,000 days of fishing took place in the Raahe and Pyhäjoki sea area during the survey period. Most of the fishing took place between June and September. The least active periods were the late fall and early winter. The most popular fishing tackle was a bottom-set net with a mesh size of less than 40 mm. These were used by approximately half of the fishing households (6,721 fishing days). Other popular fishing tackle types included a bottom-set net with a mesh size of more than 45 mm (5,435 fishing days), a casting rod/trolling lure (3,081 fishing days), and hook and line (2,028 fishing days).

Approximately 30% of the households also fished in the wintertime. Forms of winter fishing included ice, net, and hook fishing.

The average total catch per household was 86 kg and the cumulative total catch was approximately 78,500 kg. The most frequent species of fish caught were perch (23%), sea-spawning whitefish (23%), and common whitefish (16%). Other common species were pike, roach, and carp bream.

Impact of cooling water intake

The impact of the operation of the nuclear power plant on fishery has been assessed by fish and water research company Kala- ja vesitutkimus Oy in 2014. The impact of cooling water intake on fish stocks and fishery, presented in this section, are based on an impact assessment report (Karppinen et al. 2014) and its supplements.

Most of the fish pulled into the cooling water intake channel will be small, young individuals and small species moving in schools. Newly hatched fry drifting with water columns are particularly susceptible to ending up in the water intake channel. All the fish species found in the area usually get drawn into the water intake structures of a power plant, and the number of fish generally increases with the increase of the water volume.

At the Swedish nuclear power plants around the Baltic Sea, 14–29 million fish (25,000–51,000 kg) are annually drawn into the water intake channels. The volumes have been lower at the Finnish Olkiluoto nuclear power plant, approximately 6 million fish (11,000 kg) per year. This translates to 3.3–8.3 individuals per 1,000 m^3 of cooling water. The size of the fish ending up in the intake channels is similar at all the plants, and the majority of the fish are very small.

The number of fish seems to increase as the regional plankton production increases, towards the south. Based on these considerations, the volume of fish expected to be drawn into the cooling system of the Hanhikivi 1 nuclear power plant has been estimated to remain considerably lower than at power plants in southern Sweden, and somewhat lower than at Olkiluoto (3.3 individuals per 1,000 m^3). If the number of fish ending up in the cooling water channel of the Hanhikivi 1 nuclear power plant was, for example, two individuals per 1,000 m^3 of cooling water, the annual fish volume would be approximately 2.8 million individuals or 4,800 kg.

Species that undergo a pelagial juvenile phase are at particular risk of being drawn into the water intake channel. Many of the species common in the Pyhäjoki sea area are such species, such as Baltic herring, whitefish, vendace, lesser sand eel, and gobies. Adult fish and small species also get drawn into the cooling water channel. The fish species most commonly found in the water intake channels at the nuclear power plants mentioned above has been the three-spined stickleback. Large amounts of Baltic herring and smelt also end up in the plants. Other common species include ninespine stickleback, perch, straightnose pipefish, and ruffe. All these are likely to end up in the water intake channel also at Hanhikivi 1 nuclear power plant. Most of the fish drawn into water intake channels are small fish living in large schools, and small fry that have a high natural death rate. Young graylings may also occasionally end up in the water intake channel, most of which are likely to be individuals planted in the sea area. To mitigate the negative impact, an escape pipe for fish is being designed for the plant. It will set some of the individuals free. The impact of the lost fry on the fish stocks and catch in the area is assumed to remain minor and local.

Impact of cooling water discharge

The impact of cooling water discharge on fish stocks and fishery, presented in this section, is mainly based on the impact assessment report by fish and water research company Kala- ja vesitutkimus Oy (Karppinen et al. 2014).

Impact on fish

The tolerance of fish to temperatures and temperature variations differs between species and stages of growth. Adult fish and juveniles above the fry stage tolerate temperature changes better and can move to other locations if the temperature becomes too high. Smaller juveniles and newly hatched fry and eggs, in particular, are more sensitive to temperature and are not able to avoid the direct impact of the nuclear power plant's warm discharge water. The changed conditions are most likely to benefit species that are able to tolerate temperature fluctuations. The detrimental impact will be largest for species that have adjusted to cold waters and the eggs of which develop in cold waters during the winter or require cold water to develop (e.g. grayling; Keränen 2015). The season, weather conditions, and wind direction have a significant impact on the spreading of cooling water around the Hanhikivi peninsula. According to simulations (Lauri 2013), the impact of warm cooling water will be greatest, and reach the most extensive area, in the surface layer of the water (0–1 m). Temperature increases are not commonly observed at a depth of more than four meters. The total scope of the cooling water impact area was estimated in the fishery impact assessment by combining the surface area data and spread maps of the simulation report (Lauri 2013) and by dividing the area into three zones based on the intensity of the impact. At the mouth of the discharge channel, in an area of 0.03–0.19 km² (3–19 ha), the temperature will remain fairly consistently approximately 10°C higher than in the surrounding area (intense thermal impact). Within this area, most fish will be repelled due to the high temperature, particularly in the summer season. The reproduction of fish in this area is not likely to succeed.

A temperature increase of 3°C or more will be observed in the surface layer (0–1 m) in an area of approximately 4 km² (high thermal impact). Fish move in this area regularly but are likely to be repelled at least during the warmest summer season. The increased temperatures and temperature fluctuation may cause problems with the reproduction of sensitive species and kill eggs. The reproduction of whitefish and vendace, for example, is likely to be disturbed in this area.

The size of the total impact area where a minimum temperature increase of 1°C can be observed in the surface layer, at least occasionally (the low thermal impact area) will be approximately 40 km². The area in which the temperature of the surface layer increases by at least 1°C will, however, always be smaller than the total impact area, and will vary between 5–19 km² within the total impact area. The shape, location, and surface area of the warmed water area, as well as the intensity of the thermal impact (temperature increase) will vary continuously depending on the weather conditions and the season. The spreading and cooling of the warm water is generally efficient around the Hanhikivi peninsula due to the open, windy sea and the good water turnover rate.

However, there are extensive, very shallow coastal waters favored by fry where the impact of the warm cooling water will be intense. Based on the typical winds prevailing in the sea area of the Hanhikivi peninsula, the warm cooling water will mostly spread to the north and east into Kultalanlahti Bay, where good growth conditions for fry and even adult fish may occur under favorable weather conditions. However, the temperature of the water in Kultalanlahti Bay may become too high for fish in hot summer weather. Eutrophication caused by the temperature increase will probably remain small around the Hanhikivi peninsula due to the low nutrient levels and poor primary production in the area. Increased primary production may have a positive impact on the food volumes available to fish as benthic fauna production improves over a more extensive area. On the other hand, nutrient loads enter the area from the catchment area of the Pyhäjoki river, for example, and as the primary production increases, these nutrients will be recycled more efficiently in the local ecosystem. This may lead to intensified eutrophication, particularly in shallow areas near the coastline that will be regularly subjected to the thermal impact.

The species most likely to benefit from the changed conditions via faster growth are perch and various Cyprinidae, as well as pike that feed on these species. Fish species that may experience increased populations in the area include pike-perch, which is currently not very common in the area.

Baltic herring will be able to reproduce in the cooling water impact area, but there will be a high risk of increased mortality of fry that hatch too early in the spring if spawning happens early due to the increased temperatures. The impact of cooling water is likely to be stronger for whitefish and vendace, which have adjusted to cold waters and spawn in the fall. Their fry production is likely to suffer. Furthermore, the grayling may become more common in the sea area. The warm cooling waters are likely to cause changes to local fish stocks and the species distribution in the area. Local changes may be large, but in the scale of the entire Bothnian Bay, the impact is expected to remain very low.

Impact on fishery

The operation of the nuclear power plant will have a variety of impacts on both commercial and recreational fishing. Fishing may be prevented or rendered more difficult, and the species distribution and fry production may change. As a whole, the impact on fishing activities is estimated to be large in the area where the thermal impact of cooling water will be high. The impact will gradually reduce as the distance from the Hanhikivi peninsula increases. The impact on fishing will mainly be negative, but positive effects, such as improved growth of fish, may also occur.

A movement restriction area will be established around the nuclear power plant. Due to the movement restriction zone, fishing in the net and fyke net areas along the Hanhikivi peninsula shoreline will end. Recreational fishing from the shore will also be prevented. As a result of the discharge of cooling water, the immediate water area around the discharge location at the tip of the Hanhikivi peninsula will remain unfrozen. According to simulations, there will be strong annual variation in the size of the unfrozen area and the area where ice will be thin. However, ice fishing in the winter fishing areas off the Hanhikivi peninsula and Kultalanlahti Bay is expected to end. Similarly, thinning of ice will prevent ice fishing from time to time in more distant areas (Figure 2-4). Fishing in the unfrozen area is also likely to be impossible after the sea has frozen over, as boats will not be able to easily access the area. Because winter fishing will be prevented, fish that may be attracted by the warm cooling water will most likely not be fully utilized. The impact or the establishment of a movement restriction area and the deterioration of the ice cover is estimated to be high.

The restricted area will have an impact on some commercial fishermen operating in the vicinity of the Hanhikivi peninsula, as well as recreational fishermen. The limitations to winter fishing, on the other hand, will have an impact in a more extensive area and on a larger number of both commercial and recreational fishermen. The thermal load to be discharged into the sea will increase eutrophication near the Hanhikivi peninsula, which may increase the accumulation of slime in various types of netted fishing gear. Increased accumulation of slime will require more frequent cleaning of the gear. This will have an impact on the amount of work required for fishing operations, and thus the profitability of fishing. It is also possible that as eutrophication increases, the portion of unwanted fish species (e.g. Cyprinidae and ruffe) in the catch will increase. Increase in unwanted catch volumes will add to the workload of fishermen and thus weaken the profitability of fishing operations.

Fishing may also be rendered more difficult by potential changes to the living areas and migration routes of fish, brought on by the changing conditions. It is possible that traditional fishing areas will no longer yield a sufficient catch, or that fish will be found in these areas at untypical times, making it necessary to find new fishing areas or change fishing schedules. Acquiring new fishing areas is often a challenge. Permits may be difficult to acquire, and typically the distances will get longer, which will be reflected in fuel costs and working hours. The impact of changes to the living areas of fish and the difficulties in acquiring new fishing areas is estimated to be moderate or high. The impact of the increased need to clean fishing gear is estimated to be low. The effects will be targeted at an area extending to several kilometers from the Hanhikivi peninsula. The effects will gradually decrease as distance from the peninsula increases. The effects will affect several commercial fishermen as well as recreational fishermen.

Changes will take place in the distribution of fish species within the cooling water impact area. Changes in species distribution are generally diverse and complicated processes that happen over a long period of time. The intensity of changes will vary between different parts of the impact area. A general tendency is that Perciformes and Cyprinidae benefit from the warming of waters and cold water species suffer. The total catch in the cooling water impact area will probably increase, but the portion of the currently important species will decrease.

The most important current commercial fishing species are cold water species, such as sea-spawning whitefish and common whitefish, which together form 60–70% of the commercial fishermen's catch. Whitefish are sensitive to changes and likely to react strongly to disturbances and the warming of the water. Fishing for whitefish with fyke nets will end at the area of the strongest impact, at the tip of the Hanhikivi peninsula, but fishing with nets will probably move to new areas at an increased distance of the cooling water discharge area.

Fishing of perch is likely to increase in the area. As a consequence of the warmer water, perch will grow faster and are also likely to become more abundant in the area. It is also possible that the local pike-perch population, which is currently small, will become larger. Most of the effects listed above are positive. On the other hand, the increase in Cyprinidae populations in the area would render fishing more difficult. The operation of the nuclear power plant will also have an impact on the fry production of various fish species (cooling water discharge) and the mortality of fry (cooling water intake and discharge).

The negative impact of the changes in fish populations on fishing is estimated to be high. The positive impact is estimated to be moderate. The effects will be targeted at an area extending to several kilometers from the Hanhikivi peninsula. The effects will gradually decrease as distance from the Hanhikivi peninsula increases. The effects will affect several commercial fishermen as well as recreational fishermen.

Routes of migrating fish and access of fish into spawning rivers

Routes of migrating fish in the Bothnian Bay

Migrating fish found in the Bothnian Bay include sea-spawning whitefish, salmon, trout, and river lamprey. Migrating grayling is also considered a migrating fish according to the Fishing Act. This section contains a description of the populations of these migrating fish in the Hanhikivi peninsula sea area and the timing of their migration, as well as an assessment of the impact of the operation of the nuclear power plant on their routes and access to their spawning rivers.

River-spawning common whitefish can be found in the Hanhikivi peninsula sea area. Common whitefish are generally larger than sea-spawning whitefish. In the Bothnian Bay area, common whitefish are found in several rivers, particularly in the Kiiminkijoki, Simojoki and Tornionjoki rivers. In the lower sections of the Pyhäjoki river, adult whitefish that come to the river to spawn yield a good catch every year. Plenty of newly hatched common whitefish fry are released into the Pyhäjoki river and the sea area near it. These fish are farmed at a hatchery in Pyhäjoki (Perämeren kalatalousyhteisöjen liitto 2021). Natural reproduction may also take place in the Pyhäjoki river (e.g. Karppinen et al. 2014, Happo et al. 2021.)

Common whitefish fry leave the river to migrate to the sea soon after hatching, when they are a few centimeters long, in the early summer or later in the summer (Leskelä et al. 1991, Lehtonen & Himberg 1992). According to Leskelä (2006), migration of the fry to the sea takes place in shallow coastal waters. The common whitefish stocks of rivers emptying into the Bothnian Bay may migrate further into the Gulf of Bothnia or even to the Archipelago Sea to feed, only to return to their reproduction or planting areas (Lehtonen and Himberg 1992). Some common whitefish only migrate within the Bothnian Bay. Common whitefish males achieve sexual maturity at the age of four or five, and females at the age of five or six, at which time they migrate from the feeding areas towards their spawning rivers (Leskelä 2006). Migration of the common whitefish to various spawning rivers takes place at different times. Migration into the large rivers emptying into the Gulf of Bothnia, such as the Tornionjoki river, mainly occurs between the end of July and October (Lehtonen and Himberg 1992). Migration into smaller rivers, such as the Kiiminkijoki and Simojoki rivers, takes place in September and October.

There are both planted and regular river-spawning common whitefish, the latter of which breed in the local rivers, in the sea area off the Hanhikivi peninsula. According to a commercial fisherman operating in the area (e.g. Karppinen et al 2014), common whitefish migrate into the area starting from the end of June.

Earlier, when the use of drift nets was still allowed in whitefish fishing, fishing with drift nets took place off Yppäri, approximately 10 kilometers from the coast. The net haulers followed the whitefish schools to Maanahkiainen. Migrating fish passed the Hanhikivi peninsula in the surface layer of water areas more than ten meters deep. On this basis, it can be assumed that whitefish coming from rivers in the north migrate along routes located 5–10 km from the Hanhikivi peninsula (Fig. 2-6; Karppinen et al. 2014).

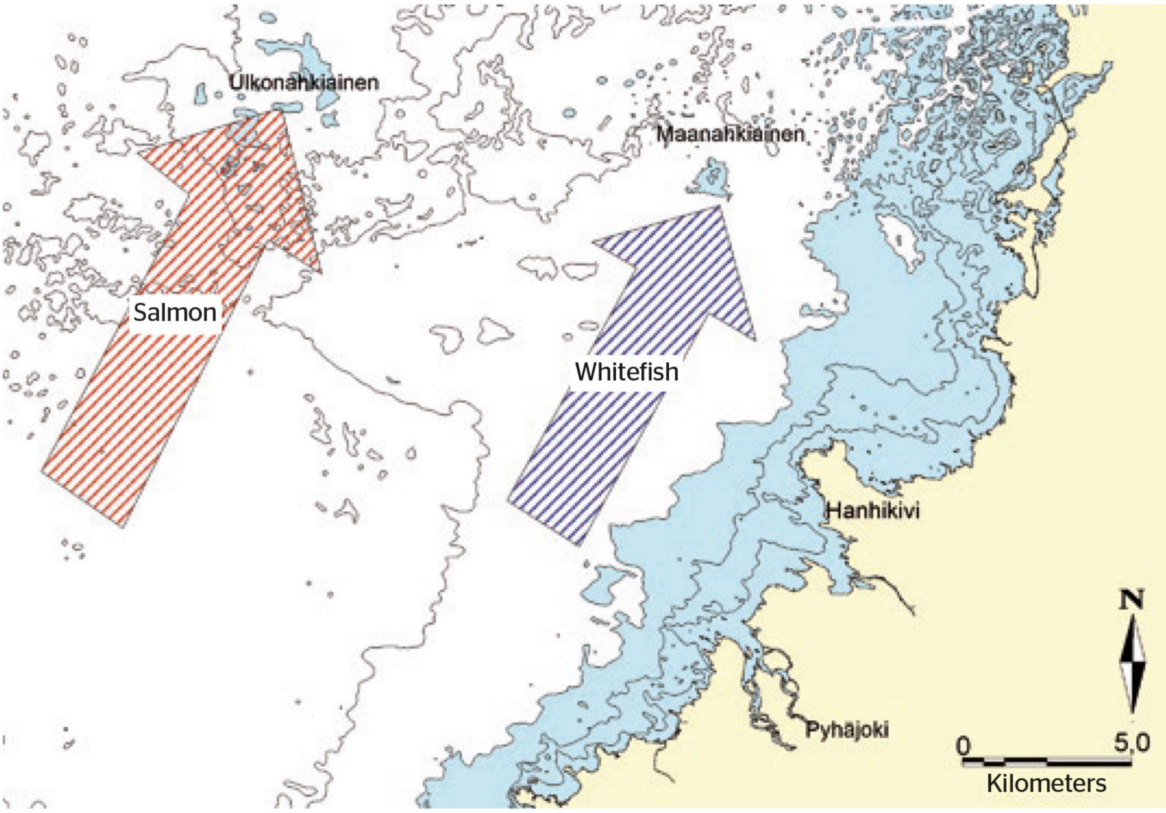

Figure 2-6 According to interviews with commercial fishermen, the main migration routes of whitefish and salmon to the rivers in the north are located fairly far from the shoreline, in waters at least 10 meters deep, close to the surface (Karppinen et al. 2014).

The most important spawning rivers of wild salmon in the Finnish part of the Bothnian Bay are Tornionjoki and Simojoki. Some natural reproduction of the Tornionjoki and Oulujoki salmon population may also occur in Pyhäjoki (Ministry of Agriculture and Forestry 2014). Salmon spawn in September and October on gravel bottoms in locations with a strong current. Salmon fry spend an average of two to four years in rivers and then migrate to the sea to feed (Haikonen et al. 2006). Salmon hatched in the rivers emptying into the Bothnian Bay migrate to the sea between the end of May and early July (Jutila et al. 2005).

Salmon migrating to spawn are found in the Bothnian Bay starting from May. The main migration in the sea area takes place in June, but significant numbers of fish also migrate in July and August (e.g. Niva 2001, Siira et al. 2009). In the Tornionjoki river, the migration peak is in late June, around Midsummer, but migration continues until the end of summer. Some salmon are caught in the sea even in September, during whitefish fishing (Siira et al. 2009).

Migration of salmon back to their hatching rivers takes place in the warm water layer close to the surface, at a depth of 2–3 meters (Karlsson et al. 1999). Migration has been observed to occur in a narrow strip parallel to the coastline (Westerberg et al. 1999). There is annual variation in migration routes, and migration is regulated by the water temperature and the prevailing winds (Westerberg et al. 1999). In the Bothnian Bay, salmon generally prefer to migrate along the shallower Finnish coast, which will warm up more quickly. However, migration also takes place along the Swedish coast if the water is warm enough. During weak or northerly winds, salmon have been observed to migrate further from the Finnish coastline.

According to commercial fishermen, salmon migrate both in the outer sea area and close to the Hanhikivi peninsula. Most of the salmon in the Hanhikivi peninsula area migrate towards the north, but not close to the shore where the fyke nets are placed (Taskila 2009). The salmon catches in the area are therefore rather small (around 200 kg in 2019; Karppinen et al. 2020). Very few Carlin tags of salmon are returned from the Pyhäjoki area (Natural Resources Institute Finland (LUKE), fish tagging register), and the tag returns are mostly from fish planted in the Pyhäjoki river. Salmon planted in northern rivers have represented a small minority in the tag returns from the Pyhäjoki area in the last 20 years. There have been no tag returns since 2014 (Natural Resources Institute Finland (LUKE), fish tagging register).

There is only little research-based information about smolt migrating in the sea area. According to Ikonen (2006), young salmon migrating in the sea, post-smolt, travel southwards along both Finnish and Swedish coastlines, as the water near the coast warms up more quickly than in the deep sea area. South of the Kvarken, migration of post-smolt mainly takes place along the Swedish coast. A very small portion of Carlin tag returns (11 returns) of post-smolt have come from the surveyed area in the last 20 years, and all the returned tags have been from fish planted in the Pyhäjoki river (Natural Resources Institute Finland (LUKE), fish tagging register). There have been no returns since 2014. In trawling surveys carried out in summer 2014, two smolts, most likely hatched from natural spawning, were caught off the Hanhikivi peninsula (Haikonen et al. 2014). Based on information recorded in the survey fishing register, some minor natural reproduction of salmon has been observed in the Pyhäjoki river. The smolts that have been found may, however, have come from other salmon rivers that empty into the Bothnian Bay.

Sea trout, like salmon, reproduce in strong currents and migrate to the sea after spending an average of 3–5 years in the river (Haikonen et al. 2006). The trout usually stays close to the shore and does not migrate as great distances as the salmon does (Lovikka et al. 2006, Ministry of Agriculture and Forestry 2014). Sea trout from the Bothnian Bay have been observed as far as the Archipelago Sea, but most of them remain in the Bothnian Bay. The sea migration of sea trout normally takes 1–4 years, after which it returns to its hatching river to spawn (Haikonen et al 2006, Ministry of Agriculture and Forestry 2014). Few of the sea trout in the Bothnian Bay originate from natural spawning. Plenty of sea trout fry are planted in the Bothnian Bay area, also resulting in large sea trout catches in the sea area off Pyhäjoki. Based on Carlin tags (Natural Resources Institute Finland (LUKE), fish tagging register), plenty of fish planted further away, mostly in rivers in Ostrobothnia and northern Finland, are caught in Pyhäjoki. Trout come closer to the shore than salmon in the Pyhäjoki sea area, and trout are caught all year round. However, only a small number of tag returns have occurred since 2014.

The spawning of **river lamprey** takes place in May and June. Sexually mature river lampreys usually rise into rivers already between August and October of the previous year, but migration takes place later as well (Natural Resources Institute Finland 2021 (LUKE), fish observations). Soon after spawning, the river lamprey will die. Protected by a layer of gravel, the eggs of river lamprey develop for a period of two to three weeks. River lamprey larvae, or fry (ammocoetes), spend their first years in the sand and mud bottoms of riverbanks. The fry stage takes from four to seven years. Migration of river lamprey into the sea occurs during spring floods. The sea stage has been estimated to usually last from the spring to the fall in the next year, but based on tagging, some river lamprey seem to rise back to the rivers to spawn already in fall of the same year. During their first summer in the sea, young river lampreys move widely in the river. There is little information on how river lampreys move in the sea at other times. In the sea, river lampreys eat bottom fauna and fish, for example. Suction marks left by river lampreys have been observed on fish such as Baltic herring, sprat, smelt, and vendace. (Natural Resources Institute Finland 2021 (LUKE).)

Within the surveyed area, river lampreys reproduce in at least the Pyhäjoki and Liminkaoja rivers. Pyhäjoki river has been classified as a very important river lamprey spawning river (Oikarinen 2012). In addition to the Pyhäjoki river, fishing of river lamprey takes place in the lower section of Liminkaoja. The largest catches of river lamprey come from the Pyhäjoki river in September and October. There is no information of the migration of river lamprey around the Hanhikivi peninsula. In 2019, commercial fishermen caught 300 kg of river lampreys (Karppinen et al. 2020). Table 2-3 presents a summary of the migration timing of salmon, trout, whitefish, river lamprey, and grayling, and their populations in the sea area off the Hanhikivi peninsula.

Table 2-3. Timing of the various stages of migrating fish found in the surveyed area (edited from Karppinen et al. 2014).

Species	Spawning period	Spawning in the area	Timing of juvenile migration	Spawning migration	Populations in the area
Salmon	October	Pyhäjoki (minor)	May–June	June–August	in connection with migration, fairly common
Sea trout	October	Pyhäjoki (minor)	May–June	June–August	all year round after the juvenile river stage, common
Common whitefish	October–November	inadequate data, possibly Pyhäjoki	May–June, planted in large numbers in spring	June–October	in connection with migration
River lamprey	May	Liminkaoja	probably in the spring, inadequate data	August–November, probably also in winter	found, little data about life in the sea
Grayling	May–June	Liminkaoja, maybe the sea	inadequate data	inadequate data	occurs, some planted

The critically endangered **grayling** occurs in the sea area off the Hanhikivi peninsula in Pyhäjoki. Based on the survey, the entire coastal area between Yppäri and Raahe is a grayling feeding area. This area includes the shore area of the Hanhikivi peninsula where feeding grayling occur, according to test fishing. Grayling migrating in the sea to feed are known to rise up the Liminkaoja river to spawn. However, the existence of a grayling population that spawns in the sea off the coast of Pyhäjoki has not been verified with certainty on the basis of the studies carried out in 2012 and 2016 (Karppinen et al. 2016, Karppinen et al. 2020). The grayling population is and will be monitored using several methods.

No direct observations regarding the spawning of grayling have been made and no newly hatched fry have been observed, despite the fact that there are areas potentially suitable for fry production. The spawning areas reported by fishermen are based on the occurrence of graylings ready to spawn in the area. Fish preparing to spawn or recently spawned fish were also caught during test fishing in the Hanhikivi peninsula in spring 2016. It is possible, however, that these specimens were ones that spawn in the Liminkaoja river. Specimens that spawn in rivers typically return to the sea soon after spawning. Future transmitter monitoring will provide more information on the migration behavior of the sea-migrating graylings and their feeding areas in the Hanhikivi 1 project's impact area (Karppinen et al. 2020).

Grayling fry have been planted in the area off the coast of Pyhäjoki, an extensive area in the Bothnian Bay, and in the rivers emptying into the Bothnian Bay during several decades. Several grayling populations were previously used in the planting, but in the 21st century, grayling from the Ulkokrunni population have been planted in the sea area and off the coast of Pyhäjoki. There is no information on the success of the planting, but it is justified to assume that there are both naturally spawning graylings and planted graylings in the sea area off the coast of Pyhäjoki. Therefore, it is likely that there are several different grayling populations in the sea area off the coast of Pyhäjoki and in the rivers emptying into this area, and that these populations may consist of specimens of different origins (Table 2-4; Karppinen et al. 2020).

Table 2-4. Grayling populations that may occur off the coast of Pyhäjoki (Karppinen et al. 2020).

Grayling population	Occurrence	Origin
sea-spawning grayling population	occurs/has extensively occurred in the surveyed area (planted sea-spawning grayling), but no verified natural spawning	no verified natural population; planted
river-spawning (anadromous) grayling populations	occurs in Liminkaoja and possibly in other rivers in the area, feeds in the sea area	natural population at least in Liminkaoja; some of the migrating graylings may also be planted
local grayling populations living in rivers	occurs in several rivers emptying into the area	planted; natural population

On the basis of fishing surveys, some graylings have occurred in the area for decades; the annual catch has varied between 4 and 39 kg (Karppinen et al. 2016). The observations are focused in the Piehinkijoki area to the south of Raahe and the sea area to the south of Pyhäjoki. Some graylings were caught during electric test fishing in 2020 at the Liminkaoja river (Haikonen & Vatanen 2020).

Impact on the routes of migrating fish and on their access to spawning rivers

There are no significant salmon or trout spawning rivers in the surveyed area, but reproduction on a small scale may take place in rivers such as Pyhäjoki or Liminkaoja. Migration routes of common whitefish, salmon, and sea trout run along the coastline, and there are also planted graylings and feeding river-spawning graylings in the area (e.g. Karppinen et al. 2016). Large numbers of common whitefish are planted in the Pyhäjoki river and the sea area near the Hanhikivi peninsula. Fishing of common whitefish, salmon, and sea trout takes place in the surveyed area, including the immediate vicinity of the project location. (Karppinen et al. 2014.)

Trout thrive in cool waters, and generally avoid temperatures of over 20°C. The migration of trout and salmon in rivers has been observed to come to a total standstill when the water temperature exceeds 20°C. Salmonids have also been observed to go around any warm water along their migration route and then continue the migration. The spread of warmed cooling water in the sea area off the Hanhikivi peninsula may thus slow down the migration of fish passing through the area on their way towards the spawning rivers in the Bothnian Bay. Most of the northbound migration routes of salmon and whitefish are, however, located at a greater distance from the shoreline of the Hanhikivi peninsula. Thus, the Hanhikivi 1 project is not expected to have a significant impact on the migration of fish towards the north. It can also be assumed that the project will have no impact on the migration of post-smolt, with the exception of any fish coming from the Pyhäjoki river, some of which could be drawn into the cooling water intake channel of the nuclear power plant. The operation of the nuclear power plant may have an impact on the feeding behavior of sea trout, whitefish and grayling feeding in the vicinity of the Hanhikivi peninsula. Salmon, on the other hand, do not feed during their spawning migration (Karppinen et al. 2014).

The grayling is more susceptible to high temperatures than the trout or salmon. Graylings are able to tolerate a temperature of 0–24°C, but 4–18°C is considered to be the ideal range for growth. The ideal temperature for the development of spawn is 10°C, and it has been observed that the spawn will die if the temperature exceeds 16°C. Grayling fry areas have been observed to be colder than the other sea areas, which makes them different from the fry areas of other fish species. The graylings go farther out to the sea once they have reached the length of a couple of centimeters. There is hardly any research data on the habitat requirements of the grayling outside the spawning season, but data will be obtained from the Hanhikivi peninsula area in connection with future surveys (Karppinen et al. 2020). It is safe to assume, however, that the grayling moves and feeds in the outer archipelago in areas where there is a sufficient amount of food suitable for the grayling, and there are such feeding areas along the shores of the Hanhikivi peninsula. River-spawning graylings usually come back into the sea after spawning, where they mostly stay in coastal areas with rocky bottoms and in shallows with deep slopes (Keränen 2015). Natural reproduction of the grayling has not been observed in the Hanhikivi peninsula sea area, which means that the operation of the nuclear power plant will likely not influence the reproduction of the grayling. The thermal impact from the operation of the plant may have a slight negative impact on the migration of river-spawning graylings to their spawning rivers and the movements of feeding graylings as they avoid the warmer areas. The impact on grayling is also discussed in sections “Impact of cooling water intake on fish stock” and “Impact of cooling water discharge on fish stock”.

Charophyte meadows and bottom dominated by submerged macrophytes

Aquatic vegetation in the Hanhikivi peninsula area was last studied in 2018 (Syväranta & Leinikki 2019). The applied research method was the main zone line method, which was also the method used in the survey in 2014 (Syväranta et al. 2014). In the extensive surveys in 2014 and 2018, aquatic vegetation was surveyed at 15 locations in the area between the Hanhikivi peninsula and Lännennokka, as well as at five locations in a reference area in Ulko-Harmi of Yppäri (Figure 2-7). The research results and impact assessment presented in this section are mainly based on the 2014 and 2018 research reports.

The Yppäri reference area is located approximately 13 kilometers to the south from the Hanhikivi peninsula and has a similar seabed and open environment as the Hanhikivi peninsula. Extensive brackish water bays open on the east side of both peninsulas, allowing comparison of vegetation. The survey paid particular attention to endangered species and habitat types, the most probable of these being charophyte meadows.

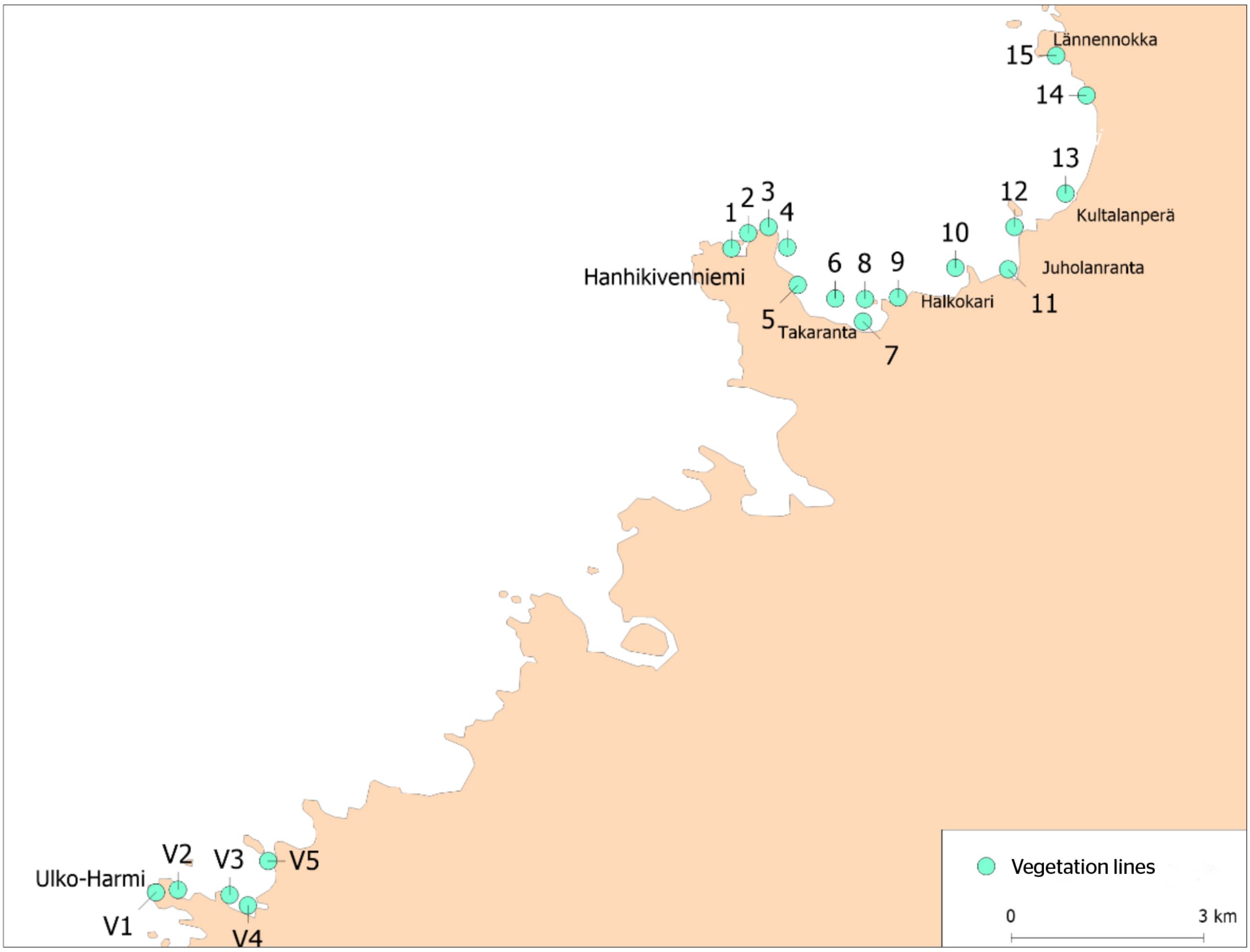

Figure 2-7. Aquatic vegetation survey lines 1–15 between the Hanhikivi peninsula and Lännennokka, as well as reference lines V1–V5 in Yppäri (Syväranta & Leinikki 2019).

Occurrence of charophyte meadows and bottom dominated by submerged macrophytes

A total of 30 vascular plants, five species of Charophyta, and two species of hard bottom algae were observed along the survey lines of the aquatic vegetation surveys (Syväranta & Leinikki 2019). The most common species of Charophyta was the rough stonewort *(Chara aspera)*. The charophyte meadows also included fragile stonewort *(Chara globularis)* and delicate stonewort *(Chara virgata)*. Both of these are common in the low-saline brackish water of the Bothnian Bay. Bird's nest stonewort *(Tolypella nidifica)* and other species of stonewort *(Nitella spp.)* were also observed.

The most common vascular plants were claspingleaf pondweed *(Potamogeton perfoliatus)*, lesser pondweed *(Potamogeton pusillus)*, slender-leaved pondweed *(Potamogeton filiformis)*, fennel pondweed *(Stuckenia pectinata),* and horned pondweed *(Zannichellia palustris)*. Water milfoils *(Myriophyllum spp.)*, which thrive in shallow bays, were considerably fewer in number than pondweeds. Observed species of hard seabed algae were Cladophora glomerata and marimo

(Aegagropila linnaei). Charophyta were observed along a total of 15 lines in the surroundings of the Hanhikivi peninsula and four lines in the Yppäri reference area. Nine lines could be classified as charophyte meadows.

The only endangered species observed during the survey was the long-beaked water feather-moss *(Rhynchostegium riparioides)*, which grows in the Yppäri reference area. The species was also observed during the previous survey of 2014, although along a different line. The species is included in class near threatened (NT), in the Red List of Threatened Species.

In the new assessment of the conservation status of habitat types, charophyte meadows are divided into open and sheltered charophyte bottoms (Kontula & Raunio 2018). The former is vulnerable (VU) in the whole of Finland and the latter is endangered (EN). In the case of northern Finland, there is not enough information on the prevalence of or threats to the habitat type to determine its status.

A phytocoenosis was classified as a charophyte meadow if the coverage of the dominant plant taxon was more than 10% of the surface area. This complies with the HELCOM (Baltic Marine Environment Protection Commission – Helsinki Commission) Underwater Biotope and Habitat Classification System (HELCOM 2013). The studied areas mainly represent charophyte meadows, as there are relatively few underwater plants when compared to Charophytes (Syväranta & Leinikki 2019). Charophyte populations in the bay to the east of the Hanhikivi peninsula are representative. There have been no major changes in their abundance since 2014. The most representative charophyte meadows are still located in the same area, in Takaranta to the east of the Hanhikivi peninsula, where the openness, the quality of the seabed, and the shoreline profile are optimal for charophyte meadows. Charophytes do not thrive as well in the steep and rocky shores of the Hanhikivi peninsula (lines 1–4) or in the northern part of the research area (lines 11–15), which are too open and too susceptible to the impact of waves (Fig. 2-7).

Data has been gathered on the distribution and frequency of aquatic vegetation and the occurrence of habitat types has been modelled in the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). Figure 2-8 presents the survey and modelling observations in the sea area off the coast of Hanhikivi peninsula and in its immediate vicinity. There are plenty of charophyte bottoms in the project area, and the populations are abundant especially in the Takaranta area, which was also determined on the basis of the aquatic vegetation surveys (Syväranta & Leinikki 2019).

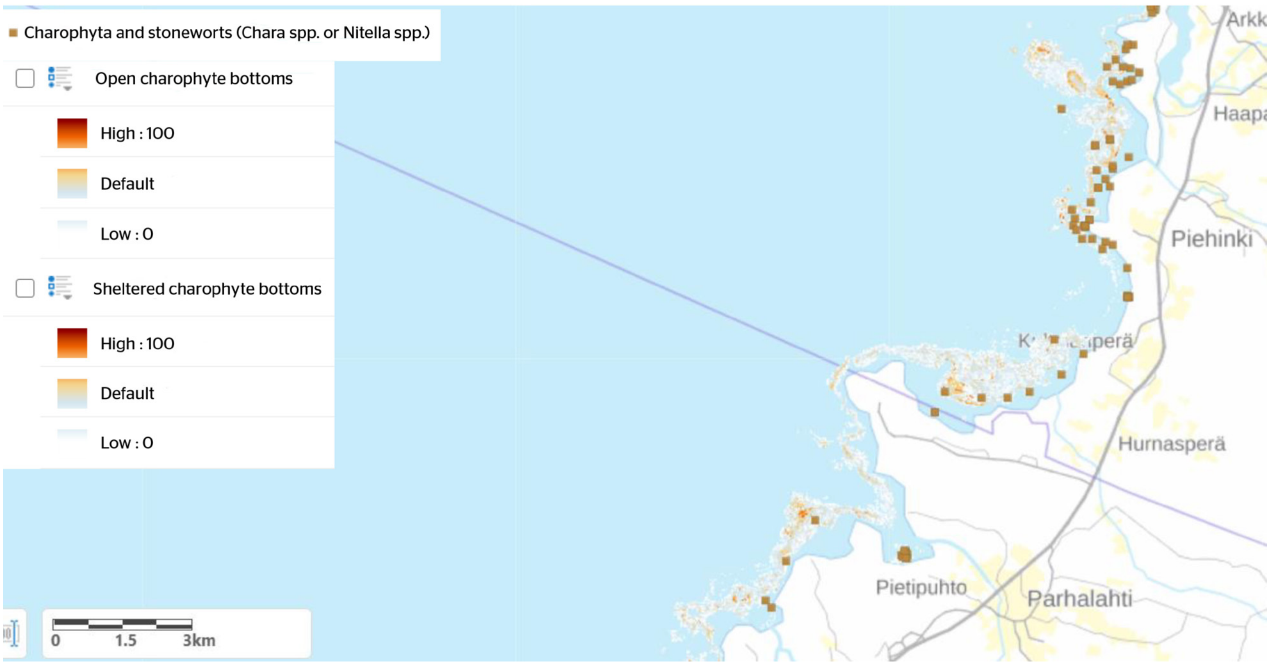

Figure 2-8. Modelled occurrence of open and sheltered Charophyte bottoms off the coast of Hanhikivi peninsula and Charophyte observations made during VELMU surveys (VELMU map service 2021).

Impact on charophyte meadows and bottom dominated by submerged macrophytes

Aquatic vegetation to the north and east of the Hanhikivi peninsula mainly consists of various pondweeds and Charophyta. The two most common species are the rough stonewort *(Chara aspera)* and the claspingleaf pondweed *(Potamogeton perfoliatus)*. Extensive charophyte meadows grow between the Hanhikivi peninsula and Halkokari. The most abundant populations were found in lines 6–8 in the shore section of the Takaranta seashore meadows (Fig. 2-7).

Myriophyllum and other vascular plants will benefit from the temperature increase. Their populations are likely to grow between the Hanhikivi peninsula and Halkokari. Pondweeds will also benefit from the temperature change and are expected to become more abundant. A long period of frozen sea is typical in the Bothnian Bay. If the erosive impact of pack ice on vegetation decreases in the Kultalanlahti Bay area, perennial aquatic mosses may become more abundant in shallow waters. Eutrophication, dredging, and water construction works are considered to be the reasons why bottom dominated by submerged macrophytes has become an endangered habitat type (Raunio et al. 2008). Water construction works and dredging destroy seabed plants directly and via increased turbidity, or the habitat may deteriorate as the water depth increases. Eutrophication accelerates the growth of filamentous algae, which attach to submerged vegetation, prevent light from reaching them, and thus slow down their growth. Floating mats of filamentous algae also destroy benthic fauna.

The thermal load discharged from the nuclear power plant will cause mild eutrophication, but no aggressive growth of filamentous algae is expected to occur. Rather, the mild eutrophication and longer growth season are likely to increase submerged plant populations. The dredging and water construction works for the nuclear power plant project will cause at most limited and temporary damage to submerged plant populations. It has been estimated that the conditions required by bottom dominated by submerged macrophytes will improve around the Hanhikivi peninsula as the temperature of the seawater increases, but the species distribution in the habitat type may change.

Threats to charophyte meadows include eutrophication and the overgrowth of habitats (Raunio et al. 2008). Temperature increases are known to have impacts similar to those of eutrophication (Løvendahl Raun 2013). The increased seawater temperature may thus have a similar impact on charophyte meadows. Charophyte meadows are most likely to suffer in the area between the north tip of the Hanhikivi peninsula and Takaranta, along vegetation survey lines 1–6 (Figure 2-7). To the east of Takaranta, along vegetation lines 7–15, the impact will be more limited, as the surface water temperature increase in these areas will remain between one and two degrees. This could be obscured by normal annual variation and may not have any negative impact on the frequency of charophyte meadows. A small temperature increase may even improve the growth conditions for Charophyta, as they are naturally found in sheltered bays where the water turnover rate may be low in the summer, and temperatures higher than in the surrounding sea areas. If the temperature increase is too high, however, competition with vascular plants may limit the growth of Charophyta. Charophyte meadows may therefore either suffer or benefit from the temperature increase.

In the Bothnian Bay, vegetation is typically covered by a layer of diatoms. If the temperature increase leads to increased diatom populations, photosynthesis may become difficult for Charophyta. In addition, warm water binds less soluble oxygen than cold water. The high temperature and the low oxygen content of the water column may weaken the formation of the roots and leaves of aquatic vegetation. The extensive Charophyta populations found in the Takaranta area are representative. According to the VELMU modelling, charophyte bottoms are common in the coastal area between Kalajoki and Oulu, which means that any decline in the charophyte meadows of the Hanhikivi peninsula area, the Takaranta charophyte meadows in particular, will not deteriorate the habitat type's protection level as a whole at the regional level.

Habitats Directive biotypes and EMMA areas

According to the modelling of the VELMU project and the survey data, there are several Habitats Directive habitat types in the immediate vicinity of the Hanhikivi 1 project area: reefs (1170), estuaries (1130), and large shallow bays (1160). The Habitats Directive habitat types are habitat types with an extremely small natural area of occurrence or that are in danger of disappearing from the territory of the Community. Their number and protection level are regularly reported to the European Commission.

The most recent report was compiled in 2019, and it was based on data from 2013–2018 and the VELMU modelling.

Most of the reefs at Hanhikivi peninsula are located farther out into the sea, but there are a couple of extremely small reef habitats approximately 2 km to the southwest of the project area (Fig. 2-9). The estuary areas are located to the south of Hanhikivi peninsula in the Pyhäjoki and Liminkajoki river estuaries (Fig. 2-9). Kultalanlahti Bay has been classified as a large shallow bay in its entirety (Fig. 2-10). Species typical to the habitat type large shallow bay include a variety of vascular plants, such as pondweeds and Charophytes, which means that the habitat type partially overlaps with the habitat type charophyte meadow and bottom dominated by submerged macrophytes. Hence, the observations made during the aquatic vegetation surveys and the VELMU modelling can be considered to apply to this habitat type as well.

Figure 2-9. Locations of the estuaries and reefs habitat types in the Hanhikivi peninsula sea area. (VELMU map service 2021).

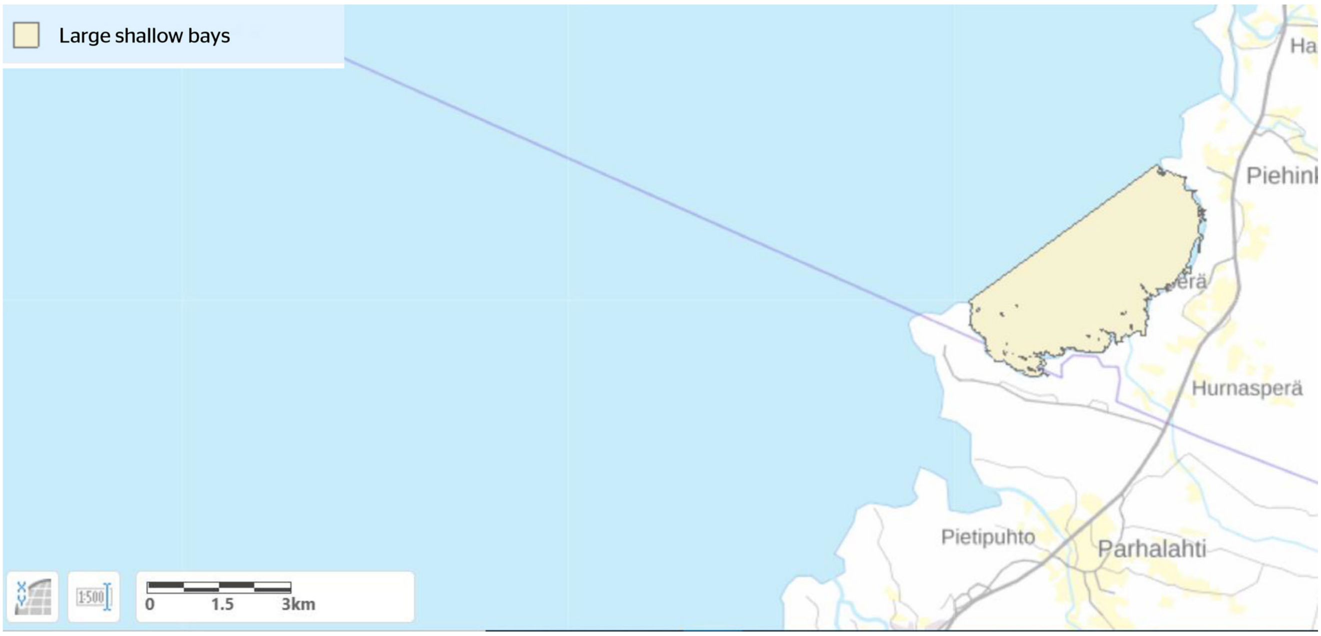

Figure 2-10. Locations of the large shallow bays habitat type in the Hanhikivi peninsula sea area. (VELMU map service 2021).

The Kalajoki-Pyhäjoki area is an EMMA area or an underwater marine nature area of ecological significance in Finland. The area limitations are mainly based on data collected by the VELMU project on aquatic plants, macroalgae, invertebrates, habitat types of the Baltic Sea, geology, and fish spawning areas. The Kalajoki-Pyhäjoki area is important due to its fish stocks, sea-spawning whitefish and vendace in particular, as well as its versatile aquatic vegetation (Lappalainen et al. 2020).

Impact on Habitats Directive habitat types and EMMA areas
The operation of the nuclear power plant is not expected to have any impact on the reefs and estuaries habitat types. The habitat type large shallow bays partly overlaps with the habitat type charophyte meadows and bottom dominated by submerged macrophytes, which means that the impact and the impact mechanisms are the same as described in the section above. Dredging and construction at the shoreline may deteriorate the habitat type's natural state, but the impact is expected to be local. The Kalajoki-Pyhäjoki area is an underwater marine nature area of ecological significance in Finland (an EMMA area) due to its fish stocks. The impact on the fish stock is described in the section on fish stocks.

Objectives and implementation of the marine management plan

Marine management planning is based on the European Union Marine Strategy Framework Directive (2008/56/EC), implemented in Finland by the Act on the Organization of River Basin Management and the Marine Strategy (1299/2004, amended by Act 272/2011) and the Government Decree on the Organization of the Development and Implementation of the Marine Strategy (980/2011).

The marine management plan covers all marine areas in Finland from the shoreline to the outer edge of the exclusive economic zone. For marine management purposes, the Finnish sea area has been divided into sectors. The sectors enable the use of sectors in different scales, depending on the subject matter.

The objective with marine resource management is to achieve and maintain a good status. In the first part of the marine management plan, which was completed in 2012 and has been approved by the Government, the achievement of a good status was set as the objective for 2020. The first part included a preliminary assessment of the current status of the sea, a definition of a good status of the marine environment, environmental objectives, and the related indicators. The first part of the marine management plan set six general environmental objectives to, for instance, reduce eutrophication and the load from harmful substances, protect biodiversity, ensure the safety and environmental friendliness of maritime traffic, and ensure proper marine area planning. The second part, a marine management monitoring program, was completed in 2014. The Government approved the third part, the marine management action plan for 2016–2021, in 2015. The completion of the action plan meant the completion of Finland's first comprehensive marine management plan. The second management period started with a review of the first part of the marine management plan. New environmental objectives have been set for 2018–2024 under the following main themes, which also include supplementary sub-objectives (Finnish Environment Institute 2019):

- **Reduction of nutrient load**
- **Reduction of load from harmful substances**
- Reduction of littering
- **Preventing the spreading of harmful invasive species**
- Sustainability of marine natural resources
- **Nature conservation and restoration**
- Improving knowledge base of marine management
- Marine area planning promotes the achievement of a good status of the marine environment

In its environmental permit application filed in 2015, Fennovoima has defined the marine management plan objectives that are of particular importance for the Hanhikivi 1 nuclear power plant. Below, these key objectives are presented in the form of updated marine management objectives (which are marked in bold in the list above), and the achievement of the objectives during the operation of the nuclear power plant is assessed.

Theme/objective 1: Reduction of nutrient load

General objective: Remaining below the set limit for phosphorus and nitrogen loads, and decreasing the solids load.

Description: In order to achieve a good status in terms of eutrophication, the total phosphorus load in the Finnish sea areas may be a maximum of 3,160 metric tons per year and the nitrogen load a maximum of 79,500 tons per year. The limit has been divided among the sea areas (for the Bothnian Bay, the phosphorus load is 1,400 t/a, and the nitrogen load 33,100 t/a). The objective in terms of organic matter and solids loads is a decreasing trend.

The very low nutrient releases emerging from the Hanhikivi 1 nuclear power plant to the sea will not affect the total regional release volumes. When set in proportion to the load from the Pyhäjoki river alone, the phosphorus load from the power plant (approximately 15 kg per year) remains insignificant. The operation of the nuclear power plant will not conflict with the nutrient release or organic matter and solids reduction objectives.

Theme/objective 2: Reduction of load from harmful substances

General objective: No general objective for the load from harmful substances has been specified. However, more specific sub-objectives for different substance groups and emission sources or routes have been specified.

No substances hazardous or harmful to the aquatic environment, listed in Annexes 1A, B or C of the Government Decree 868/2010 are to be released to the aquatic environment from the Hanhikivi 1 power plant during operation. The operation of the nuclear power plant will not conflict with the objective, as the operation will not lead to releases of harmful substances hazardous to the aquatic environment, and quality standards shall thus not be exceeded.

Theme/objective 3: Preventing the spreading of harmful invasive species

Sub-objective INVASIVE1: The number of species spreading with marine vessels is decreased.

Description: The number of species spreading through marine vessel traffic, in ballast tank water and sediment, as well as attached to the hulls of vessels, will decrease from the previous levels in 2018–2024.

A navigation channel and harbor basin to be constructed along the western shoreline of the Hanhikivi peninsula are required to enable maritime transport serving the Hanhikivi 1 nuclear power plant. The maritime connection will be required for transporting machinery and equipment during the construction of the power plant and during its annual outages as well as, later in the future, for operations such as the transport of spent nuclear fuel. The occurrence of invasive species in the area will be monitored. Different types of power plant structures will be used to prevent any occurring invasive species. Compliance with the Ballast Water Management Convention can prevent the spreading of invasive species. Natural spreading of invasive species or spreading by other means are more likely than spreading due to the marine traffic to the Hanhikivi 1 power plant. Furthermore, the highly local thermal load from the cooling water or the low nutrient load from the power plant are not expected to influence the occurrence of invasive species which are already present in the area.

Theme/objective 4: Nature conservation and restoration

Sub-objective NATURE1: Marine protected areas cover at least 10% of the sea area and create an ecologically unified network.

Description: The target is to achieve the protected area objective of 10% of the surface area achieved in the entire Baltic Sea area and also in marine areas of the Finnish waters by 2020. Furthermore, the protected areas must form an ecologically unified network of conservation areas both in the Baltic Sea and in the Finnish waters.

Sub-objective NATURE2: Converting the marine protected areas into efficient marine nature conservation areas.

Description: The marine protected areas must efficiently protect the elements why the area was established. The stress to which the population and the habitat within the protected areas are subjected must be clearly lower than in the surrounding areas so that the vitality of the population in the area can be protected and the protection level of the species and habitat types is favorable. Plans on the management and use of the areas must be prepared based on the natural value of the underwater nature and the stress to which it is subjected.

The operation of the Hanhikivi 1 power plant will have a local impact on the marine environment within the cooling water impact area. In this area, primary production may increase. The operation of the nuclear power plant will not risk maintaining and achieving the favorable protection level of species or habitat types. The impact from the operation of the nuclear power plant will not compromise the objective of securing the functional prerequisites of the food webs of the sea. The structure or functions of seabed ecosystems will not be compromised, either. Local changes may occur, but the Hanhikivi 1 nuclear power plant will not compromise the marine management plan sub-objectives NATURE1 and NATURE 2.

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