PROJECT 'PURCHASE OF STUDIES FOR THE PREPARATION OF A DESIGNATED SPATIAL PLAN AND THE ASSESSMENT OF IMPACT'

PROJECT PART 'STUDIES NECESSARY FOR THE ESTABLISHMENT OF THE RADIOACTIVE WASTE REPOSITORY'

ACTIVITY 1. Determining the three most optimal locations for the repository

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REVISION SHEET

Revisions of this document are made by replacement of the complete document, including the title page with signatures. Replacement of individual pages is not permitted.

Current revision is indicated in the header of all pages.

The reasons for the release of a new revision and/or main modifications to the current revision and the pages concerned are recorded in the list revision below.

Rev.	Reason for revision	Date of issue
1	Original issue	26 April 2022
2	Comments of the Contracting Agency (12 05 22), and Recommendations of WG1 meeting (11 03 22)	25 May 2022
3	Comments of the Contracting Agency (07 06 22)	14 June 2022
4	Comments of the Contracting Agency (21 06 22)	25 July 2022

Contents

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Structure the document

The performed studies cover two different site selection stages: definition of the siting process and initial phase of the site selection (screening of a territory of interest). Therefore, the Report for the Activity 1 is divided into two Parts:

Part 1: **Methodology and siting criteria**

Part 2: **Selecting of three most optimal sites in the territory of the Lääne-Harju local municipality**

The First Part of the Interim Report contains all relevant results achieved during implementation of the Sub activity 1.1 “Minimum requirements for the location of the repository, and the siting criteria”, while the Part 2 integrates results of Sub activities 1.2 “Determining the three most optimal locations in the territory of the Lääne-Harju local municipality”, 1.3 “Study of the social situation” and 1.4 “Analysis of roads and infrastructure”.

The Part 2 covers screening of the territory, identification of acceptable candidate locations and ranking to select the most preferable ones. It also includes results of the studies devoted to characterisation of the region of interest relevant to construction of the disposal facility and initial investigations of the locations for purposes of the screening and ranking.

Detailed structure of the Interim Report Part 1:

1) An overview of IAEA principles, requirements and guides regarding site selection for disposal facility in chapter 1;
2) A synthesis of the **radioactive waste management strategy** already set by the Estonian government. Key aspects, such as selection of the district suitable for further investigations will be presented in chapter 2;
3) A synthesis of the **waste inventory, basic design options and safety strategy for the disposal facility** already set out by previous studies; these aspects will be presented in chapter 3;
4) A description of the **methodology for the selection** of the 3 most optimal locations for the Estonian radioactive waste repository in chapter 4;
5) An analysis of **criteria for Estonian siting process** that will lead to exclude areas and set criteria for selecting the most appropriate location that will be presented in chapter 5;
6) A **ranking criteria and strategy** in view of selection among the sites, presented in chapter 6.

7) Criteria for Final Selection of the Site for Waste Disposal Facility, presented in chapter 7.

Tables

Definitions and abbreviations

Definitions relevant in the contexts of the site selection taken from the Directive 2011/70/EURATOM [1] and the IAEA Glossary [2]:

'Clearance level' means a value, established by a regulatory body and expressed in terms of activity concentration, at or below which regulatory control may be removed from a source of radiation within a notified or authorized practice.

'Radioactive waste' means radioactive material in gaseous, liquid or solid form for which no further use is foreseen or considered by the Member State. In this report, the word 'waste' means 'radioactive waste' unless the type of waste is specified.

'Radioactive waste management' means all activities that relate to handling, pretreatment, treatment, conditioning, storage, or disposal of radioactive waste, excluding off-site transportation.

'Radioactive waste management facility' means any facility or installation the primary purpose of which is radioactive waste management.

'Radioactive waste conditioning' means the process which converts the waste into an acceptable concentration and stable form for packaging, shipment and disposal. The process may involve solidification of the waste and/or encapsulation in a stable matrix such as concrete.

'Radioactive waste package' means the waste form and its container as prepared for handling, transport, storage or disposal.

'Decommissioning' means administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility. Decommissioning typically includes dismantling of the facility to reduce the associated radiation risks.

'Dismantling' means the taking apart, disassembling and tearing down of the structures, systems and components of a facility for the purposes of decommissioning.

'Disposal' means the emplacement of radioactive waste in a facility without the intention of retrieval.

'Disposal facility' means any facility or installation the primary purpose of which is radioactive waste disposal.

'Storage' means the holding of radioactive waste in a facility with the intention of retrieval. Both options, disposal and storage, are designed to contain waste and to isolate it from the accessible biosphere to the extent necessary. The important difference is that storage is a temporary measure following which some future action is planned.

'Nuclear security' means the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive material or their associated facilities.

'Safety' means the protection of people and the environment against radiation risks, and the safety of facilities and activities that give rise to radiation risks.

'Closure' means the completion of all operations at some time after the emplacement of radioactive waste in a disposal facility, including the final engineering or other work required to bring the facility to a condition that will be safe in the long term.

'Institutional control' means the control of a radioactive waste site by the appropriate authority or designated institution. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a disposal facility.

'Intrusion, inadvertent or intentional' means the process by which living organisms, including humans, may come in contact with disposed of waste.

List of abbreviations:

ALARA – As Low As Reasonably Achievable
EIA – Environmental Impact Assessment
EU – European Union
IAEA – International Atomic Energy Agency

NSDF – Near Surface Disposal Facility

IDDF – Intermediate Depth Disposal Facility

ILW – Intermediate Level Waste

LLW – Low Level Waste

GIS – Geo-Information System

PHES – Pumped-Hydro Energy Storage

FPNS – Former Paldiski Nuclear Site

SEA – Strategic Environmental Assessment

Objectives and Goals of the Document

The overall objective of the project is to define the most suitable location of the establishment of the repository for the Estonian radioactive waste. The siting is to be performed using a step wise approach: the current report is to present results of the initial studies devoted to identification of several locations potentially suitable to accommodate a disposal facility for the radioactive waste available in Estonia, including waste coming from the foreseen decommissioning of the Former Paldiski Nuclear Site. The goal of the performed studies is to identify three potentially suitable locations that would be the subject of further detailed and comprehensive investigations, including on-site, on their suitability for waste disposal. The performed studies are related to Activity 1 "**Determining the three most optimal locations for the repository**".

Introduction

The Euratom Treaty establishing the European Atomic Energy Community provides for the establishment of uniform safety standards to protect the health of workers and of the general public. To assure implementation of this principle in practice the Council of the European Union has adopted Directive 2011/70/EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste [1]. A main goal of this Directive is to ensure that Member States provide for appropriate national arrangements for a high level of safety in radioactive waste management to protect workers and the general public against the dangers arising from ionising radiation and to avoid imposing undue burdens on future generations.

It is recognised in the Directive that radioactive waste requires containment and isolation from humans and the living environment over the long term. Its specific nature of radioactive waste requires arrangements to protect human health and the environment against dangers arising from ionising radiation, including disposal in appropriate facilities as the end location point. The storage of radioactive waste, including long-term storage, is an interim solution, but not an alternative to disposal. Therefore, it cannot be regarded as a sustainable solution.

Member States should establish national programmes to ensure the transposition of political decisions into clear provisions for the timely implementation of all steps of radioactive waste management from generation to disposal. The Directive requires that the national radioactive waste management policies of the Member States be based on the following general principles:

- the generation of radioactive waste shall be kept to the minimum which is reasonably practicable, both in terms of activity and volume, by means of appropriate design measures and of operating and decommissioning practices;
- the interdependencies between all steps in radioactive waste generation and management shall be taken into account;
- radioactive waste shall be safely managed, including in the long term with passive safety features;
- an evidence-based and documented decision-making process shall be applied with regard to all stages of the management radioactive waste.

The Member States shall ensure that necessary information on the management of radioactive waste be made available to the public and the public be given the necessary opportunities to participate in the decision-making process.

1 IAEA Principles, Requirements and Guides Regarding Site Selection for Disposal Facility

1.1. The Siting Approach: an Overview of Relevant IAEA Documents

The International Atomic Energy Agency (IAEA) is an organ of the United Nations competent in fields of radiation protection, nuclear safety, and management of radioactive waste. The IAEA is authorized to establish standards of safety for protection of health and minimization of danger to life and property, and to provide for their application. The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

The IAEA issues Safety Standards Series, which has three categories: Safety Fundamentals, Safety Requirements and Safety Guides.

There is a single IAEA document SF-1 [3] devoted to definition of Safety Fundamentals. It presents the fundamental safety objective and ten associated safety principles, and briefly describes their intent and purpose. The safety principles are applicable, as relevant, throughout the entire lifetime of all facilities and activities, existing and new, and to protective actions to reduce existing radiation risks.

Safety Requirements. An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. There is a single document SSR-5 providing the requirements for radioactive waste disposal [4].

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended. The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety [5].

IAEA recommends to follow a step-by-step approach to the development of a disposal facility for radioactive waste. Requirement No. 11 of SSR-5 states that the disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Four stages are admitted in the siting process for a radioactive waste disposal facility [5]:

1) The conceptual and planning stage;

2) The area survey stage;

3) The site investigation stage;

4) The stage of detailed site characterization leading to site confirmation for construction of the disposal facility.

Each step shall be supported by iterative evaluations of:

1) The site,

2) Technical options for disposal design, and

3) Performance and safety of the disposal system.

Identification of the site suitability requirements (limitations and desirable features) is a key component of the conceptual and planning stage. The site suitability requirements are, by essence, minimum requirements to geologic, hydrologic, environmental, and demographic characteristics of a disposal site.

Requirement No 5 [4] enhances importance of passive means for the safety of the disposal facilities. The sites for the disposal facilities shall be evaluated as well as designed, constructed, operated and closed in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the facility is minimized. Providing for the safety of a disposal facility after closure by means of passive features of the natural and engineered barriers will entail proper closure of the facility and ending the need for its active management. The cessation of management means that the disposal facility, with its associated radiological hazard, is no longer under active control.

However, in the operational stage of a disposal facility for radioactive waste, certain active control measures have to be applied to assure the safety. In the post-closure period to some extent, the safety of a disposal facility can depend on some future actions such as maintenance or surveillance. However, this dependence has to be minimized. This is necessary because of the possibility that safety measures that depend on future actions, such as maintenance work or surveillance, will not be taken or will not be continued.

Guidance document SSG-29 [5] recommends that the key geoscientific criteria that will be used in support of judgements concerning the potential suitability of a site should be developed by the operator, in accordance with national regulatory requirements. Such criteria might include requirements or preferences for the host rock and surrounding geosphere, for example tectonic setting, rock characteristics and groundwater properties. From these criteria, screening guidance should be established for the selection of suitable areas and host rocks and later for the selection of the preferred sites. It is also recognized that, as knowledge improves, the criteria, or limits placed on the criteria, may change during the siting process. Consideration of the criteria could be enhanced using the results of preliminary assessments of the total system.

At the area survey stage, these features and limitations are used to focus on selection of few potential sites in a region of interest. The site should be selected by narrowing the region of interest and focusing on areas with appropriate features. This step should lead to the elimination of unsuitable areas and the identification of potentially acceptable locations.

The potentially suitable sites should be characterized to an appropriate level of detail to provide the necessary information to ensure that the disposal facility can meet the safety requirements for disposal of the intended type of waste. Detailed site characterization should be carried out to provide the site specific data necessary to support the safety assessments of the long term containment and isolation of the waste within the disposal facility.

IAEA Safety Requirements SSG-35 [6] are applicable to site selection for a wide range of nuclear facilities from nuclear power plants till facilities for the predisposal management of radioactive waste and to waste disposal. Although not all aspects described in this document are applicable for the current project, the approach is suitable for siting of disposal facilities too.

1.2. Site Selection Criteria

According to international practices [6] the site selection process has three distinct steps starting with the region(s) of interest as given.

1) Regional analysis: This is the first step, in which region(s) of interest are analysed to identify potential sites. All potential sites in a region should be taken to the next step (screening) unless their exclusion can be appropriately justified.

2) Screening: In the second step, the potential sites are screened to choose the candidate sites. The principal objective of this step is to exclude unfavourable sites based on both safety related considerations and non-safety-related considerations.

3) Evaluation, comparison and ranking: The purpose of the third step is to evaluate the sites in order to ensure that there are no features that would preclude the construction and operation of the nuclear installation, to compare the candidate sites and to rank them in order of their attractiveness as possible sites for a nuclear installation.

Siting criteria provide the basis on which decisions are made in consideration of the site attributes in the different steps of the siting process. Siting criteria are used to evaluate specific site related issues, events, phenomena, hazards and other considerations.

The potential sites are screened to choose the candidate sites. The principal objective of this step is to exclude unfavourable sites based on both safety related considerations and non-safety-related considerations. The screening of potential sites should be conducted using screening criteria of two types: exclusion criteria and discretionary criteria.

The exclusion criteria are used to discard sites that are unacceptable based on attributes relating to issues, events, phenomena or hazards for which there are no generally practicable engineering solutions. Screening by exclusion criteria enables sites with unfavourable characteristics to be excluded from further consideration.

The discretionary criteria (non-mandatory) are associated with those attributes relating to issues, events, phenomena, hazards, or other considerations, for which protective engineering solutions are available. The main purpose is to decrease the number of possible candidate sites if their number is too large to conduct the exercise of comparison and ranking. These criteria facilitate the selection process of elimination of less favourable sites when there are a large number of possible candidate sites.

Existence of a certain hazard or even the high likelihood of its occurrence should not constitute the sole basis upon which an exclusion criterion is based. Screening out on the basis of an arbitrary criterion may lead to the discarding of a site with otherwise favourable qualities for safety and may finally result in the choice of a site that is less safe than the site that has been discarded.

The resulting candidate sites should then be placed in an order of preference through an exercise of comparison and ranking using ranking criteria.

The screening criteria (exclusion and discretionary criteria) and ranking criteria consist of both safety related and non-safety-related criteria.

Ranking involves cross comparison of sites with respect to all their attributes, both safety related attributes and non-safety-related attributes. This may involve the weighting of various attributes in an appropriate form. Ranking criteria are necessary to provide bases for comparison between the candidate sites to arrive at a list of preferred candidate sites. The most difficult is comparison between topics, for example to compare a site with a higher seismic hazard but lower flood hazard with another site that has a higher flood hazard but lower seismic hazard. Ranking criteria are generally developed by using considerations relating to discretionary criteria together with relevant non-safety-related considerations.

1.3. Classification of Siting Criteria

The IAEA Safety Guide [6] provides the following classification of the criteria used in the siting process for a nuclear installation:

1) Safety related criteria;

2) Criteria relating to nuclear security;

3) Non-safety-related criteria.

Such criteria may be screening criteria (i.e., exclusionary or discretionary criteria) or ranking criteria.

1.4. Safety Related Criteria

Safety related criteria to be considered in the siting process and later in the characterization studies, exposed hereafter have been designed for any kind of nuclear installation. They have also been specifically developed in the framework of the NSDF [5].

From a thematic perspective, these criteria are grouped into four sets. Aspects relevant to siting of disposal facilities are presented below.

Potential impact of natural hazards. The following natural hazards should be considered:

- Capable faults (i.e. faults that may cause surface displacement near the nuclear installation);
- Vibratory ground motion due to earthquakes;
- Volcanic hazards;
- Coastal flooding;
- River flooding (overtopping of banks due to failure of water retaining structures such as dykes or dams);
- High winds — both straight winds such as hurricanes and tropical storms and rotational winds such as tornadoes;
- Other extreme meteorological events such as droughts, extreme precipitation, including snow pack, extreme hail, lightning and extreme temperatures;
- Geotechnical hazards such as slope instability, soil liquefaction, landslides, rock fall, avalanche, permafrost, erosion processes, subsidence, uplift and collapse;
- Forest fires;
- Credible combinations of events (i.e. combinations of both dependent and independent events that potentially could lead to more severe consequences than for a single hazard, such as a seismic event together with flooding, or wind together with snow).

Human induced events. The following origins of potential human induced hazards should be considered:

Stationary sources:

- Other nuclear installations, oil and gas operations, chemical plants, processing of hazardous materials such as commercial facilities for manufacturing or storing munitions, broadcasting and communication networks, mining or quarrying operations, high energy rotating equipment and hydraulic engineering structures;
- Military facilities (permanent or temporary), especially shooting ranges and arsenals.

Mobile sources:

- Surface transportation (e.g. railways and roads, and oil, gas and other pipelines);
- Airport zones and harbour zones (military and civilian);
- Air traffic corridors and flight path zones (military and civilian).

Characteristics of the site and its environment. The characteristics of the site could influence the transfer of radioactive material released from the nuclear installation to people and the environment. In this context, the following phenomena should be considered:

- Dispersion of radioactive substances in atmospheric air (only relevant during operational period of disposal facilities);
- Dispersion of radioactive substances in surface water;
- Dispersion of radioactive substances in groundwater;
- Population density and population distribution and distance to centres of population, including projections for the operating lifetime of the nuclear installation.

1.4.1 Criteria Relating to Nuclear Security

Nuclear security aspects should also be considered in siting nuclear installations. Typically, this includes consideration of site characteristics that could affect the ability to implement physical protection measures and the capability to deter, detect, delay and respond to nuclear security events.

1.4.2 Non-Safety Related Criteria

In the site survey and site selection process, another set of criteria are concerned with considerations that are not directly related to nuclear safety (e.g. availability of infrastructure, non-radiological environmental impacts, socioeconomic impacts). Such non-safety-related criteria should be considered together with the considerations relating to nuclear safety, especially in the ranking of the potential sites.

2 Management of Radioactive Waste in Estonia

2.1 Current Situation and National Policy

Estonia has no commercial nuclear power reactors or research reactors. However, there is a former nuclear submarine training centre at the Paldiski site with two defueled reactors. There are no spent nuclear fuel, because it was repatriated to Russia in 1994. With respect to current operations of the FPNS, the first assessment was started in 1999. It considered a number of options for the defueled reactors, including entombment in position and dismantling for disposal. The conclusion at that time was the facility should be finally dismantled but as Estonia had no storage and disposal facilities and the inventory contains many radionuclides with half-lives of 5 years or less, a delay of 50 years was recommended to allow for in-situ decay.

Between 2005 and 2007, an EU-funded project re-evaluated safety under a number of potential scenarios and suggested improvements to the facilities at the site to improve confidence in safety over a 50-year timeframe. There was some improvement to the building housing the sarcophaguses and a monitoring system, covering air, soil and water, was introduced. Decommissioning of the Paldiski reactor compartments is scheduled from 2040.

Legacy waste from former Tammiku Radon-type disposal facility has already been retrieved and transported to the FPNS, where it is held in a low and intermediate level waste storage facility, awaiting final disposal. Estonia’s current waste generation is small and arises from institutional practices only (all together is less than 1 m^3 annually).

In addition to the dismantling waste, small amounts of institutional radioactive waste, mostly Disused Sealed Sources, is generated in the country continually (in industry, medicine and research). All the waste is managed and stored in a low and intermediate level waste storage facility at the FPNS, awaiting for future disposal.

Since it is no room to store the reactor decommissioning waste in the existing Paldiski storage facility, a disposal facility should be established for this purpose by 2040, at the latest.

The Euratom Treaty establishing the European Atomic Energy Community provides for the establishment of uniform safety standards to protect the health of workers and of the general public. To assure implementation of this principle in practice the Council of the EU has adopted Directive 2011/70/EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste [1]. This Directive ensures that Member States provide for appropriate national arrangements for a high level of safety in radioactive waste management to protect workers and the general public against the dangers arising from ionising radiation and to avoid imposing undue burdens on future generations.

It is recognised in the Directive that radioactive waste requires containment and isolation from humans and the living environment over the long term. A need for the surveillance and control of waste should be minimised. Specific nature of radioactive waste requires arrangements to protect human health and the environment against dangers arising from ionising radiation, including disposal in appropriate facilities as the end location point. Member States should establish national programmes to ensure the transposition of political decisions into clear provisions for the timely implementation of all steps of radioactive waste management from generation to disposal. The objective in establishing a waste disposal facility is to isolate radioactive waste in a way which ensures that there is no unacceptable health risk to humans, biota and the environment from the operation of the facility and following its closure.

The Directive also points out, that the storage of radioactive waste, including long-term storage, is an interim solution, but not an alternative to disposal. It cannot therefore be regarded as a sustainable solution. The main principle of the national radioactive waste management policy is that radioactive waste generated in Estonia has to be disposed of in Estonia. Thus, a Governmental Decision to build a disposal facility for radioactive waste in Estonia was taken in April 2016.

2.2 Selection of the Region of Interest for the Disposal Facility

The territory of Lääne-Harju municipality which includes territory of FPNS has already been identified in the radioactive waste disposal program of Estonia as the region accommodating the Estonian Radioactive Waste Repository [7]. Lääne-Harju Municipality Council supported the plan to construct the disposal facility.

On August 4th 2019, the Government of the Republic of Estonia obliged the Ministry of the Environment to apply to the Lääne-Harju Municipality Government for starting a local government special planning and strategic environmental impact assessment procedures for the construction of a radioactive waste disposal facility [7]. Therefore, all potential sites in this region are taken to the next siting step consisting of screening of the identified region. Lääne-

Harju Rural Municipality Council initiated the local government designated spatial planning and strategic environmental assessment on 28.01.2020.

2.3 Time Scale for Operation and Closing the Disposal Facility

The disposal facility is scheduled to be licensed in 2035 with an operational start-up in 2040 [7]. Waste disposal operations are foreseen at least until 2050 when the decommissioning of the two reactor compartments of the FPNS is planned to be complete. After finishing waste emplacement activities, the disposal facility will be closed.

3 Waste, Basic Design and Safety Options

3.1 Waste to be Disposed of

The most relevant amounts of radioactive waste is expected from decommissioning of the FPNS. Several options were considered for the dismantling of the reactor compartments [8] either to disassemble these or dispose of in one piece. It was found that economically and from the viewpoint of radiation safety, it would be expedient to demolish the reactor compartments into smaller pieces. However, the reactor vessels themselves must be disposed of as a whole. Weights of reactor vessels are 30 and 50.4 tons for the first and second units respectfully (reactors VM-A and VM-4), while the overall dimensions are 2.100*2.100*4.295 m and 2.550*2.550*4.660 m.

According to the preliminary estimates, the waste to be disposed of will contain low level short lived radioactive waste and intermediate level long lived waste. A part of the waste will contain relatively large activity concentrations of long-lived radionuclides, not acceptable for near surface disposal. Therefore, a combination two different disposal options, near surface disposal for low level waste and intermediate depth disposal for intermediate level waste, have been selected [8, 9]. The IDDF concept has been chosen for mitigating intrusion risks over long period of time.

Based on a feasibility study of 2014-2015 the estimated volume of Low Level -Short-Lived waste is 2160 m3 and the estimated volume of Intermediate Level Long- lived waste is 960 m3 [9]. However, these estimates of the required disposal space are largely based on conservative assumptions, with no precise knowledge of the actual characteristics of the waste [10].

Detailed information on the decommissioning waste volume and characteristics, will be available only during implementation of the Activity 4 of the current Project. Therefore, the exact volumes and dimensions of the needed disposal facilities can be decided considering the updated waste inventory (subject of Sub activity 2.16).

3.2 Basic Design Options for the Disposal Facilities

Considering the small amount of waste and looking for the most efficient means of operation and maintenance, it was decided to locate the two disposal facilities of different types on the same site [7]. This decision reduces total land area occupied by the disposal facilities and thus reduces overall environmental impact, however, it significantly complicates the site selection process as the site must meet the criteria of both facilities, each of them having their specific technical and safety requirements.

The both disposal concepts are flexible enough, i.e. easily adaptable to different waste volumes and waste packages as well as to site specific environmental conditions.

3.2.1 Near Surface Disposal Facility Concept

The conditioned Low Level Waste is to be emplaced into reinforced concrete vaults with protective clay layer. The NSDF would consist of two such vaults with dimensions of about 15*12.5*6 m (Figure 1) [9]. A geological environment needed for the facility is such that there is little moisture saturation, good sorption characteristics which limit the spread of radionuclides, and possibility for water to be drained effectively. So, various geological media can be used for hosting the NSDF, for example: till, sand, gravel, limestone, clay.

According the available experience such facilities demonstrate better performance comparing with similar facilities in water saturated zone. Therefore, the disposal vaults should be established at least three or two meters above the ground water level (i.e. in vadose zone or at the ground level). However, a possibility to adapt the design by introducing a thick protective soil layer below the basis of the facility could be considered.

After finishing waste emplacement activities (operation stage) of the NSDF, it will be closed by installation of a multifunctional capping system. The main functions of this multi-layer system is to protect against infiltration of water, intrusion (human, animal or plant) and erosion [11].

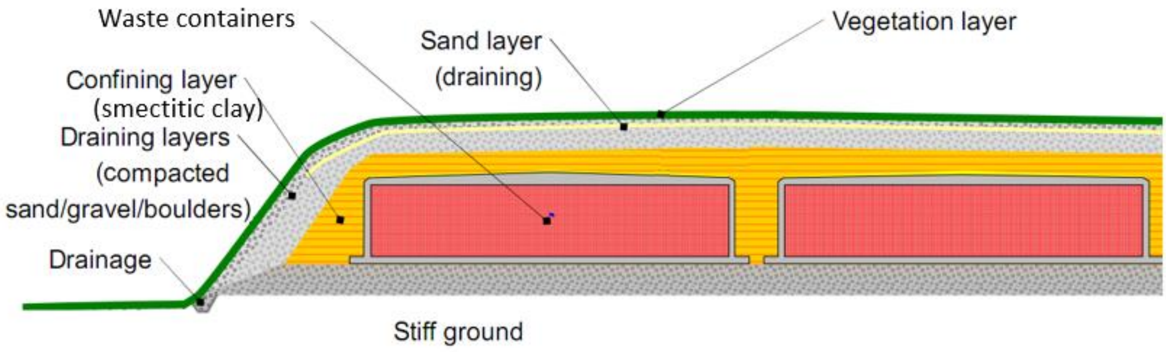

Figure 1. Conceptual design of NSDF: cross section of closed concrete vaults and the main engineered barriers multilayer capping system [9]

3.2.2 Intermediate Depth Disposal Facility Concept

Considering very small amounts of wastes requiring intermediate depth disposal, an Intermediate Depth Disposal Facility (IDDF) of shaft type established at a tentative depth of 30-50 m has been proposed, Figure 2 [9].

The foreseen minimal depth of the IDDF is 30 m. Such depth has been accepted as the lower level of the normal residential intrusion zone (a depth beyond which human intrusion is limited to drilling and significant excavation activities, such as mining, tunnelling and quarrying), therefore is commonly used to differentiate between near surface and intermediate depths disposal [12].

Performance of IDDF depends on geological stability of the site.

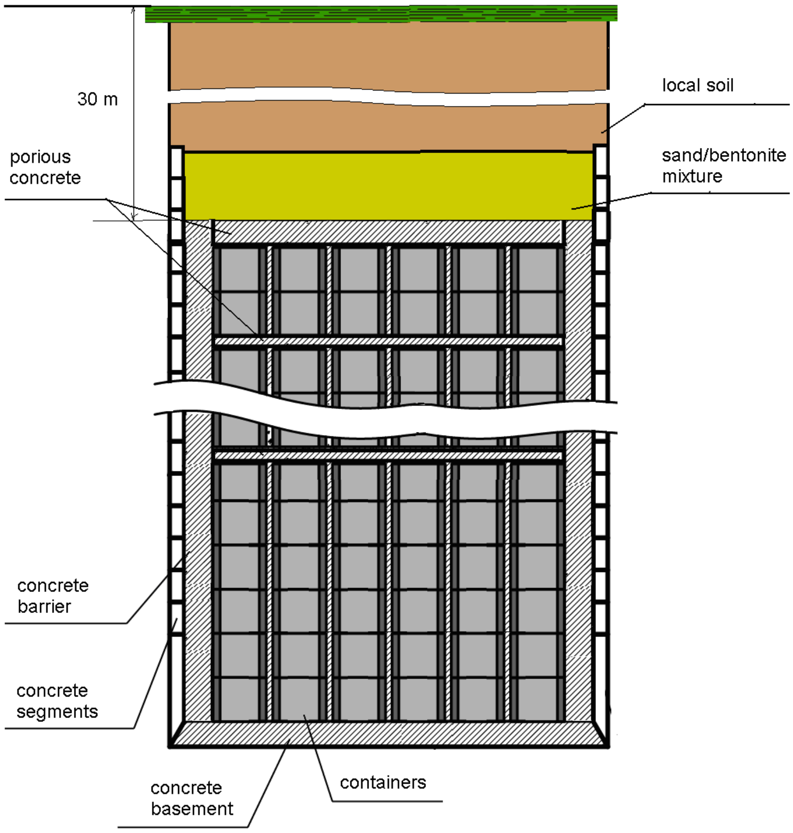

Figure 2. Conceptual design of IDDF: cross section of closed shaft-type disposal facility [9]

3.3 Basic Safety Options for the Disposal Facility

Following the preferred strategy for the management of all radioactive waste is to contain it (i.e. to confine the radionuclides to within the waste matrix, the packaging and structures the disposal facility) and to isolate it from the accessible biosphere [4]. Considering activity of the waste, the necessary containment properties after closure can be provided by the multiple engineered barriers. In a case of failure or malfunction of one barrier, safety is ensured by the others. The natural environment would mitigate dispersion of eventually released radionuclides.

Thus, the disposal design options and the various elements of the disposal system, including physical components and control procedures, contribute to performing safety functions in different ways over different timescales.

3.3.1 Basic Safety Options for Near Surface Disposal Facility

The NSDF is a disposal option suitable for waste that contains such an amount of radioactive material that robust containment and isolation is needed for limited periods of time up to a few hundred years are required [5, 12].

This class covers a very wide range of radioactive waste. It ranges from radioactive waste with an activity content level just above clearance levels, that is, not requiring shielding or particularly robust containment and isolation, to radioactive waste with a level of activity concentration such that shielding and more robust containment and isolation are necessary for periods up to several hundred years.

The safety relies on a significant radioactive decay of these LLW during the period of reliable containment and isolation provided by the engineered barriers, the site and institutional controls.

The appropriate time periods of active and passive control following closure of the NSDF are 100 and 200 years respectfully (300 years in total). During this time the prevailing amount of short-lived radionuclides (with half- lives not exceeding 30 years limit) will naturally decay. These time periods are proposed taking into consideration features of the disposal facility and an exciting the best practice related to the near surface disposal [13, 14]. They would be proposed for consideration and approval by the national regulatory authority. Detailed institutional control measures will be elaborated in the later stages (Activity 2 of the current project).

A precise boundary between LLW and intermediate level waste (ILW) cannot be provided, as a limit for the acceptable levels of radionuclide activity concentrations depends very much on features of the disposal facility and conditions of the site [12]. Waste Acceptance Criteria for a particular NSDF are dependent on the actual design of the facility (e.g. performance of engineered barriers), site specific factors as well as duration and character of institutional control measures.

Restrictions on levels of activity concentration for long lived radionuclides in individual waste packages may be complemented by restrictions on average levels of activity concentration or by simple operational techniques such as emplacement of waste packages with higher levels of activity concentration at selected locations within the disposal facility.

3.3.2 Basic Safety Options for Intermediate Depth Disposal Facility

Intermediate level waste is defined as waste that contains long lived radionuclides in quantities that need a greater degree of containment and isolation from the biosphere than is provided by Near Surface Disposal. Disposal in a facility at a depth of between a few tens and a few hundreds of metres is indicated for ILW [12].

Disposal at such depths has the potential to provide a long period of isolation from the accessible environment if both the natural barriers and the engineered barriers of the disposal system are selected properly. In particular, there is generally no detrimental effect of erosion and other surface related processes at such depths in the short to medium term.

Another important advantage of disposal at intermediate depths is that, in comparison to NSDF, the likelihood of inadvertent intrusion (i.e., human and bio intrusion) is greatly reduced. Consequently, long term safety for disposal facilities at such intermediate depths will not depend on the application of institutional controls. Barrier capabilities of the natural system include the ability of the host formation to control groundwater movement around the facility and to retain radionuclides or delay their release to the accessible environment [15].

3.4 Basic Options for the Perimeters of the Disposal Facility

A land plot required to accommodate the underground and surface disposal facilities as well as auxiliary premises and leaving space for contingency waste is approximately 5 ha or slightly larger if the land is not sufficiently drained and an additional drainage layer below the NSDF is needed. An optimal form of the plot is a rectangular (shorter edge at least 220 m). However, the layout of the repository can be easily adapted to the local conditions. The repository area would be limited by a fence.

In addition, a protection zone around the repository area may be required for security reasons, see schematic illustration Fig. 3. This zone up to a few tens of meters wide should be free of visual obstacles. The need of this zone and its area are subjects of discussions with authority responsible for security and physical protection. The following alternative definitions of the protection zone are proposed for consideration:

1) An exclusion perimeter in which no activities potentially jeopardizing the safety and security of the disposal would be carried out;

2) A protection perimeter in which activities will be subject to authorization.

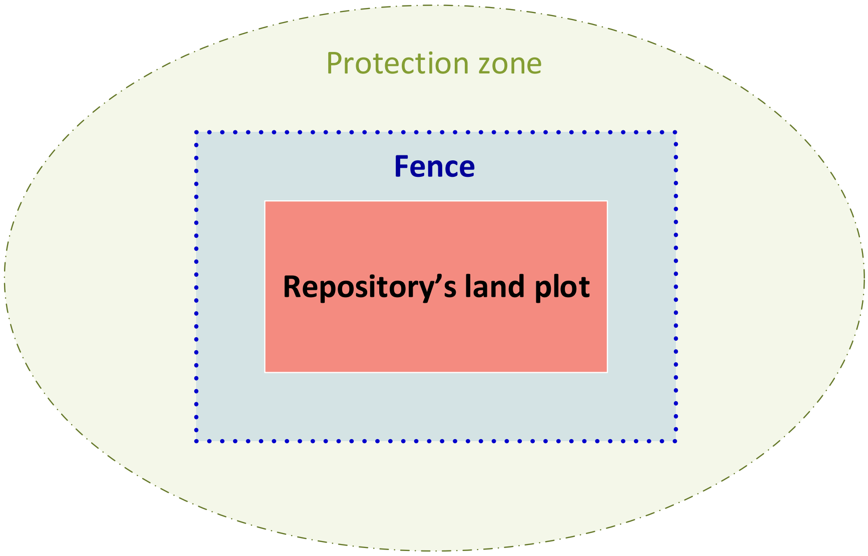

Figure 3. Perimeters to be taken into account during siting processes

4 General Methodology for the Selection of the Three Most Optimal Sites

4.1 Objective

The objective of this chapter is to describe the general methodology to be applied for the selection of the 3 most optimal sites to develop a radioactive waste repository in Estonia (see Figure 4).

As mentioned earlier, the territory of Lääne-Harju municipality which includes FPNS has already been identified as the region accommodating the Estonian Radioactive Waste Repository. Territory of the FPNS is pre-selected candidate site for characterisation and final evaluation as one of the three most optimal sites. The pre-selected site is a suitable location mainly because the territory is already being used by a waste disposal organization and is (partially) owned by the organization, using the current location does not need transportation of the waste, it is supported by existing infrastructure and the local community is used to the existence of the site in the existing location.

Objective of the screening process is to find other two candidate sites.

4.2 Rationale

The methodology is defined considering the Estonian regulations and relevant IAEA documents.

First, the exclusion criteria and the discretionary criteria to be used for the screening stage will be defined. Those criteria are defined based on the IAEA documents but also on the analysis of legal requirements and comprehensive plan of Lääne-Harju municipality. Some criteria are also set by expert's judgment.

A first screening stage of the territory of Lääne-Harju municipality will be completed using a geo-information system and Estonian national and local data bases gathering public information on environment and infrastructures.

Then, compliance with each discretionary criterion will be assessed by raking of the available sites in order to identify the two favourable (in addition to the FPNS). This assessment will be based mainly on expert's judgment.

The final site will be approved within the public process of Lääne-Harju municipality's designated spatial plan. The first stage of the planning procedure is pre-selection of the local government designated spatial plan.

4.3 Illustration of the Methodology

The first step, aim of Activity 1 of the project, consist in selecting the three most optimal locations for the future disposal, in a pre-selected region, using Estonian national policy options, local municipality development plans, GIS and national and local data bases gathering public information on environment and infrastructures as well as outcomes of previous technical studies. Figure 4 illustrates the methodology to be applied for selection of the two candidate sites.

These two sites will be identified by implementing the following steps:

1) Excluding areas where legal requirements and the municipality comprehensive plans may not allow the implementation of such a disposal facility ("negative screening") and identifying potentially suitable area (or areas) for further investigations (investigation territory).

2) Studies of the identified investigation territory. The following features will be analysed: topography, geomorphology, hydrology, climate tectonics, seismic properties, mineral resources, hydrogeological structure, environmental conditions, social situation, roads and infrastructure.

3) Identifying several candidate sites in the investigation territory. This selection would be based on expert judgement, taking into account available information and discretionary criteria that are easy to assess (such as information on land use, population density, availability of

access roads). Only areas that are readily accessible for geological exploration and thus suitable for detailed characterization will be selected for further considerations.

4) Ranking of the candidate sites using discretionary criteria identified as relevant for the site selection in order to identify two most favourable sites in addition to the pre-selected candidate site of the FPNS.

The next steps will consist of site studies of the three sites to acquire data for detailed conception and refined safety studies. The potentially suitable sites should be characterized to an appropriate level of detail to provide the necessary information to ensure that the disposal facility can meet the safety requirements for disposal of the intended type of waste. Detailed site characterization should be carried out to provide the site-specific data necessary to support the safety assessments of the long term containment and isolation of the waste within the disposal facility.

Thus, the final selection will be based on the actual results of the investigations survey and the concept complying the most adequately with the safety requirements and the site characteristics.

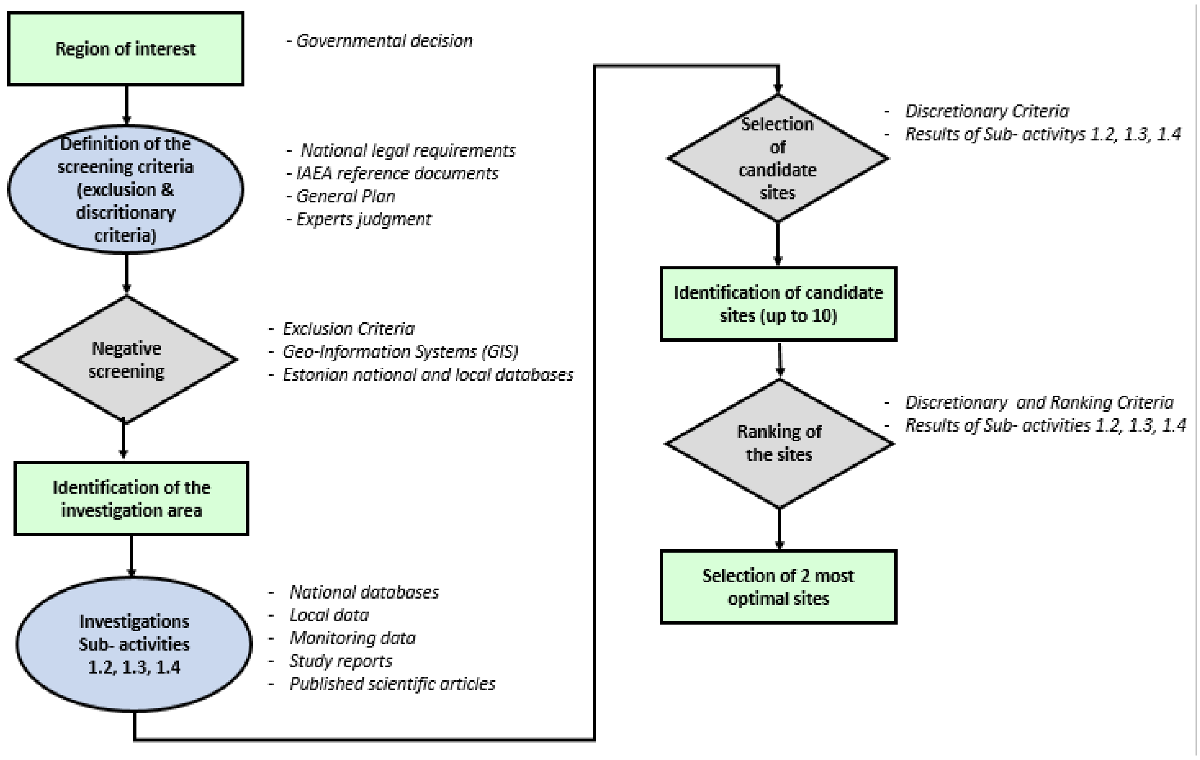

Figure 4. Synthesis of the methodology to be applied for the selection of the two most optimal sites (Activity 1)

5 Identification of Criteria for Siting of Estonian Radioactive Waste Disposal Facility

5.1 Suitable Geological Formations and Consideration of Geological Conditions for Siting

The disposal facilities under consideration in Estonia (NSDF or IDDF) are not 'geological disposal', which by essence requires geological confining barriers, the geological and environmental characteristics may play a role in safety during the period under consideration.

The first key parameters are the specific geodynamic and seismic environment. However, for the territory concerned, these geological and environmental conditions are considered to be equivalent throughout the whole area, whatever the lithological nature of the formation. The other key parameters are:

- overall geological and soil stability, which may limit or reduce the effects of climate and other surface processes,
- the characteristics of the soil and rocks which, in reasonable economic conditions, allow construction means, in particular the shaft wall support technics, and
- low chemical aggressiveness for concrete structures.

The more favourable soil and geological formation are those that will support withstand the load of the surface constructions or super structures of the disposal units without any specific work. In the same way the most favourable rock and geological formations are those that will not need advanced excavation technics, such as soil congelation or heavy duty support structures to ensure the stability of the disposal shaft walls.

The region is situated on the East-European Craton recognized as a tectonically stable region. The Earth's crust is about 50 km thick and consists mainly of Palaeoproterozoic igneous and metamorphic rocks. The rather flat surface of the crystalline basement lies at a depth of 182–205 m (186 m in Põllküla borehole F-317; Annex 3) and its uppermost part (mainly gneisses) is strongly weathered. Thickness of the sedimentary cover is mainly ranging from 100–150 m. It is represented with Vendian (Ediacara), Cambrian and Ordovician rocks, belonging to different regional stages. The basement is overlain by Upper Vendian clastic rocks, mainly sandstones with thin interlayers of clays and siltstones about 35–50 m in thickness (Kotlin Stage).

The covering Lower Cambrian rocks (Lontova and Dominopol stages) are represented by clays, sandstones and siltstones with a total thickness of about 100 m. The topmost part of the Cambrian (Tiskre formation) consists of light fine-grained silt- and sandstones, some 4 m thick, with green claystone interlayers, which crop out only in the cliff of Pakri north of the harbour.

The Cambrian terrigenous rocks are overlain by Ordovician medium- and fine-grained sandstones of the Pakerort Stage, about 4 m thick, and darkbrown kerogen-bearing graptolite argillite (Türisalu Formation), about 4.5 m thick. The overlying Varangu, Hunneberg and Billingen stages are represented by clays (0.15–0.45 m) and glauconitic silt- and sandstones (3.5–4.0 m). The topmost part of the section is composed of carbonate rocks of Volkhov, Kunda, Aseri, Lasnamäe and Uhaku stages.

The bedrocks show monoclinal bedding regionally dipping about 7'. Present shape and features of bedrock topography result from the erosion caused by the continental ice, which retreated from the Pakri Peninsula some 11 500 years ago. Later the territory was flooded with the waters of Baltic Ice Lake, the Yoldia Sea, Ancylus Lake, the Litorina Sea and the Limnea Sea. The peninsula emerged from the sea during the regression of Ancylus Lake when in the central part of the peninsula a rocky island formed. Since then the Pakri Peninsula has been subjected to wave action. The eroded deposits are transported by longshore currents southward and the process is still in progress. The land uplift at the present is some 2.5 mm per year and the sea is still retreating.

Due to shortage of existing relevant information it is not possible to conclude which of the existing geological formation suites better for hosting the IDDF. Analysis of available general geological information as well as short distances between the potential sites indicates that changes in the region are insignificant.

The expected changes of geological setting at the scale of the region should be insignificant considering very small distances between the potential sites, therefore at the current knowledge level the geology doesn't make influence on the selection of site. Based on the available geological information there are no specific issues to construct and develop a disposal facility in the region. Site-specific studies (drilling and laboratory testing) should provide information that affects complexity of the design, construction, and ultimately the cost for waste disposal. All these issues will be addressed in later stages.

At this preliminary stage, taking into consideration the relatively shallow depth, no geological formation should be excluded, as the suitable rock and soil treatment techniques already exist for civil engineering infrastructure. **A decision on suitability of geological conditions can be done only after comprehensive consideration of multiple factors (geological,**

mechanical, geochemical, hydrogeological, and others.) influencing safety and constructability.

5.2 Minimum Requirements for the Disposal Site and Exclusion Criteria

A disposal facility is designed to contain radionuclides associated with the radioactive waste and to isolate them from the accessible biosphere. The disposal site must be accepted both nationally and locally as being suitable. In addition, the site must be suitable for the purpose of the construction and operation of a waste repository. The following general requirements must be fulfilled for the selected site [16]:

1. The constructed waste repository must be safe;

2. The stakeholders must agree to the location; and

3. It must be possible to construct, operate and close the disposal facility without undue difficulty.

The Exclusion Criteria are mandatory requirements used to exclude those areas, whose application is not feasible due to exiting legal, environmental, social, demographic restrictions as well as characteristics do not ensure the full compliance with the technical and safety requirements. The Exclusion Criteria have a meaning opposite to Minimum Requirements for a disposal site. Following internationally applied terminology, the term of ‘Exclusion Criteria’ is used in this document. These criteria are based on the following:

1) international and national legal restrictions,

2) requirements of comprehensive plans,

3) expert knowledge and experience of other countries.

The Exclusion Criteria are used to discard sites that are unacceptable on the basis of attributes relating to issues, events, phenomena or hazards for which there are no generally practicable engineering solutions. Screening by exclusion criteria enables sites with unfavourable characteristics to be excluded from further consideration. The Exclusion Criteria to be used for the screening of Lääne-Harju territory are listed in Table 1. A detailed description of the

Table 1. List of exclusion criteria to be used for screening of Lääne-Harju territory

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
Protected areas of wildlife: 1.Protected areas 2. Limited-conservation areas 3.Species' protection sites 4.Individual protected natural objects 5.EU Natura 2000 network areas 6.Natural objects protected at the local government level 7.Protected species 8. Planned protected areas	Estonian Nature Conservation Act, EU Directive 2009/147/EC, Directive 92/43/EEC No negative impact is allowed on Natura sites	No protection zone	Building the disposal facility can influence the habitats, so the buffer zone or other preventive measures can be established during SEA process considering site specific conditions
Key habitats in forests: 1.KH areas on the state land 2.KH areas on municipality land and private land, where the agreements exist	Estonian Forest Law	No protection zones indicated in the Law	Not proposed, however, can be considered taking into account site specific conditions
Territories and objects of cultural monuments: 1.Historical monuments 2.Archaeological monuments 3.Architectural monuments 4.Art monuments 5.Technical monuments 6.Historical natural sacred sites	Heritage Conservation Act	Protection zones depend on the type of the object and they are designated in the register of cultural monuments (usually they are 50-100 m large)	Can be considered in detailed spatial plan and SEA process if needed
Milieu areas: locally protected cultural areas	Lääne-Harju comprehensive plan	No protection zones according to comprehensive plan	Can be considered in detailed spatial plan and SEA process if needed
Graveyards	Heritage Conservation Act: protected graveyards as territories of cultural monuments Lääne-Harju comprehensive plan: common graveyards	50 m protection zone according to Heritage Conservation Act No protection zone according to comprehensive plan	Can be considered in detailed spatial plan and SEA process if needed

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
Water bodies with limited management zone: sea, (artificial) lakes, rivers, brooks, springs, artificial recipients of land improvement system	Estonian Nature Conservation Act Limited management zone of the shore or bank: Construction and expansion of facilities prescribed for waste processing or storage, except in the territory of ports is prohibited. Water protection and building exclusion zones are not considered here, since their scope is smaller than the limited management zone. Limited management zone extends to the farthest areas and since waste storage is prohibited in that zone, we exclude areas defined by that zone.	1. Limited management zone of the shore or bank: - 200 meters on the shores of the Baltic Sea - 100 meters on the banks of lakes and artificial lakes with an area of more than ten hectares, and on rivers, brooks and artificial recipients of land improvement systems with a catchment area of more than 25 square kilometres. - 50 metres in the event of springs and on the banks of lakes and artificial lakes with an area of up to ten hectares, and on rivers and brooks with a catchment area of up to 25 square kilometres - 50 metres on the open artificial recipient of a land improvement system with a catchment area of 10–25 square kilometres	Can be considered in detailed spatial plan and SEA process if needed
Wetlands:	Not designated in the law or spatial plans		No uniform distances are

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
bogs and bog-a-like wet areas, bog forests, peat areas, canebrake areas. **Water bodies without limited management zones:** (artificial) lakes, rivers, brooks, artificial recipients of land improvement systems.	Exclusion is based on expert judgment considering safety implications. All poorly drained areas pose the high hazard to the NSDF, therefore they must be excluded from further consideration. In Estonian climatic conditions water drainage have particular importance because of very low evapotranspiration intensity.		proposed; the drainage conditions are to be assessed on case by case basis (drainage depends not only on distance from a wetland, but on other features of the specific site too)
Flood hazard areas	Flood hazard risk areas identified and mapped by the Estonian Ministry of Environment, Map data from Estonian Land Board. There are no such areas in Lääne-Harju territory.	-	-
Residential areas: - densely populated areas and other residential areas with significant amount of population (currently existing as well as envisaged by the comprehensive plan)	The areas are defined in the Lääne-Harju comprehensive plan	No buffer zones indicated in the comprehensive plan	700 m to reduce a risk of intrusion. In order to gain better public trust and avoid conflicts, it makes sense to build a storage facility no closer to the residential area than the current waste storage facility
Industrial and retail/business areas: existing as well as future development areas.	Areas are determined in Lääne-Harju comprehensive plan: business and retail land use, mixed land use, industrial area for solar power land use, mining land use.	-	Can be considered in detailed spatial plan and SEA process if needed
Recreation and public facility areas: existing as well as future public areas.	Areas are determined in Lääne-Harju comprehensive plan:	-	Can be considered in detailed spatial

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
	green areas and forest parks, protected forest areas, locally protected forest areas, natural green areas, recreation areas, public buildings, publicly used areas.		plan and SEA process if needed
Active mining areas and territories containing valuable mineral deposits	Earth's Crust Act	No protection zone determined by the law	Can be considered in detailed spatial plan and SEA process if needed
Military and national defence areas	Military areas according to the decree of the Ministry of Defence. Other areas that are determined in Lääne-Harju comprehensive plan as national defence land use.	Military areas: different zones according to certain object. Zones vary between 25-2000 m	Can be considered in detailed spatial plan and SEA process if needed
Airfields	Estonian Aviation Act	The protection zone depends on the size of the airfield. The airfield's height restriction zones are under discretionary criteria.	-
National Border areas	Not relevant for Lääne-Harju parish		
Water supply and sewage systems: existing and planned water and sewage pipework, water wells in communal use	Building Code	The protection zones vary between 2-5 m	Not proposed
Gas installations and pipelines: existing and planned	Building Code	The protection zones vary between 1-10 m	Not proposed
Electrical installations: existing and planned towers, transmission lines etc,	Building Code	The protection zones vary between 2-40 m	Not proposed
Communication installations:	Building Code	The protection zone of 1 m	Not proposed

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
existing and planned towers and lines			
Pressure equipment	Not relevant for Lääne-Harju parish	-	Not proposed
Roads and railroads: existing and planned objects	Building Code and Lääne-Harju Comprehensive Plan: transportation land use areas.	Protection zones for roads vary between 10-50 m. Railroad: 30 m in high density areas, 50 m in low density areas.	Can be considered in detailed spatial plan and SEA process if needed
Dangerous and hazardous enterprises: petrol stations, terminals with dangerous goods, cold storage plants, grain drying plant, fur farm etc.	Estonian Chemicals Act	Protection zones according to Estonian Chemicals Act and Rescue Board information. The protection zones vary between 50-2000 m, depending on the enterprise.	Can be considered in detailed spatial plan and SEA process if needed
Special geological forms: tectonic fracture zones, karst areas	Proposal of geologists: 2 tectonic fracture zones Klooga and Kuijõe-Vihterpalu to be excluded. Two tectonic faults, proven Kuijõe-Vihterpalu and suggested Klooga, have to be considered exclusive to determine the most optimal locations. Concerning the precision of the base information and some width of such fracture zones in general, a zone of at least 1 km on both sides of the mapped line is excluded.	-	1 km zone on both sides from the mapped capable fracture edge
Human activities: Construction PHES in Paldiski	During the EIA for PHES, no negative impacts were identified that could affect the FPNS [18]	-	Can be considered in detailed spatial

Feature	Basis for exclusion	Legally established protection zone	Proposed buffer zone for the disposal site
			plan and SEA process if needed
Small land plot: area is less than 5 ha or of unsuitable geometry (plot width is less than 220 m	Feasibility studies [9] and judgement of Stakeholders and local experts. The area must be sufficient to accommodate disposal and auxiliary facilities as well as facilities management of future waste (if needed)	-	-
Land ownership: private and municipality land	Using municipality land needs agreement from municipality. Planning and building on private property incorporates complex procedures: collaboration with the owner, possible expropriation. Both options are very time consumable and will jeopardise project schedule	-	-

Notes:

- Densely populated areas are cities, towns and built up areas of small towns and villages with clearly determined boundaries. They do not follow administrative borders, but take into account existing and future population and it's density. Densely populated areas have or will have in the future compact and dense settlement and buildings.
- Ämari is a military object as well. The protection zone is excluded, but not the height restriction zones. Humala airfield protection zone doesn't extend to Lääne-Harju parish, but the height restriction zones extend and those are disserted under discretionary criteria.

Events and processes that do not pose a danger in Estonian conditions (for example, tsunamis, volcanic eruptions) are not considered as reasons for exclusion. Glacier formation is a very slow process. As a result, the glaciation does not pose a threat to disposal of Low and Intermediate Level Waste (it is generally assumed that the hazards caused by such wastes last much shorter than the formation of glaciers). Seismic hazard is not an exclusive factor in the context of Estonia either. However, resistivity to ground motion due to seismic waves of different types, resulting from potential earthquakes are subject to be considered at later stages of the disposal facility development programme (site characterisation, technical design, and safety assessment). The seismic hazard consideration approach is described in Annex 2.

The required minimal land plot has to be sufficient to accommodate the underground and surface disposal facilities, auxiliary premises, security and monitoring systems, location for storage of materials and leaving space for disposal of contingency waste. Also, a footprint of the NSDF (including capping and drainage systems) would be significantly greater if the land is not sufficiently drained and an additional drainage layer below the NSDF is needed.

The existing waste treatment facility is expected to be demolished at the end of the reactor decommissioning process. If the repository is to be constructed outside the FPNS, after the dismantling and demolition of the existing waste treatment facility, it may be appropriate to consider building of a new one at the disposal site for future waste treatment.

For security reasons the territory of the disposal facility has to be fenced. In addition, there must also be sufficient space to establish a restriction zone around the repository if a decision is made to establish such a zone. Therefore, the minimal area of a required land plot is 5 ha. An optimal form of the plot is a rectangular with e shorter edge at least 220 m long, however, the layout of the facility can be adapted to other geometric forms.

Usually, the excluded areas and objects have certain protection zones established by legal acts. However, experts recognise that in many cases these legislative zones are far insufficient [16]. There are several reasons why large protection (or buffer) zones need to be established:

- enhancing safety and security of the repository,
- minimising ionising radiation doses to members of the critical group due to waste disposal activities,
- increasing public acceptancy.

Dimensions of the proposed protection zones should be mainly based on judgment of experts taking into consideration experience of siting programs of other countries. For example, in the case of a railway, construction is not allowed on the ground under the railway, but also in a protection zone extending up to 30 m from the centre of the railway track. However, additional risk arises due to transportation of dangerous goods by a train. Therefore, significantly larger protection zone (up to 1 km) has been excluded in Italy [17].

The intensity of ionizing radiation decreases very quickly moving away from the source of radiation. Therefore, increasing the distance between the repository and places where people live or visit regularly significantly reduces human exposure doses due to waste handling and emplacement activities. Therefore, it facilitates implementation of the main radiation protection principles of limitation and optimisation, keeping human exposure “As Low As Reasonably Achievable”.

Another reason to increase the surrounding exclusion zone is increasing public acceptability of the repository by setting a buffer zone to minimise visual or psychological negative impacts.

5.3 Discretionary Criteria

The Exclusion Criteria are supplemented by non-mandatory Discretionary Criteria. They are associated with attributes related to issues, events, phenomena, hazards, or other adverse aspects for which protective engineering solutions are available, i.e. by modifications of the facility design. The main purpose is to decrease the number of possible candidate sites if their number is too large and to conduct the comparison and ranking of the sites. When there are a large number of potential candidate sites, these criteria facilitate the selection process by removing less favourable ones.

Discretionary criteria (presented in Table 2.) were determined based on international recommendations, international experience and expertise and will be applied in the GIS analysis at the selection stage using public databases, geographic information systems, archives, the results of previous studies, expert knowledge and specific assessments, as well as to confirm the absence of exclusion elements that were not identified at the stage of applying the exclusion criteria.

The discretionary criteria were defined analysing international recommendations, internationally available experience and expert knowledge. Discretionary criteria to be applied at the screening stage in the GIS analysis are presented in Table 2. A screening of Lääne-Harju territory will be carried out to identify the two most optimal sites using public databases, geographic information systems, archives, results of earlier performed studies, expert's knowledge and specific evaluations, also with the aim to confirm the absence of excluding elements not identified in the phase of application of the exclusion criteria. Then the resulting candidate sites should be placed in an order of preference through an exercise of comparison

Table 2. List of Discretionary Criteria to be used for screening of Lääne-Harju territory

Feature	Rationale	Discretionary criteria	Comments
Geology	The geology of the disposal site should contribute to the isolation of waste and the limitation of release of radionuclides to the biosphere. It should also contribute to the stability of the disposal system and should provide sufficient volume and favourable properties (geological, mechanical, geochemical, hydrogeological, etc.) for disposal.	Predictability of geological features	Simple, predictable and easy to characterise geology is preferred
Hydrogeology	The hydrogeological characteristics of the host site should include low groundwater level and long flow paths in order to restrict the migration of radionuclides. Possibilities of contaminating water intended for human consumption should be excluded. Expected changes in important hydrogeological conditions (e.g. hydraulic gradient) due to natural events and the construction of the disposal facility should be evaluated.	Simple geological setting making characterizing and modelling of the hydrogeological system easier and more reliable. Low and stable ground water table. Not expected changes in important hydrogeological conditions due to natural events or human activities	Simple geological setting, easy to characterise and model is preferred Low and stable ground water table is preferred
Geochemistry	Chemical composition of groundwater and the geological media should contribute to limiting the release of radionuclides from the disposal facility and should not significantly reduce the longevity of engineered barriers. Chemical interactions within the disposal system (i.e. corrosive action of groundwater on the engineered barriers) must be investigated.	Environment with moderate pH and Eh levels (nonaggressive to ordinary concrete) Absence of chemical conditions facilitating fast migration of radionuclides Absence of soils of low bearing strength, soil stability	Nonaggressive chemical environment not facilitating migration of radionuclides is preferred Chemical interactions within the disposal system (i.e. corrosive action of groundwater on the engineered barriers) must be investigated in the stage of site characterisation

Feature	Rationale	Discretionary criteria	Comments
		according to construction requirements	
Tectonics	The site should be located in an area of low tectonic activity such that the isolation capability of the disposal system will not be endangered. The design of the disposal facility should take into account tectonic stability and seismic activity of the site that could adversely affect the proposed disposal system.	Low potential for adverse tectonic events, absence of recent or historic evidence of active faulting, tectonic processes.	Territories characterised with low tectonic hazard are preferred
Surface processes	The site for NSDF must be well drained and free of areas of flooding or frequent ponding. Accumulation of water in upstream drainage areas due to precipitation or snowmelt and the failure of water control structures, channel obstruction or landslides should be evaluated and minimized so as to decrease the amount of runoff that could erode or inundate the facility. Surface processes such as landslides, flooding of the disposal site, or erosion should not occur with such frequency or intensity that they could affect the ability of the disposal system to meet safety requirements.	Topographical and hydrological features that preclude the potential for flooding and limit erosion, i.e surface inclination is modest. Absence of soils of low bearing strength, soil stability according to construction requirements	Smooth topography, modest surface inclination and absence of low strength soils and soils without a liquefaction potential are preferred
Meteorology	The meteorology of the site area should be characterized such that the effects of unexpected, extreme meteorological conditions can be adequately considered in the design and licensing of the disposal facility. The potential for extreme meteorological events should be evaluated.	Extreme weather condition frequency and impact	Sites with low potential impact due to extreme weather conditions are preferred

Feature	Rationale	Discretionary criteria	Comments
	Closed NSDF can be sensitive to extreme weather conditions (i.e. heavy rainfalls, droughts, very deep freezing) not foreseen in the facility design		
Human activities	The site should be located so that activities carried out by present, or future, generations at or near the site will not be likely to affect the isolation capability of the disposal system. Areas in the immediate vicinity of major hazardous facilities, airports or transport routes carrying significant quantities of hazardous materials should be evaluated for suitability of waste disposal. The sites should be evaluated for valuable geological resources or potential future resources, including groundwater suitable for drinking or irrigation, that are likely to give rise to interference activities resulting in a release of radionuclides in quantities beyond the acceptable limits.	Distance from hazardous facility Distance from airports Distance from major routes with frequent movement of hazardous material. Low potential for future territory development Low mining potential Low potential for ground water use	The following sites are preferred: - located away from the hazardous facilities, airports, major roads and territories of foreseen development - having low development, mining and ground water extraction potential
Transport of Waste	The site should be located so that the access routes will permit the transport of waste with minimal risk to the public	Availability of suitable roads	Preference will be given to minimal transportation distance
Land use	**Development areas** designated in the Comprehensive Plan[1] could further spread in nearby areas	Potential for future territory development is assessed by the distance to existing and known business, industrial, residential, pulblic use etc	Site with low potential for future development is preferred

Feature	Rationale	Discretionary criteria	Comments
	E9 hiking trail	The possible impact is assessed in SEA	Preventive measures if needed can be proposed during SEA procedure
	Valuable agricultural land designated in the Comprehensive Plan[1]	Potential site in valuable agricultural land	It is preferred that they are used as agricultural land, but if the state's and municipality's interest is to build something else there, it could be discussed
	Additional national defence areas, not designated in the Lääne-Harju comprehensive plan, however included in the Land Register[2]		Preference is given to sites that are not expected to be used for defence purposes
Land ownership	Jurisdiction over the land, or land ownership, may be a significant factor in some States with respect to the financial viability and public acceptance of the disposal facility[3]	Existing possibilities for state and unreformed state land	Building repository on state land is the easiest. Unreformed state land incorporates more complex procedures. Using municipality land needs agreement from municipality. Planning and building on private property incorporates complex procedures: collaboration with the owner, possible expropriation
Population	Consideration should be given to avoiding areas of high population density[1,3]	Current population density and population grow potential need to be considered	Preference is given to sites that are farthest from the densely populated areas
Environment	The site should be located so that the environment will be adequately protected for the entire lifetime of the facility and so that potential adverse impacts can be mitigated to an acceptable degree, technical, economic, social and environmental	Strictly protected areas are excluded, the possible impact is assessed in SEA	Certain activities (e.g. building the repository) might influence the habitats, so the buffer zones or preventive/mitigation

Feature	Rationale	Discretionary criteria	Comments
	factors being taken into account. Near surface disposal facilities should comply with the requirements for protection of the environment.		measures can be given during SEA procedure.
	Protected areas of wildlife: Species of category III[4]	Protected areas of wildlife (species of category III)	Certain activities (e.g. building the repository) might influence the habitats, so the buffer zones or preventive/mitigation measures can be given during SEA procedure. The buffers should be discussed and approved by the Environmental Board.
	Green network area (designated in comprehensive plan)[1]	Existing green network areas	Green network areas are designated in comprehensive plan. In general waste disposal areas are not welcome in those areas, but exceptions are possible. Restrictions might apply for fencing and depends on the location, e.g. the planned object must not deteriorate green network performance.
	Valuable landscapes designated in comprehensive plan[1]	Existing valuable landscapes	Traditional village landscape milieu should be preserved. The planned object must harmonise with the surrounding area and not deteriorate the protected values.
	Key habitats in forests (according the Estonian Forest Law)	Strictly protected areas are excluded,	Certain activities (e.g. building the repository)

Feature	Rationale	Discretionary criteria	Comments
		the possible impact is assessed in SEA	might influence the habitats, so the buffer zones or preventive/mitigation measures can be given during SEA procedure.
Historical heritage	Locally protected heritage objects: hereditary culture objects, last century architectural objects, farmstead architecture objects, military heritage objects, ancient history objects, holy places[1]	Strictly protected areas are excluded, the possible impact is assessed in SEA	It's preferred that those objects should not be deteriorated but certain combinations with repository is possible. Those objects need to be further analysed.

Notes specifying information sources:
1) Lääne-Harju comprehensive plan
2) Land register information,
3) National Land Board Data
4) Estonian Nature Information System
5) National Heritage Board Information

6 Definition of Ranking Criteria for Selection of Detailed Investigation Sites

Ranking Criteria are necessary to provide bases for comparison between the preselected candidate sites so as to arrive at a list of preferred candidate sites. They are applied together with the Discretionally Criteria for selection of candidate sites most optimal for establishment of waste disposal facility. The ranking will be done by evaluating the available information and expert judgement. The regional studies implemented under sub-activities 1.2, 1.3 and 1.4 will be the main sources of the needed information.

The proposed Ranking Criteria are presented in Table 3, together with scoring example using a three-point system (the highest score "2" is given for favourable feature, while "0" for the

Table 3. Ranking criteria to be used for selection of the three potential sites

Discretionary criteria	Ranking criteria			Comments
	Min value **Score 0**	**Interim value** **Score 1**	**Max value** **Score 2**	
Geology				
Predictable geology	Limited information	Substantial uncertainties in interpretations of geological structure	Sedimentary sequence with simple structure	
Ability to be characterized with geological investigation technics	Difficult physical access to the investigation territory	Access is moderately difficult	Easy physical access to the investigation territory	
Hydrogeology				
Simple geological setting making characterizing and modelling of the hydrogeological system easier and more reliable	Unknown water bearing units and hydrogeological features, no hydrogeological observation wells in vicinity	Limited information on the hydrogeological features	Single and well know water bearing unit; well known features of aquifers; existing modelling (for scientific, industrial or water supply reasons), water wells or boreholes available in vicinity	
Low and stable ground water table. Not expected changes in important hydrogeological conditions due to natural events or human activities	High and unstable ground water table. Changes of hydrogeological conditions are possible	Ground water table is relatively stable, at depths of about 1 m Changes of hydrogeological conditions are of low probability	Low (at least 3 m deep) and stable ground water table. Not expected changes in important hydrogeological conditions due to natural events or human activities	If the groundwater level is too high, protection measure would be required, such as introduction of a layer of properly selected soil under the basis of NSDF
Geochemistry				
Geo- and hydro chemical environment with moderate pH	Unknown chemical conditions	Existing information or predictions on chemical	Existing information or predictions on low chemical	High aggressiveness is an exclusive

Discretionary criteria	Ranking criteria			Comments
and Eh levels (nonaggressive to commonly applied concrete)		aggressiveness to commonly applied concrete, however the impact can be minimised by application of resistive concrete	aggressiveness to commonly applied concrete (i.e. Portland cement); According standard ISO EN 206-1:2000	factor, if it cannot be reduced with application of resistive concrete The chemical conditions are to be investigated during site characterisation stage (Activity 2 of the current project)
Absence of chemical conditions facilitating fast migration of radionuclides	Unknown chemical conditions		Retention of relevant radionuclides is expected (i.e. high pH, presence of clayey particles)	
Tectonics				
Potential for adverse tectonic events	Located just beyond exclusion limit. Recent or historic evidence of active faulting, tectonic processes	Moderate distance from active faults	The site furthest from the active faults Low potential for adverse tectonic events, absence of recent or historic evidence of active faulting, tectonic processes	
Potential for seismic events	Historical earthquakes of such magnitude and intensity that, if they recurred, could adversely affect isolation of the waste	Not applicable	No evidence of soil liquefaction in seismic loads and indications on presence of soils with high liquefaction potential	
Surface processes				

Discretionary criteria	**Ranking criteria**			**Comments**
Topographical and hydrological features that preclude the potential for flooding and limit landsliding and erosion	Slopes more than 10% or less than 2%	Inclination is only slightly differs from the limiting values	A hill with modest slope inclination	
Absence of soils of low bearing strength	Unknown properties of basement rocks	Not applicable	Stiff basement rocks	According to construction requirements for heavy buildings Soils of insufficient bearing strength are not suitable
Meteorology				
Extreme weather conditions	Frequency of extreme weather conditions is low	Frequency of extreme weather conditions is moderate	Extreme weather conditions are common	Closed NSDF can be sensitive to extreme weather conditions (i.e. heavy rainfalls, prolonged droughts, very deep freezing), not foreseen in design of facility
Human activities				
Distance from hazardous facility	Located just beyond exclusion limit	Medium distance	No facility at less than 2 km	
Distance from airports	Located just beyond airport exclusion limit	Medium distance	The site furthest from the airport	
Distance from major routes with frequent movement of hazardous material	Located just beyond exclusion limit	Medium distance	No movement of hazardous material at less than 2 km	
Transport of waste				
Availability of suitable roads	Limited access route is available	Improvement of existing roads is needed	Roads are suitable for waste	Preference will be given to minimize the

Discretionary criteria	Ranking criteria			Comments
			transportation and emergencies	waste transportation distances
Land use and ownership				
Low potential for future territory development	Located just beyond exclusion limit	Moderate development potential of the territory	No potential for development areas	
Low mining potential	Located just beyond exclusion limit	Medium distance	The furthest distance from identified potential mining areas and valuable mineral deposits	
Low potential for ground water use (low potential for water extraction wells)	Existing potential	Moderate potential for water extraction in future	No such potential	
Valuable agricultural land	The site is on valuable agricultural land	Not applicable	The site is outside valuable agricultural land	
Distance from land improvement system	Located just beyond exclusion limit	Medium distance	There is no drainage system in proximity of the site	
Land ownership	Unreformed state owned land	Not applicable	State owned land	
Population				
Densely populated areas	Site next to densely populated area	Site is at intermediate distance from densely populated area	Site is far away from densely populated area	
Environmental protection				
Protected areas of wildlife (species of category III)	The site is in the protected area	Not applicable	The site is outside protected area	A thorough assessment is needed during the SEA procedure

Discretionary criteria	Ranking criteria			Comments
Green network area	The site is in the green network core area	The site is in the green network corridor	The site is outside green network area	
Valuable landscape	The site is in the area of valuable landscape	The site is next to valuable landscape area	No valuable landscapes in vicinity	
Constructability				
Land plot size	Less than 6 ha	More than 6 ha but less than 10 ha	Over 10 ha	

7 Negative Screening by Exclusion Criteria

The methodology and criteria for selection of sites for radioactive waste disposal has been derived within Sub- activity 1.1 of the current Project (presented in the Interim Report Part 1). Based on the Exclusion Criteria a negative screening of the territory of Lääne-Harju municipality was performed.

The screening was mainly based on existing legal restrictions and plans. The following sources of the relevant information were used: Estonian Nature Information System [1], National Heritage Board Information [2], National Heritage Register [3], Lääne-Harju comprehensive plan [4], National Land Board Data [5], Land register [6], Estonian Topographic Data Base [7], PSH station Detail Plan [8]. Also, results of an overview of conditions influencing siting in the Lääne-Harju local municipality (see Appendices of this Report), were used for screening too.

Areas not readily accessible for geological exploration and thus not suitable for detailed characterization were screened out in addition. Areas that are accessible for geological exploration mainly answer to the two criteria: they are located on state owned or unreformed land and they are not further than 150 m from accessible roads. These criteria were addressed in the GIS analysis as well.

Results of the territory screening according to the exclusion criteria are presented in Figure 5. There are 18 sites (GIS application) left as potentially suitable in the territory of Lääne-Harju municipality after the screening. The sites are named after a village or cadastral unit name, and three letter abbreviations are added:

- Keibu – KEI (KEI-1, KEI-2, KEI-3)
- Alliklepa - ALL
- Vihterpalu - VIH
- Pedase - PED
- Altküla - ALT
- Lemmaru - LEM
- Ingeri - ING
- Tallinn – TAL (TAL-1, TAL-2, TAL-3, TAL-4, TAL-5, TAL-6, TAL-7)
- Kadaka – KAD (KAD-1, KAD-2).

The sites that were relatively close to each other, were grouped under one area (Kadaka, Tallinn and Keibu), but each individual site was given an identification number.

The grouped areas are the following:

- KADAKA consists of 2 sites: KAD-1, KAD-2;
- KEIBU consists of 3 sites: KEI-1, KEI-2, KEI-3;
- TALLINN consists of 7 sites: TAL-1, TAL-2, TAL-3, TAL-4, TAL-5, TAL-6, TAL-7.

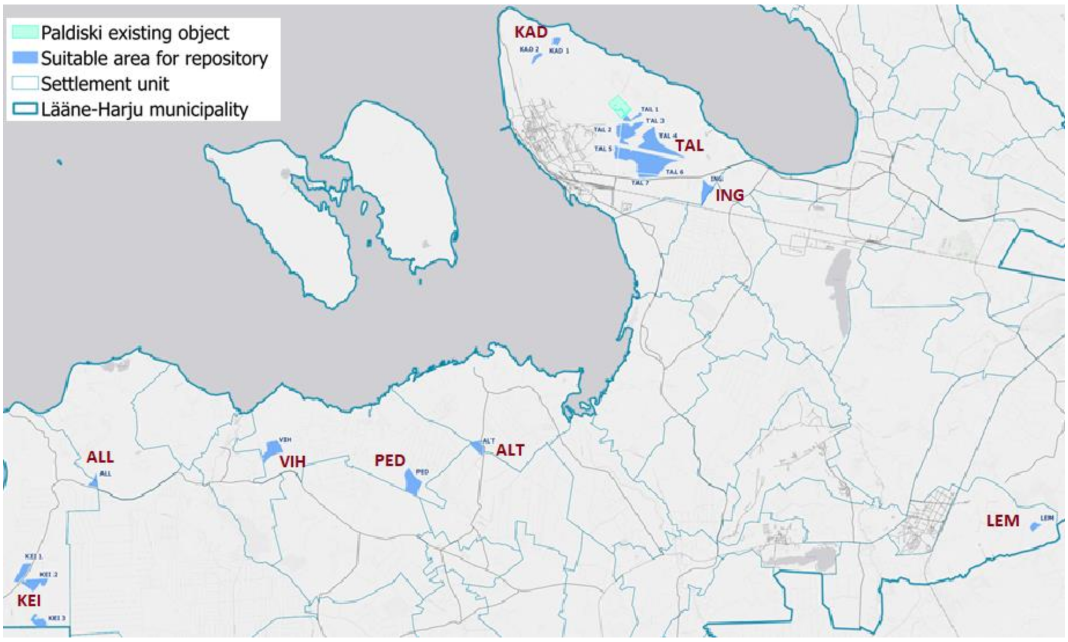

Figure 5. Results of negative screening using the exclusion criteria

As a result, 9 areas on the territory of Lääne-Harju municipality are proposed for comparison and ranking using the discretionary criteria (Part 1 of the current Report) in order to and for determine two most optimal sites for the repository, while the third area is already pre-selected. These three sites will be proposed for further planning and SEA procedure.

7.1 Explanation of Evaluation and Ranking

At the current level of knowledge, all potential sites are geologically very similar. All the sites have predictable geology. Their sedimentary sequence is with simple structure (score 2), containing Quaternary sediments and limestone basement. All sites are easily accessible for geological investigation (score 2).

All sites have single and well known water bearing unit, well known features of aquifers and water wells or boreholes available in vicinity (score 2). Water resources and movement has already been evaluated by Estonian Geological Service. All sites have similar geo- and hydro chemical characteristics with moderate pH and Eh levels. In many pumping wells the groundwater has been monitored during different periods of time however analysed elements were different. General data of water bodies are presented by Environmental Agency and Geological Service (see Appendix B). The ground water table level varies between 1 to 5 m. See below for more precise information.

There is existing information or predictions on chemical aggressiveness to commonly applied concrete, however the impact can be minimised by application of resistive concrete (score 1 for all sites).

All sites have similar situation regarding potential seismic events. There is no evidence of soil liquefaction in seismic loads and indications on presence of soils with high liquefaction potential (score 2).

Potential for adverse tectonic events is low in all of the sites (score 2).

All the areas have rather similar inclination that is only slightly different from the limiting values (score 1 for all sites).

Basement rock for NSDF is stiff limestone in all sites (score 2).

Extreme weather conditions are evenly moderate in all the sites (score 1).

None of the areas are less than 2 km away from the hazardous facilities (score 2).

All areas are located outside of the valuable agricultural land (score 2).

All areas are located outside of the species category III protected areas of wildlife (score 2).

7.2 Results of the Ranking

Based on the regional characterisation of Lääne-Harju municipality, application of discretionary criteria and their developments for Lääne-Harju municipality specific and publicly available data, sites that were left after applying exclusion criteria (see Chapter 3 of the current

Report) were ranked; the scoring is presented in Annex 1, while the ranking results are in Tab. 2. The aim of the ranking is to propose two possible areas to be considered and compared in the pre-selection phase of the spatial planning process for choosing the optimal location for the disposal facility. As a result, the VIH and PED areas received the highest overall ratings (46 points and 44 points, respectively), followed by ALT (43 points) and ALL (42 points).

Table 2. Results of the ranking of the sites

Location	VIH	PED	ALT	ALL	KEI	TAL	ING	KAD	LEM
Total score	46	44	43	42	41	40	40	38	35

The existing FPNS site on Pakri peninsula has already been pre-selected, which means that it will be one of three sites compared in the planning and Strategic Environmental Impact Assessment procedure.

Local conditions were checked by inspecting the top-ranked sites. The experts, seeking to verify the real conditions, visited the sites having the highest score (VIH, PED and ALT). The site visits were held during spring 2022 after melting of snow cover.
According to experts, access to the VIH site is quite good on a gravel road in good condition, see Fig. 2. The ground on the site was already dry.

Fig. 2. Access road to the VIH site

The PED site is more farther from the main access road. The access is through the small village (Fig. 3). The soil is dry, suitable for geological investigations and construction activities.

Fig. 3. Access road to the PED site

The ALT site is located next to the main road in forested area, but the forest was recently cut down. The ground is relatively dry with ditches for water drainage (Fig. 4).

Fig. 4. Photos from the ALT site

8 Consideration of Stakeholder’s Opinion

Views of relevant stakeholders play an important role in the selection of sites for nuclear installations. According to opinion of the local Lääne-Harju municipality administration expressed during a meeting held on 5th of May 2022 (see Annex 2), the sites VIH, ALL, KEI were deemed unsuitable, because nearby Keibu, Alliklepa and Vihterpalu villages have a lot of public interest to be used as vacation and recreation areas. The coastal areas are developed as summer house and residential areas and the surrounding forests in those villages are historically important part of the local recreation. The local municipality’s vision is to keep those areas for recreation. This is also supported by the Padise comprehensive plan [12] in force, where have been brought out that these areas have been popular as a place to build cottages and summer homes. Nearby forests are meant to be protected and preserved and the coast must be considered precious due to its high recreational value. Therefore, waste management function is not complying with the areas land use plans.

Taking into account the position of the local municipality and existing indications on the negative public opinion, the areas VIH, ALL and KEI are recognized as unsuitable for waste disposal and excluded from the further siting process. Therefore, the second and third top-ranked sites (PED and ALT, respectively) are proposed for further studies as candidates for construction of the disposal facility. In addition to the existing and pre-selected site on Pakri peninsula, the candidate sites to be compared in the next planning and SEA procedure are PED site near Harju-Risti and Padise villages and ALT site in territory of Altküla village (Figures 5 and 6).

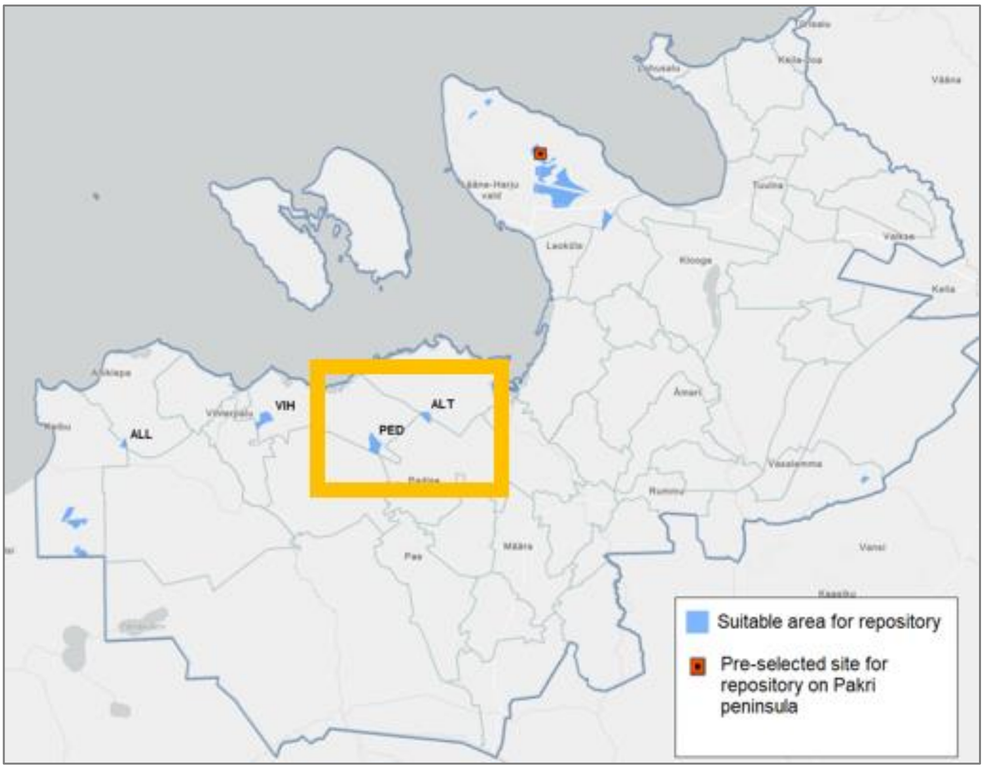

Fig. 5. The candidate sites proposed for further studies (in orange rectangle)

Fig. 6. Vicinity of PED and ALT sites

9 General Conditions of the FNPS Site

The FNPS (Former Nuclear Paldiski Site) site has been pre-selected and it is located in Pakri peninsula, where the radioactive waste storage facility was built in 1997. The FNPS location is in the Figure 7. Territory of the FNPS was not screened out using the exclusion criteria.

Fig. 7. Location of the FNPS in Pakri peninsula

The site has predictable geology with simple structure containing Quaternary sediments and limestone basement. The site has single and wellknown water bearing unit, well known features of aquifers and water wells or boreholes available in vicinity. The site has moderate pH and Eh levels. Groundwater is 5 m deep. The ground is quite even, from 18-25 m and it rises from northeast to southwest. Basement rock is stiff limestone. Area is located outside of the valuable agricultural land. The area is located outside of the species category III protected areas of wildlife. No hazardous facilities less than 2 km distance. The area is furthest from the airport perimeter zone. Roads are suitable for waste transportation and emergencies. It is located on waste management land-use zone in Lääne-Harju general plan. Some perspective gravel mineral resources are relatively close, 100 m from the outer border of the existing plot. Land improvement system area is rather far away, the nearest land improvement ditch is 100 m away. The area is state owned land. The site is outside green network area. The closest residential area is 700 m away, and the densely populated area (city of Paldiski) is 900 m away. Nearest valuable landscape is 800 m away. Land plot size is almost 30 ha. Around 4% of the plot is covered with the forest, other area is grassland or yard area.

In conclusion the existing site is suitable for further studies and as one of the three candidate sites for repository. There is no exclusion features based on the current information that may compromise the construction or the operation of a disposal facility on the existing site.

10 The Main Results

This Report integrates findings of Sub-activities 1.1, 1.2, 1.3 and 1.4 of the Project „Purchase of studies for the preparation of a designated spatial plan and the assessment of impact". The all three Sub-activities are interlinked: they give relevant inputs to determining the three most optimal locations for the repository (a purpose of the Activity 1). The work is based on detailed analysis of Estonian Legal Acts, National Strategies, Development Plans (National and Local Municipality's) as well as on international requirements and recommendations relevant for selection of a radioactive waste disposal site. As a result of the work, an integrated Geographical Information System was produced, containing base maps and data layers incorporating all collected information relevant for the siting. The Report follows the Aarhus Convention principles, since the local municipality is involved in the decision process and the results of the report will have public participation through spatial planning and Strategic Environmental Impact Assessment process.

As the Sub-activity 1.1 of the Project (Part 1 of the current Report) was focused on the methodology for candidate site selection, this Part of the Report is aimed at its practical implementation. First, the negative screening based on exclusive criteria was carried out followed by an analysis of remaining areas using the discretionary criteria.

Regional characterisation of Lääne-Harju municipality is an important component of the current Report. The characterisation results were used at all stages: screening of the territory, identification and ranking of potential candidate sites. The regional characterisation using available information sources includes the following features:

- Topography,
- Geomorphology,
- Hydrology,
- Climate,
- Tectonics and seismicity,
- Mineral resources,
- Hydrogeological structure,
- Environmental study,
- Study on social situation,
- Roads and infrastructure.

Regional characterisation showed that for many selection criteria (for example: climate, geology, environmental conditions) the area of the municipality is quite uniform. For many aspects, for example geology, choosing site mostly depends on the technological solution and the type of the repository. The main criteria influencing the selection of candidate sites are the social situation and anthropogenic activities: availability of access roads, potential for territorial development, presence of residential territories, and densely populated areas as well as areas of high recreational value. However, presence of mineral resources and dangerous objects, as well as airports, are important factors too.

Based on discretionary criteria and the collected information, ranking of the candidate sites was performed. **After considering the priorities of the local Lääne-Harju municipality, two sites – PED and ALT in the central part of the municipality, in villages Pedase and Altküla – are proposed for further analysis and comparison (Figure 2).**

In addition to the two candidate sites (PED and ALT) selected during this comparison, the existing FPNS site on Pakri peninsula is to be compared in the next stages of the process for choosing the most appropriate location for the disposal facility. At the current level of knowledge, no distinct negative features or deficiencies of the proposed sites have been identified.

The following outcomes achieved during implementing the Activity 1 are not included in this Report:

1. An outline of the special planning for the radioactive waste disposal site and intended development of the Strategic Environmental Impact Assessment; in Estonian 'Radioaktiivsete jäätmete lõppladustuspaiga eriplaneeringu lähteseisukohad ja keskkonnamõju strateegilise hindamise väljatöötamise kavatsus'.

2. Detailed mapping of the siting results mapped using a Geo-Information System. The online GIS application: https://tinyurl.com/yab8paj3.

11 Criteria for Final Selection of the Site for Waste Disposal Facility

After comprehensive multidisciplinary investigations during Activity 2, the three candidate sites will be compared again to identify the preferable one for the construction of the disposal facility. The comparative analysis (sub-activity 3.2) will be done using results of the performed site studies as well as appropriate Exclusion and Discretionally Criteria (presented in Tables 1 and 2), if they are still relevant at the final stage. However, not all criteria applied for selection of the three candidate sites will be actual at the final site selection stage, therefore a renewed set of criteria is to be applied. A new set of criteria to be used in addition to the proposed for final site selection is presented in Table 4. These criteria are be based on the general requirements on **safety**, **constructability** and **stakeholder opinio**n [16]. In addition, **socio-economic** and **environmental** factors also need to be taken into account.

Adequate protection of human and environment is a key issue in radioactive waste disposal program, therefore safety indicators make basis for site comparison criteria. According to Radiation Protection optimisation principle set in COUNCIL DIRECTIVE 2013/59/EURATOM [19], the protection shall be optimised to keep individual doses, the likelihood of exposure and the number of exposed individuals as low as reasonably achievable taking into account the current state of technical knowledge and economic and societal factors. Therefore, preference should be given to sites associated with the lowest ionizing radiation doses.

The dose limitation principle requests that in planned ionising radiation exposure situations, the sum of doses to an individual shall not exceed the dose limits laid down for occupational or public exposure. Therefore limits for human exposure are provided in the Table 3. If numerical simulation results that such limits can be exceeded, the site is to be considered as unsafe and thus unacceptable for the construction of the disposal facility. Thus, in this case these criteria acquire an exclusive character.

It is expected that environmental monitoring of the disposal facility will last up to a hundred of years or even longer. Therefore, it is important to set simple but sufficiently effective system for monitoring of radioactive effluents from the disposal facility.

Opinion of local community and stakeholders is a very important factor influencing siting of the disposal facility [16]. Results of social study (sub-activity 2.13) will used for selection of the preferable site. To avoid contradiction of local population preference is given to a sparsely populated areas or locations next to the existing nuclear site (it is common practice applied worldwide, because habitants in vicinities of such sites much better accept new activities related to waste management).

Locating the waste disposal facility close to the main waste producer has many additional advantages. First, it simplifies waste transportation process. It is particularly important when very heavy subjects are transported. In this case acceptability for disposal of very large and heavy subjects is significantly increased. Thus, disposal of the waste near the waste generation plant provides an opportunity to optimize waste conditioning method and flexibility in the choice of options for dismantling the reactor, since it becomes possible to dispose of bulky items or unconditioned waste.

Also, short distance between waste generation and disposal locations allows to simplify repository design and construction, because of optimal application of the existing infrastructure, facilities and logistics. There would be no need for additional premises and facilities for waste control, temporally storage, radiation protection, monitoring and security. In addition, geological features in vicinities of the existing nuclear site are rather known and it reduces need for additional site investigations in the future. Preference will be given to location of the repository next to the reactor shelter or in short distance.

Other features influencing selection of the site are minimising the environmental impacts and economic factors. The construction cost depends on conditions of the selected site as well on needs for road reconstruction.

The proposed criterion list will be revised after completing detailed studies of the sites. Also, other criterions may be identified through the studies of the sites (i.e. during Activity 2).

Table 4. Preliminary criteria proposed for final comparison of the three candidate sites.

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
1. Safety and Radiation Protection					
1.1 Waste disposal stage: individual effective dose of occupational exposure	Highest doses	Intermediate doses	Lowest doses	**	Input from sub-activity 2.16.
1.2 Waste disposal stage: individual effective dose for a reference member of public, mSv/a	Highest doses	Intermediate doses	Lowest doses	***	Input from sub-activities 2.11 and 2.16. Necessary assumptions must be made if needed.
1.3 Post-closure period: individual effective dose for a reference member of general public in case of normal evolution of EBS	Equivalent or slightly below the dose constraint (from 0.01 to 0.3 mS/a or slightly above)	Below dose constraint (from 0.001 to 0.01 mSv/a)	Significantly below dose constraint (less than 0.001 mSv/a)	***	Input from sub-activity 2.16. For comparison purposes same default design (proposed during preliminary studies 2014-2015) have to be applied at 3 sites.
1.4 Post-closure period: individual effective dose for a	Effective dose about 10 mSv/a or intrusions is rather likely (site features	Effective dose about 1 mSv/a and the likelihood of intrusion is moderate	Effective dose about 0,1 mSv/a and the	***	Input from sub-activity 2.16. For comparison purposes same default design (proposed during preliminary

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
reference member of public in case of human intrusion during post closure phase	increasing the likelihood of intrusion, for example presence of potential mineral deposits, area is preferable for future development)		likelihood of intrusion is low		studies 2014-2015) must be applied at 3 sites.
1.5 Conditions for monitoring of environmental radioactivity	Monitoring is complicated (for example, changes of ground water flow direction are expected, or few surface water bodies need to be monitored)	Complexity of monitoring program is moderate	There are no features complicating the monitoring program	*	Design of the monitoring program depends on site specific conditions. Evaluation will be based on results of Sub-activity 2.17.
2. Social factors					
2.1 Public acceptancy	The lowest acceptancy	Intermediate acceptancy	The highest acceptancy	***	Opinion of local community and its justified arguments have to be considered. The evaluation will be based on results of Sub-activity 2.13 and public hearings.
2.2 Presence of residential areas	Site is not far away (but at least 700 m) from densely populated areas or significant number of	Site is at intermediate distance from densely populated areas or average number of residents living nearby	Densely populated area is far away and not many residents living nearby in	**	

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
	residents living nearby in sparsely populated area.		sparsely populated area.		
2.3 Impacts on social and cultural objects	The disposal facility has significant negative influence for existing objects. The impact avoiding or mitigating measures are very costly	The facility has relatively small negative influence. Avoiding or mitigation measure are inexpensive	The impact is unexpected	*	A thorough assessment is needed during the SEA procedure
3. Environmental factors					
3.1 Wildlife protection areas, impact on flora and fauna and biodiversity, Natura 2000 sites	The significant negative impact is expected. The impact mitigating measures are very extensive and costly.	The possible negative impact is relatively small and it's possible to apply mitigation measures to avoid that.	The negative impact is not expected.	*	A thorough assessment is needed during the SEA procedure
3.2 Impact on green network areas	The site is in the green network core area and/or the coherence of green network is very hard to provide	The site is in the green network corridor and/or the coherence of green network can be provided with mitigation measures	The site is outside green network area, or the coherence of green network is very easy to provide	*	

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
3.3 Tectonic features	Limited conditions	Average conditions	Good conditions	**	Specific criteria will be developed after results of Sub-activity 2.1 are available.
3.4 Seismic analysis	Limited conditions	Average conditions	Good conditions	**	Specific criteria will be developed after results of Sub-activity 2.2 are available.
3.5 Geological-lithological properties	Limited conditions	Average conditions	Good conditions	**	Specific criteria will be developed after results of Sub-activity 2.3 are available.
3.6 Geodetic conditions of surface terrain	Limited conditions	Average conditions	Good conditions	*	Specific criteria will be developed after results of Sub-activity 2.4 are available.
3.7 Geomorphological features	Limited conditions	Average conditions	Good conditions	*	Specific criteria will be developed after results of Sub-activity 2.5 are available.
3.8 Hydrogeological conditions	Limited conditions	Average conditions	Good conditions	*	Specific criteria will be developed after results of Sub-activity 2.6 are available.
3.9 Hydrographic conditions	Limited conditions	Average conditions	Good conditions	*	Specific criteria will be developed after results of Sub-activity 2.7 are available.

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
3.10 Chemical composition and properties of groundwater and surface water	Limited conditions	Average conditions	Good conditions	**	Specific criteria will be developed after results of Sub-activity 2.8 are available.
3.11 Properties of soil and its deeper layers	Limited conditions	Average conditions	Good conditions	*	Specific criteria will be developed after results of Sub-activity 2.9 are available.
3.12 Impact of the climate change during next 300 years	Considerable impact	Average impact	No impact	***	
3.13 Atmospheric air quality	Meets criteria in all 3 phases of facility lifetime with significant mitigation measures	Meets criteria in all 3 phases of facility lifetime with simple mitigation measures	Meets criteria in all 3 phases of facility lifetime without mitigation measures	*	Specific criteria will be developed after results of Sub-activity 2.10 are available. Comparison the quantities of pollutants emitted into ambient air by the repository (i.e., in the construction, operation and closure of the facility).

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
3.14 Possible transboundary environmental impact	High possibility	Average possibility	Low possibility	*	Input form sub-activity 2.19.
4. *Human activities enhancing facility demerge risks					
4.1 Impact from hazardous facility: the airports and routes with hazardous materials	Significant negative impact and costly mitigation measures	The possible negative impact is relatively small and it's possible to apply mitigation measures	The negative impact is not expected	**	Input from sub-activity 2.18.
4.2 Potential for future territory development	High development potential. Located just beyond exclusion limit	Moderate development potential	Development unlikely	**	
4.3 Mining potential	Presence of mineral deposits, mining is presumable	Mining is unlikely	No valuable mineral deposits	***	Evaluation will be based on results of Sub-activity 2.3
4.4 Potential for ground water use (low potential for water extraction wells)	Establishment of water extraction wells is presumable	Moderate potential for water extraction	No such potential. Water is not suitable as potable	***	Evaluation will be based on results of Sub-activities 2.6 and 2.8.

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
4.5 Impact on land improvement system	The significant negative impact is expected, and the impact mitigating measures are very extensive and costly	The possible negative impact is relatively small and it's possible to apply mitigation measures	The negative impact is not expected	*	
5. Technical and economic factors					
5.1 Constructability: land plot size	Less than 6 ha	More than 6 ha but less than 15 ha	15 ha and more	*	Bigger land plot gives more flexibility to design specific location for facilities and supporting infrastructure.
5.2 Availability of infrastructure for waste disposal and institutional control measures (roads, water lines, sewerage, security system, environmental monitoring, data connections etc.)	Supporting infrastructure is missing	Supporting infrastructure needs substantial improvement	Supporting infrastructure exist and needs only minor adjustments	**	

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
5.3 Locating the disposal facility next to the FPNS. Complexity of the waste transport	The waste to the disposal site is transported via public roads.	N/A	Location of the disposal facility on the territory of the FPNS. Waste will be moved only within FPNS.	***	Use of public roads will increase possibility of radiological accidents. If PED or ALT will be selected waste transport distance is 25-30 km vs Paldiski site 300 m. Carrier on public roads will need hazardous material class 7 license.
5.4 Construction costs of the facilities	The highest cost	The intermediate cost	The lowest cost	***	The construction cost of the disposal facility will be higher in case of unfavourable conditions of the site
5.5 Establishment of radioactive waste management center	New waste treatment center established on Disposal Facility site for future waste treatment.	N/A	Existing waste treatment center will be used for future waste treatment.	*	Before reactor compartments decommissioning new waste treatment center must be built on Paldiski site. At the end of the decommissioning different scenarios will evolve depending about the repository site: In Paldiski same facility will be used for future waste treatment. If PED or ALT will be selected, Paldiski facility have to be

Criteria	Min value Score 0	Interim value Score 1	Max value Score 2	Assumed importance	Comments
					demolished and new waste treatment center will be built next to repository.
5.6 Impact of noise and vibration levels from building and operating phase of the establishment	Noise and/or vibration levels exceed the norms significantly and the mitigation measures are costly to apply	Noise and/or vibration levels exceed the norms to a small degree and it's possible to apply mitigation measures with reasonable costs to avoid that	Noise and vibration levels don't exceed the norms.	*	Specific criteria will be developed after results of Sub-activity 2.14 are available.

12 Conclusions

1. The location of the radioactive waste disposal facility shall comply with the basic requirements: the disposal facility must be safe, the location must be agreed upon by the stakeholders; and it must be possible to construct, operate and close the disposal facility without undue difficulties.

2. The main requirements for the geological environment are sufficient bearing capacity of rocks and low chemical aggressiveness to concrete structures. In addition, other properties must be considered such as water permeability, intensity of water flux, radionuclide retention, distance of ground water flow to discharge zone. Due to shortage of existing relevant information it is not possible to conclude which of the existing geological formation suites better for hosting the disposal facility.

3. Based on the available geological information there are no specific issues to construct and develop a disposal facility in the region. Site-specific studies (Activity 2) should provide information that affects complexity of the design, construction, and ultimately the cost for waste disposal.

4. The chosen disposal concepts for Low Level Waste and Intermediate Level Waste are highly flexible. They can be easily adapted to different geological environments and waste inventories.

5. The final conclusion on suitability of a particular site for disposal of radioactive waste can only be taken after detailed investigations of the site specific conditions and comprehensive Safety and Risk Assessments (subjects for Activity 2).

6. After thorough examining the available information gathered through the implementation of sub-activities 1.2, 1.3 and 1.4 and combined into a single Geographical Information System, it was found that due to various factors (safety, social, environmental, technical and others), most of the territory of the local Lääne-Harju municipality is not suitable for the construction of the radioactive waste disposal facility.

7. Only about ten areas, including the territory of the Former Paldiski Nuclear Site, were identified as potentially acceptable. Among some cases, these areas consist of several isolated plots.

8. After comparison using the methodology developed under sub-activity 1.1 and consultations with the administration of the local municipality, priority is given to two sites, PED and ALT, located in the central part of the municipality. They are proposed for further investigation of

suitability for waste disposal together with the Former Paldiski Nuclear Site. There are indications that a safe radioactive waste disposal facility can be constructed at any of these three sites, using commonly applied techniques, while potential for human intrusion and damage from hazardous activities is also low.

9. The final decision on the selection of a site for the disposal facility for radioactive waste must be taken into consideration, regarding protection of present and future generations and with the active participation of the local people in the selection process.

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