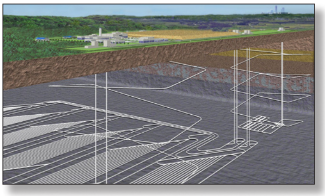
Radioactive Waste Management
2016

Japan's Siting Process for the Geological Disposal of High-level Radioactive Waste

An International Peer Review



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Radioactive Waste Management

Japan's Siting Process for the Geological Disposal of High-level Radioactive Waste: An International Peer Review

NEA No. 7331

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Cover photos: Conceptual figure depicting a deep geological repository (Nuclear Waste Management Organization of Japan); The International Peer Review in Japan (METI, Japan).

Foreword

To select a geological disposal site for high-level radioactive waste in Japan, the government of Japan enacted the Designated Radioactive Waste Final Disposal Act in 2000 to specify the procedure for repository site selection. The site selection process was expanded in May 2015, with a set of site screening criteria being issued based on the existing geoscientific knowledge. In 2016, the Ministry of Economy, Trade and Industry (METI) of Japan requested the OECD Nuclear Energy Agency (NEA) to conduct an independent technical peer review. The objective of this review is to assess the suitability and applicability of the Japanese site screening process for identifying suitable (or unsuitable) areas for geological disposal of high-level radioactive waste when compared to international best practices. The report presents the key findings including the potential areas of improvement recommended by the international review team.

Acknowledgements

The NEA would like to thank the reviewers for preparing and delivering their review of this report within such a short timeframe. This peer review could not have been successful without these dedicated professionals. Special thanks also go to the staff of the Ministry of Economy, Trade and Industry (METI) of Japan, the Nuclear Waste Management Organisation of Japan (NUMO) and the Japan Atomic Energy Agency (JAEA) for assisting in the organisation of the peer review.

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List of abbreviations and acronyms

DGR	Deep geological repository
EBS	Engineered barrier system
FEP	Features, events and processes
HLW	High-level radioactive waste
IRT	International review team
JAEA	Japan Atomic Energy Agency
METI	Ministry of Economy, Trade and Industry (Japan)
NEA	Nuclear Energy Agency
NUMO	Nuclear Waste Management Organisation of Japan
OECD	Organisation for Economic Co-operation and Development

Executive summary

In order to make progress on the permanent geological disposal of high-level radioactive waste (HLW), Japan has begun a process for identifying, evaluating and choosing areas that may host a permanent disposal facility. The Designated Radioactive Waste Final Disposal Act of 2000 set out a three-step process for repository site selection, as well as the responsible organisations and fund management for the disposal of HLW. The site selection process was expanded in May 2015, when the government of Japan stipulated a new introductory step in which a set of site screening criteria was issued based on the existing geoscientific knowledge. These criteria were developed by the Geological Disposal Technology Working Group of the Nuclear Energy Subcommittee which was created by the Ministry of Economy, Trade and Industry (METI), under the guidance of the Advisory Committee for Natural Resources and Energy and the Electricity and Gas Industry Committee.

In 2016, METI requested the OECD Nuclear Energy Agency (NEA) to conduct an independent technical peer review. The international peer review was organised according to NEA guidelines for international peer reviews for radioactive waste. An international review team (IRT) with broad international experience conducted its assessment in May 2016, based on the following documentation provided in English:

- Geological Disposal Technology Working Group (2014), "Re-evaluation of Geological Disposal Technology on the Basis of the Latest Geoscientific Knowledge – Preferable Characteristics and Properties of the Geological Environment and their Long-Term Stability" (referred to as the Interim Report).
- Geological Disposal Technology Working Group (2015), "Interim Summary of Requirements and Criteria for Nationwide Scientific Screening by the Geological Disposal Technology Working Group" (referred to as the Interim Summary).

During its week-long mission (24-30 May 2016), the IRT had extensive discussions with the Geological Disposal Technology Working Group to assess the newly added site screening process and its criteria. To obtain a comprehensive view of how scientific knowledge is achieved, specifically in investigations of rock mechanics during deep underground excavation and interactions between engineered materials and the host rock, the IRT also visited the Mizunami Underground Research Laboratory and learned about the ongoing research and development activities. The IRT presented the key findings of its review to METI on 30 May 2016.

The IRT review report follows the structure of the Interim Summary. Each section summarises the information on each topic, and provides acknowledgements and advisory points. In total, the IRT report has 40 acknowledgements and 24 advisory points in its six sections.

The IRT report acknowledged that the stepwise site selection process as currently specified in the Final Disposal Act and the newly added nationwide scientific screening process are consistent with international practice. Additionally, METI's current approach to ensure an informed and willing host in each step of the site selection process is consistent with the internationally accepted geological disposal strategy. Such a stepwise approach also allows the needs of individual communities to be addressed in stages. The IRT recognises METI's efforts to differentiate among "potentially less suitable areas"; "potentially suitable areas"; and "potentially more suitable areas" as a means to facilitate future site selection. However, the IRT finds that some of the terminology used in the Interim Summary is not necessarily obvious and could lead to confusion. Furthermore, the IRT stresses the importance of maintaining open dialogue and interaction between the regulator, the implementer and the public. The IRT also suggests to start the dialogue in the early phase and continue communications throughout the siting process (NEA, 2015).

The geological criteria for the categorisation of the areas properly identifies and categorises important events and processes as to their potential impacts on the safety functions of containment and isolation. Nevertheless, the Interim Summary could have noted that a features, events and processes (FEP) catalogue, such as that of the NEA, has been reviewed to ensure that all of the FEPs relevant to the natural environment for the nationwide screening process are identified and documented.

With regards to the safety of facilities, the Interim Summary provides a high-level conceptual design for the underground and surface facility that is generally sufficient for considering the potential hazards and area screening criteria. The conceptual design includes the operations to be performed at the facilities and the relevant time period for construction and operations. However, underground operations should also be considered in evaluating area characteristics.

In addition, integrating transport issues into the site selection criteria is seen as being appropriate and meets international requirements and regulation. The report also appropriately considers that the commonly rugged topography constrains the construction of transport roads or railways.

The IRT shares the general opinion that the feasibility aspects should be taken into account when selecting a site for preliminary investigations and also agrees that it is not appropriate to set exact criteria for nationwide screening at this stage, as stated in the Interim Summary. However, the IRT finds the criteria of "ease of geological environment evaluation" could be better explained to improve understanding and recommends clarification in this regard.

Overall, the IRT concludes that the nationwide scientific screening process is generally in accordance with international practices, but some areas remain where improvement could be made.

1. Introduction

Japan began to study geological disposal of high-level radioactive waste (HLW) in the 1970s. The Japanese HLW, mostly high-level liquid waste that arises from spent nuclear fuel reprocessing, is mixed with molten borosilicate glass to immobilise the substantial quantities of fission products and actinides remaining in the waste.

In 2000, Japan enacted the Designated Radioactive Waste Final Disposal Act to specify the procedure for repository site selection, the responsible organisations and fund management for the disposal of HLW. The Nuclear Waste Management Organisation of Japan (NUMO) was subsequently established by HLW producers to select a site for deep geological repository (DGR), and to construct, operate and close the DGR. In 2002, NUMO initiated a public invitation for volunteer host municipalities to participate in a literature survey as the first step of selecting a final disposal site, but no survey has yet been carried out.

The site selection procedure specified in the Final Disposal Act consists of three steps:

- literature survey;
- preliminary investigation stage;
- detailed investigation stage.

The 2011 Fukushima Daiichi nuclear power plant accident highlighted the need to re-evaluate the technical safety basis of geological disposal facilities, and recommendations were submitted in 2012 by the Atomic Energy Commission of Japan to ensure that the latest geoscientific knowledge is incorporated into the re-evaluation. The need for re-evaluation by experts was also indicated by the Radioactive Waste Working Group of the Nuclear Energy Subcommittee which was organised in 2013 under the guidance of the Electricity and Gas Industry Committee of the Advisory Committee for Natural Resources and Energy for the Ministry of Economy, Trade and Industry (METI), to review the policy for the final disposal of HLW.

To review the technical reliability of geological disposal on the basis of the latest geoscientific knowledge and to specify future research and development topics, a Geological Disposal Technology Working Group of the Nuclear Energy Subcommittee was created by METI in 2013. This working group was mandated to evaluate the long-term safety of geological disposal based on current geoscientific knowledge and available technologies.

The Geological Disposal Technology Working Group, consisting of eight experts recommended by academic societies and four technical specialists from the Radioactive Waste Working Group, carried out a review of the H12 report in 2013, taking new geoscientific knowledge obtained after 2000 into consideration. Representatives from NUMO and the Japan Atomic Energy Agency (JAEA) also participated and provided detailed information in this review. The group held several meetings from October 2013 to May 2014. Information was made public and expert opinions on the reviews were solicited from experts outside of the working group to enhance neutrality and fairness.

In 2014, the group issued its evaluation results concluding that there are potential areas where a safe DGR can be located, specifying the favourable characteristics and long-term stability properties of the geological environment for safe geological repositories of HLW (Interim Report). In May 2015, the government of Japan stipulated a new introductory step in which a set of site screening criteria was issued (Interim Summary) and “scientifically preferable areas” are identified based on the existing geoscientific knowledge and the criteria (Cabinet Decision, 2015).

To confirm the appropriateness of adding such a new step and the applicability of these screening criteria to support future site selection, METI requested the NEA to conduct an independent technical peer review.

1.1. Organisation and conduct of the review

The international peer review was organised according to the NEA’s guidelines for international peer reviews for radioactive waste (NEA, 2005) and the terms and conditions as described in the Terms of Reference (NEA, 2016). An international review team (IRT) with broad international experience was assembled independently by the NEA. It consisted of four external experts and two NEA staff. The IRT is balanced between implementers, regulators and scientists and has the following areas of competence:

- expert knowledge for developing geological repositories in crystalline and sedimentary rock formations;
- expert knowledge for developing national siting processes for radioactive waste.

To ensure independence and to avoid possible conflicts of interest, the experts chosen by the NEA have not been involved in any activities affiliated with the Japanese geological repository programme. Statements of impartiality of the reviewers are included in Annex II.

The objective of this review is to assess the suitability and applicability of the newly added site screening process and its criteria, as defined by the Geological Disposal Technology Working Group, to identify suitable and unsuitable geological disposal areas for high-level waste in Japan. In this 2016 review, the IRT is expected to address the following aspects of the Japanese siting process for a geological disposal facility for HLW:

- basic concept of geological disposal (Section 3.1);
- geological environmental characteristics and their long-term stability (Section 3.2);
- safety of construction and operation of radioactive waste management facilities (Chapter 4);
- safety of transport (Chapter 5);
- project feasibility (Chapter 6);
- other consideration items (Chapter 7).

The IRT conducted its assessment based on the following documentation (provided in English):

- Geological Disposal Technology Working Group (2014), “Re-evaluation of Geological Disposal Technology on the Basis of the Latest Geoscientific Knowledge – Preferable Characteristics and Properties of the Geological Environment and their Long-Term Stability” (referred to as the Interim Report).
- Geological Disposal Technology Working Group (2015), “Interim Summary of Requirements and Criteria for Nationwide Scientific Screening by the Geological Disposal Technology Working Group” (referred to as the Interim Summary).

In May 2016, the IRT carried out an in-depth assessment of the prescribed newly added site screening process and its criteria. During this week-long mission (24-30 May), the IRT had extensive discussions with the Geological Disposal Technology Working Group to assess the site screening process and its criteria. To obtain a comprehensive view of how scientific knowledge is achieved, specifically in investigations of rock mechanics during deep underground excavation and interactions between engineered materials and the host rock, the IRT also visited the Mizunami Underground Research Laboratory and learned about the ongoing research and development activities. Key findings of this peer review were presented to METI on 30 May 2016, and are outlined in the present report.

2. Geological disposal and initial, international site screening criteria

Geological disposal is internationally recognised as the preferred approach for the long-term management of high-level radioactive waste, protecting both humans and the natural environment. It involves containing and isolating radioactive waste inside an underground facility constructed in a suitable rock formation. As observed in NEA member countries (see NEA country reports), typical initial screening criteria are as follows:

- There is sufficient space to accommodate the surface and underground facilities. The site must exhibit suitable conditions for safe construction, operation, continuous monitoring and closure of the repository.
- The site must bear stable host rock to ensure long-term safe containment and isolation of radioactivity.
- The site does not contain economically exploitable natural resources as known today which reduces the likelihood of future human intrusions.
- The site is located in areas with no known geological, geochemical and hydrogeological characteristics that would adversely affect the long-term post-closure safety of the geological disposal system.

In addition, other international recommendations for siting of geological repositories have been compiled by the IAEA, e.g. Appendix I of *Geological Disposal Facilities for Radioactive Waste*, SSG-14.

3. Nationwide scientific screening

3.1. Basic concept of geological disposal in Japan

The high-level safety features of the Japanese disposal concept can be summarised as follows:

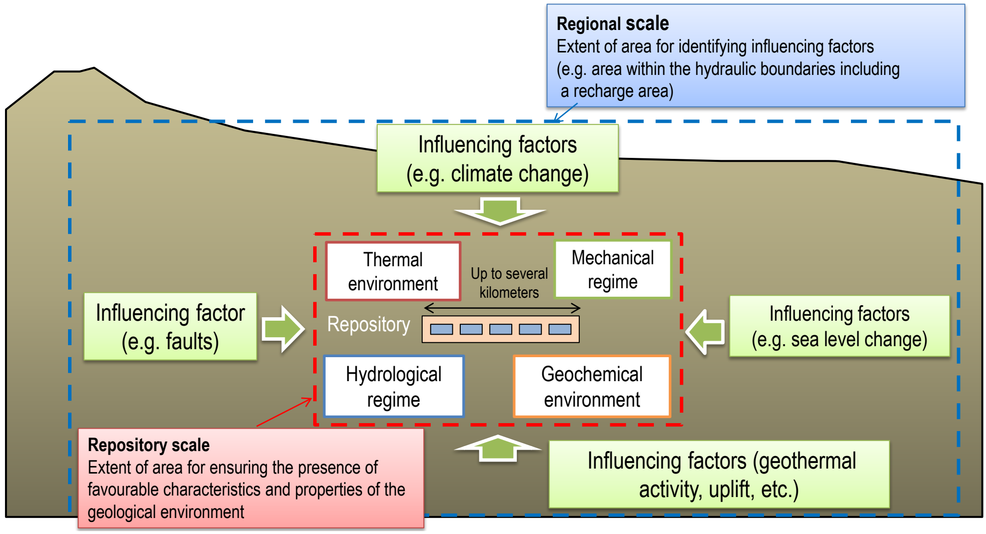
- The use of multiple engineered barriers (e.g. glass matrix, overpack, bentonite) to ensure that the failure of one barrier does not jeopardise the containment of radionuclides.
- The host rock will provide a favourable geothermal, chemical, mechanical and hydrological environment to maintain the stability and performance of the disposal system for over tens of thousands of years. The characteristics of the host rock will safely protect the emplaced high-level radioactive waste (HLW) from disturbances caused by natural events.
- The repository will be located away from valuable resources (e.g. gas and coal mines) and at a depth such that future inadvertent human intrusion into the closed repository will be very unlikely.

The geological environment in Japan consists of a wide variety of rock types including crystalline and sedimentary rocks. The crystalline rocks include granites and high-grade metamorphic rocks that are geologically and structurally comparable to granitic terrains elsewhere in the world. However, many of the sedimentary rocks have been subjected to various tectonic conditions of the Japanese islands and therefore may exhibit different geological properties to the argillaceous rocks being evaluated in other countries. The fact that the Japanese islands are tectonically active has also complicated engineering geological investigations. Spatial scales specifying the repository and regional scales are defined in order to facilitate detailed geological investigations (see Figure 1).

3.2. Criteria for nationwide scientific screening

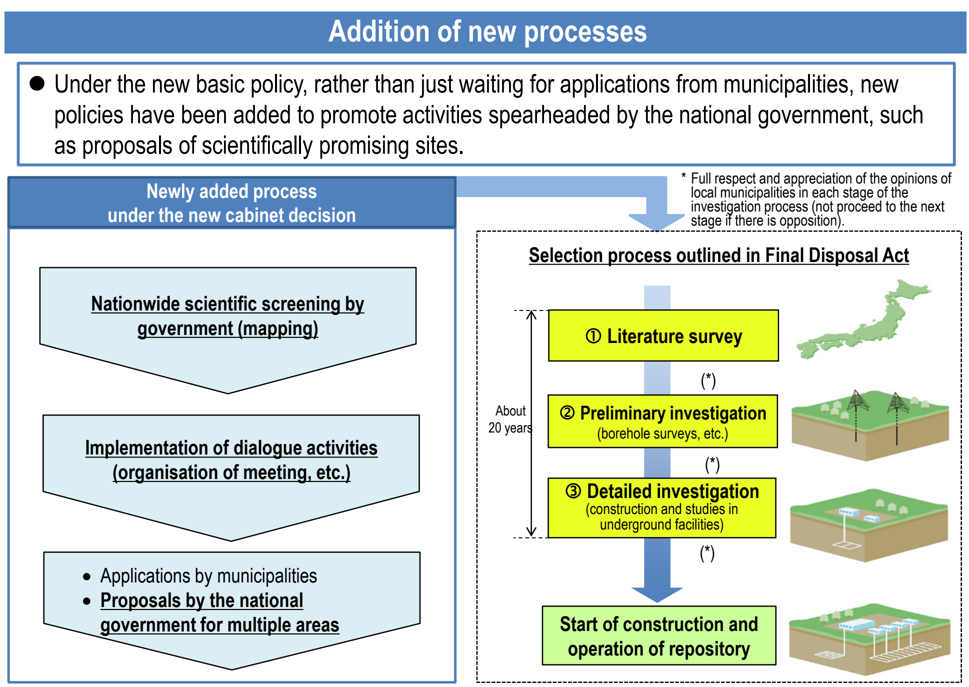
The Cabinet's decision to revise the Basic Policy in 2015 has prompted a set of scientific site screening criteria to be developed for identifying the potential repository areas prior to the formal three-step selection process outlined in the Final Disposal Act. By applying the set of criteria in a nationwide screening process, in 2016, the Ministry of Economy, Trade and Industry (METI) of Japan is planning to identify i) potentially less suitable areas; ii) potentially suitable areas; and iii) potentially more suitable areas; for hosting a geological repository of HLW.

Figure 1. Schematic illustration of spatial scales



Source: METI, Japan.

Figure 2. Newly added process



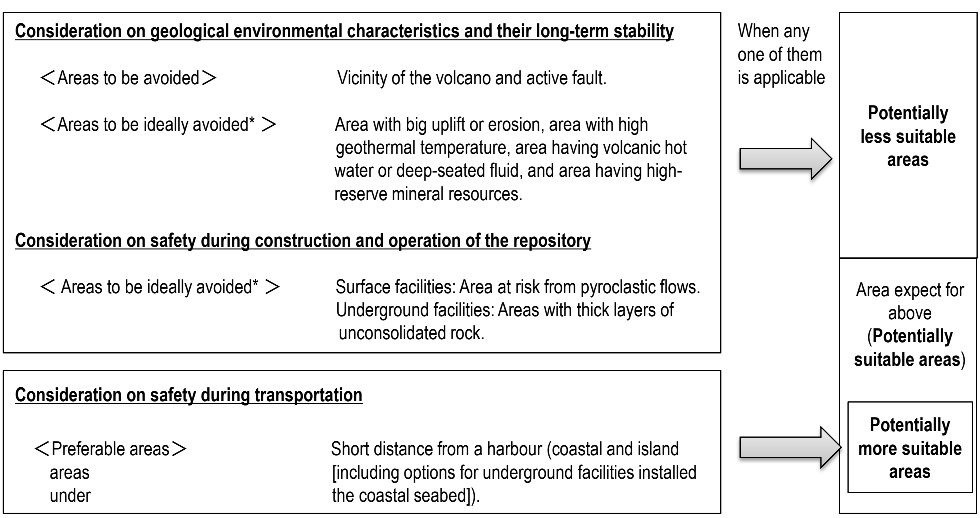
Source: METI, Japan.

In order to categorise the entire country into these three categories, the Advisory Committee for Natural Resources and Energy, Geological Disposal Technology Working Group first considered the feasibility of setting criteria for the following areas:

- Area to be avoided: "an area needs to be avoided if required engineering would be very difficult and/or a geological disposal facility is very likely to be significantly affected by events and characteristics directly associated with loss of safety functions".
- Area to be ideally avoided: "an area to be preferably avoided is one where the required engineering may be very difficult and/or a geological disposal facility might be significantly affected by events and characteristics directly associated with loss of safety functions".
- Preferable area: "an area in which there is reasonable confidence (high likelihood) that the site features and characteristics would provide a good margin of safety of geological disposal".
- Preferable area from the viewpoint of project feasibility: "an area in which there is reasonable confidence in the engineering feasibility of implementation".

Figure 3 shows how the various areas are categorised.

Figure 3. Extracted criteria for "potentially less suitable, potentially suitable and potentially more suitable areas"



* If any one of the requirements and criteria for the "areas to be ideally avoided" is applicable, the adequacy of specific areas may become clearer as the data is extended by the future surveys, research, etc. Accordingly, their potential for the future disposal site selection survey is not currently excluded.

Source: METI, Japan.

In reviewing the above concept and approaches adopted in the Japanese radioactive waste management programme, the IRT offers the following acknowledgements and advisory points.

Acknowledgements:

- The stepwise site selection process as currently specified in the Final Disposal Act and the newly added nationwide scientific screening process are consistent with international practice. The multi-step process allows essential information gathering to confirm the geological environment of the potential site, i.e. via literature surveys, preliminary and detailed site investigations.
- METI's current approach to further ensure an informed and willing host in each step of the site selection process required by the act is consistent with the internationally accepted geological disposal strategy. Such a stepwise approach also allows the needs of individual communities to be addressed in stages.
- The intent to select a site that meets Japan's current safety standards, but not necessarily selecting the "most suitable (best) site", is considered practical and consistent with international best practices and recommendations.
- A reference design of a geological disposal system for HLW currently exists. The provision of a reference design along with an inventory of radionuclides under various waste classifications allows features, events and processes (FEPs) of the repository that could potentially affect the behaviour of the repository over the time-periods of interest to be evaluated.
- The IRT considers METI's approach to establish scientific working groups to develop scientific siting criteria a reasonable and practical approach. Their approach of asking the different scientific societies concerned to nominate experts of high reputation, frequently request public comments for experts and keep science and technical communities informed, demonstrates METI's wish to involve the broader scientific and technical community.

Advisory points:

- The IRT recognises METI's efforts to differentiate among "potentially less suitable areas"; "potentially suitable areas"; and "potentially more suitable areas" as a means to facilitate future municipality volunteering activities. However, the IRT finds that some terms used in the Interim Summary are not necessarily obvious and could lead to confusion. The IRT noted certain detailed site geological environmental data are limited but nevertheless would recommend to ensure that clear definitions be used when communicating the site selection process.
- The IRT stresses the importance of maintaining open dialogue and interaction between policy makers, the regulator, the implementer and the public. The IRT also suggests to start the dialogue in the early phase and continue communications throughout the siting process (NEA, 2015).

3.3. Geological environment characteristics and their long-term stability

Geological criteria used in the nationwide scientific screening

Section 4.2 of the Interim Summary provides the criteria for the nationwide scientific screening that are considered important for "geological environmental characteristics and assuring their long-term stability". These criteria address natural phenomena and characteristics of the geologic system that could affect performance of the repository over the long term following permanent closure.

The characteristics in this section are considered as potentially impacting two of the safety functions for long-term repository performance: isolation and containment. The potential natural features, events and processes that can impact these functions are presented in Table 4.2.1.1 in the Interim Summary. Six categories of events and processes are discussed. Loss of isolation can occur through volcanic/igneous activity or uplift/erosion. Loss of containment can occur through changes in the thermal environment, mechanical regime, hydrologic regime, and geochemical environment. As discussed in this section, these changes are geothermal activity, mechanical and hydrologic effects of fault movement (both direct effects of fault movement and effects on hydraulic conductivity), and geochemical effects from movement and inflow of external fluids from igneous activity or fault movement. The presence of mineral resources is also considered as a potential loss of isolation through accidental human intrusion.

For each of these six categories, the Interim Summary considers criteria for "areas to be avoided" and for "areas to ideally be avoided". In general, the former criteria ("areas to be avoided") are assigned a more rigorous level of screening, in order to ensure that areas (physical regions of the country) that are most susceptible to the event or process are most strictly removed from consideration. In a similar manner, assignment of somewhat less strict criteria in each category defines the "areas to ideally be avoided". One exception to this general pattern is for magma intrusion into and eruption through the repository, where only the criteria for "areas to be avoided" are defined.

Acknowledgement:

- This section properly identifies and categorises important events and processes as to their potential impacts on the safety functions of containment and isolation.

Advisory point:

- The events and processes described in this section are a subset of the larger collection of FEPs that have been identified and compiled through international experience for use in assessing the performance of geologic repositories. For example, the NEA has compiled an extensive catalogue of FEPs (NEA, 2013) that is widely recognised as comprehensive. The Interim Summary could note that a FEP catalogue, such as that of the NEA, has been reviewed to ensure that all of the FEPs relevant to the natural environment for the nationwide screening process are identified and documented.

Volcanic and igneous activities

This section addresses the potential for volcanic and igneous activities to result in loss of physical isolation of the repository, i.e. magma intrusion into and eruption through the repository. The section summarises the general spatial and temporal distribution of volcanic activity in the Japanese islands, including individual eruptive centres and larger caldera complexes. The discussion is supported by several recent references, most notably the most recent edition of *Volcanoes of Japan* (AIST, 2013). The criteria provided for "areas to be avoided" are based on the distributions of Quaternary volcanic centres, large calderas, and areas "where magmas can be generated" based on high measured heat flow and/or "distributions of high temperature fluids and gas emissions".

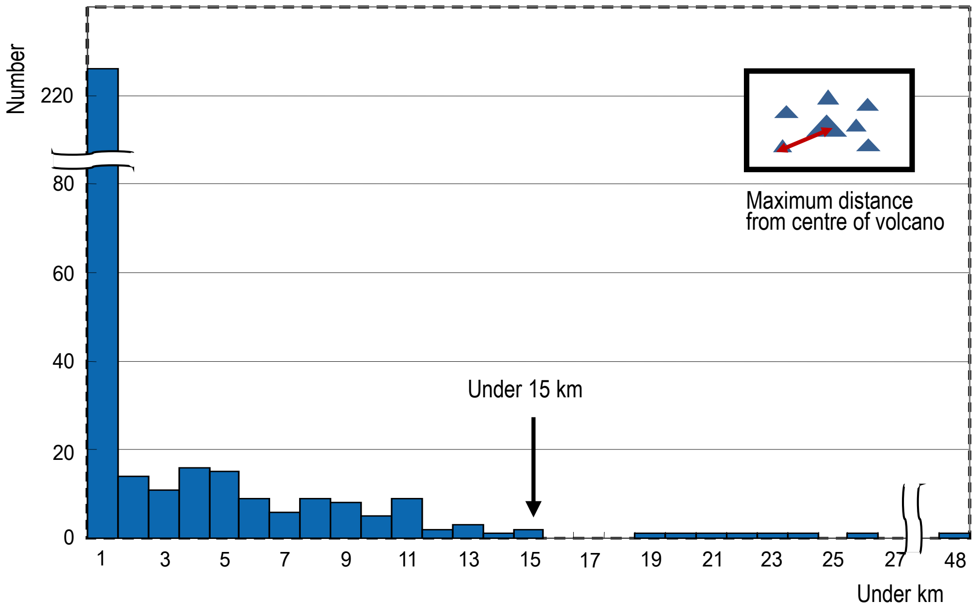
Acknowledgements:

- The Interim Summary recognises the fundamental importance of minimising the likelihood of volcanic disruption of a repository, both for performance and for public confidence.
- The distribution of Quaternary volcanoes in Japan is very well known.
- Japanese volcanoes are among the best studied in the world, with detailed eruptive histories available for many along with extensive geochemical, petrologic and geophysical data sets.
- The Interim Summary acknowledges that the current understanding of magmatic processes indicates that future volcanic hazards to a repository may be present even in areas with no known Quaternary eruptive centres.

Advisory points:

- The Interim Summary prescribes a specific setback distance of 15 km from the centre of a Quaternary volcano or within large calderas where the area exceeds 15 km. While this prescribed distance is supported by overall spatial patterns for Japanese Quaternary volcanoes (see Figure 4), eruptive episodes at some centres have included propagation of magma at shallow depth over greater distances. It is suggested to clearly state that setback distances be considered less generically and more specifically for those centres where existing information may indicate that greater distance values are appropriate, but that a minimum setback distance of 15 km be maintained.
- The current understanding of magmatic systems in large caldera complexes also suggests that less generic, but still conservative, setback distances can be developed for specific caldera locations using combinations of topographic, geophysical and eruptive history data.
- It is mentioned in the Interim Summary that "an area should be excluded if the subsurface temperature and pressure conditions could cause the generation and ascent of magma in the upper mantle and volcanic/igneous activity could thus occur in the future" (p. 15), but such an exclusionary factor is not carried over into the prescribed criteria for the area to be avoided (p. 16). It is suggested that this apparent inconsistency be resolved.

Figure 4. Maximum distance and frequency between the centre of Quaternary volcanoes and individual volcanic bodies



Source: METI, Japan. Based on the Catalogue of Quaternary Volcanos in Japan (1999).

Uplift and erosion

If rapid enough, erosion can reduce the thickness of the overburden that serves as a geological barrier lying above the repository, hence reducing its efficiency and possibly bringing the repository closer to the surface. The Interim Summary states that areas where the erosion rate exceeds 300 m/100 000 years should be avoided.

In inland areas (away from coasts), long-term (at the scale of 10^4-10^6 years) erosion is mostly controlled by crustal uplift. Therefore, an estimate of the long-term uplift rate provides an estimate of the long-term erosion rate. It can be obtained in various ways, for instance by determining the rate of river incision of alluvial terraces or by dating terraces with different ages and elevations.

In coastal areas, erosion is also controlled by uplift, but can be further enhanced by sea level lowering. The largest estimate of Quaternary sea level fall, contemporaneous with glaciations, is 150 m below the current level. This conservative figure could therefore account for an eroded thickness of 150 m of overburden. Consequently, in coastal areas, the amount of maximum acceptable uplift must take into account this component.

Acknowledgements:

- Using estimates of Quaternary or Holocene (10^4-10^6 year range) uplift rates as a conservative surrogate for erosion rates is sound and justified for nationwide scientific screening. Indeed, such long-term rates provide average values over periods in the order of 10^4 years or more.
- Crustal uplift rates used for estimating erosion are based on a large number of local or regional investigations carried out across Japan. These data are summarised in a map published by the Geological Society of Japan. This map provides uplift rates for nearly the totality of Japan except for Quaternary volcanic regions or areas with no data. The latter areas represent a small proportion of the map.

Advisory points:

- It would be helpful to estimate the maximum long-term uplift rate in the unmapped areas so that the map would cover the entire archipelago.
- The map showing the uplift rate published by the Geological Society of Japan summarises rates for rectangular areas of approximately 20 km by 15 km. For a given area, it would be helpful to indicate the number of data on which the average value is based. This would help indicate the level of confidence of the contouring.

Geothermal activity

This section addresses the potential impact of elevated temperature on the ability of the engineered barrier system to perform its containment safety function. Specifically, the section cites the risk of degraded performance of the buffer material if its temperature exceeds 100°C for an extended period. For this reason, the criteria evaluate geothermal gradients that may lead to such elevated temperatures at repository depth. The criteria are applied either through direct measurement of heat flow and geothermal gradient or through indirect evidence such as proximity to volcanic activity, presence of hot springs or anomalous gas emission, or inferences of convective heat transfer at depth.

The criterion for the "areas to be avoided" is described as where the geothermal temperature at disposal depth exceeds 100°C for a long period. The criterion for "areas to ideally be avoided" is described as "areas that do not assure an ambient temperature of 100°C or less at the disposal depth".

Acknowledgements:

- The thermal criteria in this section relate to the performance of an important component of the engineered barrier system (EBS) in the reference design. In this case, the most temperature-sensitive component of the EBS is the bentonite clay in the buffer that surrounds the waste package. Although different bentonite formulations vary in their temperature response, there is consensus that some bentonite mineral phases will alter at elevated temperatures, and that these changes can compromise buffer performance (e.g. hydration and swelling properties). It is also generally agreed that 100°C represents a conservative upper temperature limit to avoid degradation of buffer performance. The criteria in this section correctly acknowledge the temperature sensitivity of the EBS in the reference design.

- The criteria also acknowledge that heat transfer in the repository and surrounding rocks is a complex process that occurs not only by conduction but also by advective movement of groundwater or hydrothermal fluids.
- This section also recognises that lack of sufficient data constrains the ability to reliably set specific values in criteria for geothermal parameters.

Advisory points:

- The Interim Summary recognises the role of conductive and advective heat transfer in the repository and host rocks, but does not include contributions from decay heat in the waste. This contribution could be significant for the overall heat budget, especially soon after waste is emplaced and sealed in the repository. The average waste age (post irradiation) and waste nuclide content in each package could be used to assess the impact on the total heat budget.
- It would be informative to provide more explanation of the data uncertainty regarding the geothermal gradients, given that relevant maps appear to be available for Japan, such as the cited *Geothermal Gradient and Heat Flow Data* report (AIST, 2004). This would help explain the lack of a prescribed value to assess the thermal “areas to be avoided”.

Chemical perturbations by flow of volcanic or deep-seated fluids

The temperature and chemical composition of water in the repository strongly affect the performance of the EBS, particularly the potential corrosion of the carbon steel overpack and dissolution of the glass waste form. In the reference design, the buffer serves to limit water access to the metal waste package, and thus slows its potential corrosion.

This section discusses the potential for changes in water chemistry to impact the containment function of the overpack. It is presumed that the ambient groundwater at the repository level at the time of closure will not be corrosive to the EBS components. The focus of this section is therefore on possible external sources of corrosive water that could intrude at a later time from volcanic or other deep sources. The criteria defined in this section consider two chemical parameters as indicative of potentially corrosive water: pH and carbonate concentration. The report recognises low pH as a first-order indicator of highly corrosive water. It is noted that areas of low pH water frequently occur within 15 km of volcanic centres, coincident with the nominal setback prescribed to avoid volcanic activity in an earlier section of the report. The report further notes that groundwater systems can be affected over even distances greater than 15 km in the areas of larger magmatic complexes.

High carbonate concentration is also considered to act as a source of bicarbonate ions, which increases the possibility of localised corrosion when the overpack surface is partially exposed to water or contaminants. For these reasons, areas that show indications of groundwater with pH less than about 5 or carbonate concentration of about 0.5 mol/dm^3 are designated as "areas to ideally be avoided". The "areas to be avoided" are described more generally, as regions where "volcanic water or deep-seated fluids exist(s) at the disposal depth, which significantly affect the chemical environment", but no numerical values are prescribed. Lack of data is cited as a reason for not specifying numerical limits for this case.

The criteria for potential changes in water chemistry are further supplemented in this section by noting that regions with "traces of volcanic activity" or "anomalously high geothermal gradients and with high temperature fluid and gas emissions" should also be taken into consideration. Other potential indicators of the possible presence (or future appearance) of corrosive water are stated to be regions with predicted future volcanic activity (based on volcanic patterns or "estimated heat convection in the mantle"). These general indicators are similar to those noted in the previous section on geothermal activity. This interpretation is consistent with the close linking of potentially corrosive water with volcanic-geothermal systems in Japan.

Acknowledgements:

- The discussion in the Interim Summary correctly recognises that the chemical environment of the repository is critical for EBS performance. The report also correctly notes the close association of water chemistry with the volcanic and thermal conditions in the area of the repository.
- The role of deep circulating fluids in the large-scale tectonic framework of Japan is also clearly recognised in the report.
- The Interim Summary focuses on potential corrosion of the overpack as an important part of the repository performance.

Advisory points:

- In discussing the potential effects of changes in water chemistry, the Interim Summary considers only impacts on performance of the overpack. While acknowledging that this is an important component of the EBS, the overpack is not the only part of the EBS that can be sensitive to water chemistry. In particular, performance of the bentonite buffer also depends on the water chemistry. For example, extreme pH or high concentrations of sulphur species can adversely degrade the buffer and impair its swelling and sorption properties. Buffer degradation can then further enhance overpack corrosion by allowing greater water influx. This section could be improved by considering chemical effects on the buffer and other EBS components (e.g. the glass waste form).
- Another aspect of changing water chemistry that could be addressed here is the effect on chemistry of the rock-water interactions in the repository and surrounding environment. The composition of intruding water can be better treated by consideration of the water-rock system, particularly at elevated temperatures and where the host rock may be more reactive (e.g. in porous flow through a reactive matrix). Impacts of intruding water

may be greater or lesser depending on the effective buffering capacity of the host rock.

Fault activity

Fault-related displacement reaching a disposal site would damage the underground structures and would likely degrade the barrier performance with respect to water flow. Active faults in the immediate vicinity of disposal sites are thus to be avoided. The Interim Summary states that the retained safety distance is 1/100 of the length of the active fault.

Acknowledgements:

- The distinction between active fault (or active fault segment) and seismogenic fault is crucial. Indeed, even if physically discontinuous, different segments of a fault can undergo co-seismic displacement, which may propagate across the disconnections. When estimating the fault length, it is therefore accurate to sum the lengths of each constituting segment.
- Deformation in the vicinity of active faults does not consist only of fracturing. It may also include folding or flexure. The possibility of such a deformation which may affect the repository site is considered.
- The possibility of entirely concealed (“blind”) faults is also taken into account.

Advisory point:

- As acknowledged in the Interim Summary, there are several uncertainties in estimating the length of a fault. Parts of the fault, especially fault ends, may be concealed. Moreover, the length of a fault or of a fault segment may be longer at depth than at surface. Considering these uncertainties, it may be appropriate to allow a greater safety distance at a later site-specific stage of the siting process.

Mineral resources

Existing mineral resources of current or potential economic value are in potential conflict with a deep geological repository. After closure and the potential loss of knowledge and memory about the repository, resource exploration or mining activities might cause an unintentional human intrusion into the repository system, causing a loss of isolation and confinement functions of the repository and could thus enable a release of radioactivity into the biosphere.

The Japanese Final Disposal Act stipulates that a preliminary investigation area has to be selected under the condition that “there is no record of mining or the existence of economically valuable mineral resources in the target geological body for final disposal”. In this regard, mineral resources include only those minerals (metallic, non-metallic and fuel minerals) stipulated by the Japanese Mining Act.

In general, there are only few mining activities and mineral resources in Japan at present for valuable raw materials. The most considerable resource these days is coal, but there are also scarce iron deposits, as well as modest quantities of copper and gold. A comprehensive knowledge base exists, identifying areas where it is and was technically possible to extract petroleum, natural gas and coal in Japan. Databases about the distribution of other mineral resources also exist but were determined as not appropriate to use at this time. Other resources, such as groundwater and mineral water or the potential use of a site by other activities in the geological underground, e.g. carbon capture and storage (CCS), are not taken into account at this time.

The exclusion of areas from the site selection process can be seen as a more passive approach to avoid a potential future conflict of interest. As an additional, more active measure, it is also possible to keep the knowledge about the repository alive across many generations.

Acknowledgements:

- The exclusion of areas with mineral resources of current economic value from siting processes for repositories in the deep geological underground is appropriate and in line with the approaches in other countries and international recommendations.
- The selection of the databases about the distribution of mineral resources is appropriate at this stage of the siting process, taking into account that more information about mineral resources will be gathered during future geological investigations of the underground in the preliminary investigation phase.
- The focus on minerals currently stipulated by the Japanese Mining Act is appropriate, as no reliable prognosis of the value of elements and minerals for the far future is possible.

Advisory points:

- In addition to the conflict of use by mining activities due to the exploration or excavation of mineral resources, a conflictual use of the geologic underground by other activities such as carbon capture and storage should be taken into consideration. With regard to the potential drilling for groundwater, it might be useful to demonstrate that drilling to a depth greater than 300 m is also unlikely even under extreme arid conditions in future climate change.
- In addition to the more passive protection of a site against unintentional human intrusion caused by future exploration or mining activities by excluding areas of current economic value from the site selection process, more active measures such as the establishment of long-term oversight and the preservation of knowledge across generations should also be taken into account. International activities at the NEA, including participation of Japan, about preservation of knowledge, records and memories about repositories across generations are currently undertaken to evaluate and develop methodologies and technologies to preserve memory and knowledge about repositories over the midterm. In addition to this, other international organisations like the International Commission on Radiological Protection (ICRP) recommend to establish active measures for a mid-term oversight

about the repository. While loss of memory about the repository cannot be excluded, such a loss should not happen intentionally (ICRP, 2013).

3.4. Preferable geological environment characteristics for geological disposal

Preferable geological environment characteristics and properties for geological disposal of vitrified high-level radioactive waste were identified in order to ensure the engineered barrier system and the host rock will contain and isolate the waste. Such an approach is in agreement with international best practices followed by other waste management organisations worldwide and will provide a good basis to ensure the long-term safety of a disposal facility.

The identification of the preferable geological environment characteristics and properties considers a reference design that has been extensively investigated in the past by Japanese research institutes, and their findings have been properly reported (JNC, 2000).

The favourable characteristics and properties have been classified into THMC conditions (i.e. thermal, mechanical, hydrological regimes and geochemical environment) and discussed separately for both the EBS and the natural barriers. The identified preferable geological environment characteristics and properties are summarised in Table 1. The collection of favourable characteristics are then used to define requirements for “preferable areas”.

Table 1. Preferable geological environmental characteristics for geological disposal

	Favourable characteristics and properties of the geological environment in terms of the EBS	Favourable characteristics and properties of the geological environment in terms of the natural barriers
Thermal environment	Low ambient rock temperature	-
Mechanical regime	Small rock deformation	-
Hydrological regime	-	Slow groundwater movement
Geochemical environment	Neither high nor low groundwater pH Reducing groundwater Low dissolved inorganic carbon in groundwater	Neither high nor low groundwater pH Reducing groundwater

Source: Interim Report, Table 1.

The report discusses some specific aspects of each of the elements of the table in terms of favourable characteristics. For example, in the hydrologic regime, the report points to slow groundwater movement as a favourable characteristic. For the geochemical environment, the report notes that neutral pH and reducing groundwater are favourable characteristics for the natural barriers, as well as the EBS. Many of the aspects discussed in this section are the same as those considered in more detail in the section on “areas to be avoided” and “areas to ideally be avoided". The criteria discussed in this section are more qualitative than those in the previous section.

The report states that the development of quantitative requirements would need more complete data and a better understanding of the interactions of individual elements.

Acknowledgements:

- The prior understanding of the interplay of the processes that may occur within the EBS greatly improves the confidence in the identification of favourable geological characteristics and properties. The use of a reference design in this identification process is appropriate and consistent with currently accepted practices at the international level.
- Presenting the results in a format as in Table 1 clearly shows the importance of the geological environmental characteristics and properties with respect to the functioning of a disposal system (either in terms of safety functions or phenomenological evolution within the disposal system).
- The use of qualitative criteria is justified given the knowledge limitations in the existing nationwide datasets and system-level understanding.

Advisory points:

- For the overall approach for identifying "preferable areas", the interactions of the elements in addition to their individual influences on favourable characteristics should be addressed during the site-specific stage of the siting process.
- For the hydrologic regime, the consideration of groundwater flow is mainly in terms of permeability and hydraulic head (i.e. Darcy velocity). Other processes, such as osmosis and thermal convection, is expected to be evaluated during the next three-step survey.
- For the geochemical environment, considerations of additional components such as chlorides, sulphates or possible ligands that may facilitate radionuclide transport is suggested during the site-specific stage of the siting process.

4. Safety of facilities

4.1. Conceptual approach

This section addresses the aspects of the construction and operation of a disposal facility that could influence siting choices. The conceptual design and plan are for a facility that would be constructed and operated for over 50 years, on the surface and underground. The surface facilities would need to receive and inspect waste from the transport system, install the overpack and weld the lid, inspect the completed package and prepare it for transport underground. The underground facilities would need to transport the waste underground and emplace the waste packages into the repository with a surrounding buffer. The nominal repository layout provides for underground access by a sloping ramp to extensive disposal tunnels, with shafts for ventilation and (possibly) additional access. Separate underground areas for disposal of vitrified high-level radioactive waste (in approximately 40 000 packages) and transuranic waste are shown.

Acknowledgements:

- The Interim Summary provides a high-level conceptual design for the underground and surface facility that is generally sufficient for considering the potential hazards and area screening criteria.
- The conceptual design includes the operations to be performed at the facilities and the relevant time period for construction and operations.

Advisory point:

- The report addresses construction of the underground facilities, but not underground operations. Underground operations should be considered in evaluating area characteristics.

4.2. Application

The Interim Summary provides criteria for the construction of the underground facilities and for the construction and operation of the surface facilities. For the underground facilities, seven principal areas of concern are identified that refer to criteria used in tunnel design and construction (JSCE, 2006). These areas of concern are:

- unconsolidated sediments;
- geothermal heat and hot springs;

- swelling rock;
- rock burst;
- mud eruption;
- flooding;
- harmful gas inflow.

For the construction and operations of surface facilities, the Interim Summary recognises that these facilities are similar in many ways to other facilities that handle nuclear materials and high-level radioactive waste. Four specific areas of concern are identified:

- stability of the ground supporting the facility;
- prevention of damage by earthquakes;
- prevention of damage by tsunami;
- prevention of damage by external impacts.

These areas are addressed for nuclear waste management facilities in existing regulations (NRA, 2013a, 2013b). The Interim Summary also provides additional consideration of volcanic hazards, particularly from pyroclastic flows. The report references the "Guide for Evaluating the Effects of Volcanoes on Nuclear Power Generation Plants" (NRA, 2013c) as a source for additional considerations. The report gives specific criteria for "areas to ideally be avoided" as the known areas of Holocene-age pyroclastic deposits and volcanic rocks and detritus. The criteria for "areas to be avoided" are deferred to assessment for "specific sites based on detailed information obtained by field surveys".

This section also considers criteria for a "preferred area" where the margin of safety for the underground and surface facilities "could be greatly improved". For the underground facilities, the report points to known information on two of the areas of concern previously noted: unconsolidated sediments and geothermal heat and hot springs. The report notes that for the first of these, there is no available nationwide documentation, so the assessment is deferred to when more site-specific surveys are performed. For the second area, the report acknowledges that occupational health rules provide that workers be exposed to temperatures no greater than 37°C. The report states that this limit can be maintained by ventilation if the surrounding rock temperature does not exceed 45°C.

The report states that current experience with engineering countermeasures indicates that consideration of the other five areas of concern for the underground be deferred to more site-specific assessments.

For the surface facilities, the Interim Summary discusses possible siting considerations for ground stability, tsunami hazards, and damage from earthquakes and other external events. For most of these, the report cites specific references that provide guidelines for each specific area. These include recent guidelines on surface rock and sediment stability, maximum tsunami heights along the Japanese coast, and probabilistic seismic hazard maps for Japan. The report notes that, for some topics, more specific site data will need further evaluation (for example, updated evaluation of expected maximum tsunami height considering local topographic effects).

Table 4.3.3.2.1 of the Interim Report summarises the criteria assigned for "areas to be avoided", "areas ideally to be avoided" and "preferable areas" for the underground and surface facilities. Two aspects of the underground facilities are addressed, unconsolidated sediments and geothermal heat/hot springs, with only a "preferred area" criteria designated for the latter aspect. Three aspects of the surface facilities are included in the table. For ground stability and tsunami hazards, "preferred area" criteria are given. For volcanic and pyroclastic hazards, the criteria for "areas to ideally be avoided" are given.

Acknowledgements:

- The Interim Summary draws on experience and refers to appropriate codes, standards, guidance, and regulations for underground construction and surface operations. These include civil engineering experience for tunnel construction and nuclear industry experience for high-level radioactive waste handling.
- The report recognises the specific aspects that must be considered for the active tectonic environment of Japan, and the documents referenced appropriately address those local and regional aspects. In particular, the potential hazards from pyroclastic flows and other volcanic activities are correctly given specific attention.
- The report recognises that some existing information requires updating and further evaluation to incorporate more local effects.
- The report correctly recognises potential external hazards from human activity, such as accidents at a neighbouring facility or from accidental airplane crashes.

Advisory points:

- Seismic hazards are addressed in the report only for surface operations. While seismic ground motion at depth for a given earthquake is expected to be significantly lower than at the surface, consideration should also be given to potential effects of a seismic event on underground operations or construction activities (e.g. waste emplacement, loss of surface power supply).
- The potential hazards for surface operations related to external events from human activities could be given additional consideration in siting criteria. For example, accidental aircraft crash could be considered in terms of proximity to principal commercial air corridors or established military aircraft flight patterns.

5. Safety of transport

5.1. Conceptual approach

In Japan, radioactive waste is stored at two sites from where the waste will need to be transported to the repository site. The technical criteria for radioactive waste packages (shipping casks) have been stipulated by the national legislation that is based on the international regulations for the Safe Transport of Radioactive Material (IAEA, 2012). Consequently, the shipping cask is designed to shield from radiation and to maintain its integrity in case of accidents. The fact that the currently used shipping cask is a heavy container with a total weight of approximately 115 tons constrains its transport on roads and railways that have upper-limits for vehicle weight. Taking into account that either road or railroad transport is needed at least for some distance and the fact that Japan is a densely populated country, many areas along the transport route may be affected in terms of public exposure and nuclear security. As the transport of radioactive waste will take place over a decade or longer, safety of transport has been included as one of the criteria in the site selection phase of nationwide scientific screening.

Acknowledgements:

- Integration of transport into the site selection criteria is appropriate.
- The report also appropriately considers that the commonly rugged topography constrains the construction of transport roads or railways.

5.2. Application

Japan has a long experience in transporting nuclear waste from nuclear power plants and from other facilities domestically and overseas. Management of transport is stipulated by the respective legislation. Assessment of safety and nuclear security has been taken into consideration when setting the criteria for site selection. Three types of transport methods are discussed including land transport (railway and road) and marine transport (ship) based on domestic and overseas experience.

Criteria for “preferable area” have been assessed from the viewpoint of long-distance and short-distance transport keeping in mind the safety and nuclear security aspects stipulated by law.

When comparing the three methods (road, railway and marine) for long-distance transport with a focus on public safety and nuclear security, marine transport is considered preferable for several reasons. Of the three methods, marine transport has the lowest risk of public exposure because of the uninhabited marine route. Also the nuclear security risk is the lowest because the transport route is least likely to be known beforehand and does not require any restriction measures during stops. Marine transport greatly reduces requirements for traffic infrastructure in terms of weight or gradient limits for transport routes, and thus allows large volumes of waste packages for each shipment and reduces frequency of shipments.

Short-distance land transport may also be required for marine shipments, to deliver the waste to its final disposal destination. Given the weight of the transport casks, it is likely that a dedicated road or railway will be required for short-distance transport.

Both road and rail are considered suitable for the short-distance transport at this stage. As discussed in the Interim Summary, a short distance from harbour to repository site is preferred in order to minimise transport time. Taking into account the transport plan considered in the Interim Summary, a preferable transport time of approximately 2 hours indicates that a distance of approximately 20 km from the coast be applied as a criterion in the site selection.

Acknowledgement:

- Knowing that Japan has a long experience and an excellent record in transporting nuclear waste both domestically and overseas, the overall description of transport methods is comprehensive, and the initial optimisation of transport by sea and land is appropriate. The scrutiny of different methods of transport has been based on the aspects of minimising public exposure to radiation and to secure the integrity of the waste packages in regard to nuclear safety. It is therefore reasonable that marine transport is prioritised while land transport is to be minimised in terms of distance and time.

Advisory point:

- To accommodate the short-distance transport step, it is suggested that the approximately 2 hour/20 km limit may be better treated not as a strict siting criterion. Some relaxation of these values could provide more flexibility in siting without significantly affecting safety or security.

6. Project feasibility

In the Interim Summary, the project feasibility aspects have been organised in two categories that are considered relevant when defining preferable areas. "Ease of survey after the preliminary investigation phase" involves laws and regulations that restrict the land use because of private ownership or permissions needed for the public land which could make further investigations difficult at the chosen site. In this respect, fewer restrictions on land ownership and access are regarded to be important aspects in selection of preferable areas. The other feasibility aspect that is introduced relates to the "ease of geological environment evaluation".

Acknowledgements:

- The IRT shares the general opinion that the feasibility aspects should be taken into account when selecting a site for preliminary investigations.
- The IRT also agrees that it is not appropriate to set exact criteria for nationwide screening at this stage, as stated in the Interim Summary.

Advisory point:

- The IRT finds that the criteria of "ease of geological environment evaluation" could be better explained to improve understanding and recommends clarification in this regard.

7. Other consideration items

In the Interim Summary, areas where the requirements are met in terms of the long-term geological characteristics and safety of constructions and operation of the surface and underground facilities, are classified as "preferable areas" because of the safety aspects related to transport. Coastal areas that meet the criteria of "preferable areas" and exhibit relatively simple geological environment that allows easy access for safety surveys are further classified as "potentially more suitable" areas. It is also expected that some part of the coastal areas involves favourable characteristics such as reasonable low uplift rate and hydraulic gradient. From the viewpoint of assuring safety during construction and operation, it is deemed possible to take engineering countermeasures after excluding "potentially less suitable areas". It is also assumed that some part of the coastal areas has such characteristics that meet the requirements of project feasibility.

Acknowledgement:

- The report recognised not only the importance of transport safety and geological characteristics of coastal areas, but also the significance of assuring safety during construction/operation of the facility and future project feasibility.

Advisory point:

- This section of the Interim Summary appears to include several aspects of different criteria developed earlier in the report, and does not develop any new or independent criterion for the siting process. The IRT suggests that it should be made clear that the criteria from the other sections will be applied in a consistent manner to the entire country, to show which regions may be more or less suitable for siting a geologic repository. Further consideration of the relative suitability of the specific site in coastal areas may be better considered in the site-specific investigation stage.

8. Considerations from the viewpoint of social sciences

In the Interim Summary, the Technology Working Group has assessed the technological feasibility of siting almost entirely from the point of view of earth sciences. Although the social science consideration falls on the Radioactive Waste Working Group, in the Interim Summary the siting criteria have been briefly dealt with from the social science perspective. These viewpoints entail restrictions on land access by the related laws and regulations, number of landowners (ease of land access) and handling of municipal boundaries (transport).

Acknowledgement:

- The IRT regards aspects from social sciences as important and recognises that some aspects from social sciences are present in some of the criteria in the Interim Summary.

9. Conclusions

The international review team has concluded the following:

- The stepwise site selection process as currently specified in the Final Disposal Act and the newly added nationwide scientific screening process are consistent with international practice.
- METI's current approach to ensure an informed and willing host in each step of the site selection process is consistent with the internationally accepted geological disposal strategy.
- In general, the criteria defined for the site selection process are reasonably complete and capture the important areas of concern.
- Maintaining open dialogue and interaction between the policymaker, regulator, implementer and the public is considered to be important. The dialogue should be initiated in the early phase and communications should continue throughout the siting process.

The IRT has offered advisory remarks in each section as opportunities for improvement. In particular, it is important that clear and consistent terminology be used in defining the site screening criteria and area categories. Ensuring full understanding and engagement of all societal groups is critical to a successful and widely accepted siting process.

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Annex I. International review team members

Stéphane Brassinnes, clay expert
Ondraf/Niras, Belgium

Dr Stéphane Brassinnes is the Research Manager at Ondraf/Niras in charge of geological and geochemical studies for developing disposal repository for Belgian radioactive waste. He has over 15 years of experience in radioactive waste disposal, specialising in host rock assessment and radionuclide transport in disposal systems in Boom Clay. He received his PhD degree from the Université Libre de Bruxelles in 2006. Dr Brassinnes has been an active member in many international scientific activities such as the NEA Thermodynamic Database (TDB) Expert Group and the NEA Clay Club.

Olivier Fabbri, structural geologist
University of Franche-Comté, Besançon

Prof. Olivier Fabbri has been a 1st class professor at the University of Franche-Comté, Besançon since 2010. He is a geologist specialising in structural geology and has extensive experience in geotechnical and hydrogeological studies of dams, bridges and other structural establishments in Japan. Prof. Fabbri received his doctoral degree from the University of Orléans in 1989 focusing on tectonics studies of the Asian margin. He is also the Deputy Director of the UMR Chrono-Environment since 2012.

James Rubenstone, volcanologist
NRC, United States

Dr James Rubenstone is the Acting Director at the Yucca Mountain Directorate of the US Nuclear Regulatory Commission. On top to his leading role in reviewing applications for the first deep geological repository in the United States, Dr Rubenstone also manages a team of engineers and scientists conducting technical studies on high-level radioactive waste management and interacting with various involved stakeholders. Dr Rubenstone has in-depth knowledge of volcanic rocks obtained through his career and education. His doctoral degree from Cornell University focused on the geology and geochemistry of early Tertiary submarine volcanic rocks.

Timo Seppälä, siting and communication expert
Saanio & Riekkola Oy, Finland

Mr Timo Seppälä is currently a Senior Advisor at Saanio & Riekkola Oy in Finland. Prior to this role, Mr Seppälä was the Communication Manager at Posiva for over 17 years, managing various controversial and sensitive issues during Posiva's siting process for a geological repository for radioactive waste. Many successful communication campaigns had been organised by Mr Seppäla in which public acceptance was gained and favourable political decisions were reached. Mr Seppälä holds an international MBA degree specialising in communication and leadership from the Quadriga University and another Masters degree in Environmental Science from the University of Helsinki.

Michael Siemann
NEA

Dr Michael Siemann is Head of the Division of Radiological Protection and Radioactive Waste Management at the NEA. Before joining the NEA, Dr Siemann was Director and Professor for Safety of Radioactive Waste Management at the German Implementer and Operator Federal Office for Radiological Protection. In his function, he was responsible for all existing German LILW repositories as well as for the construction of the "Konrad" LILW repository and the site investigation for a HLW repository at "Gorleben". Prior to this, he was at the German Federal Ministry for Environmental Protection, Nature Conservation and Reactor Safety working in federal surveillance for the LILW repository Asse. He has a Diploma in Mineralogy and a PhD in Geochemistry from the Technical University Clausthal, Department for Repository Systems and Underground Disposal, where he also worked as a senior scientist and assistant professor for many years.

Gloria Kwong
NEA

Dr Gloria Kwong is the Deputy Head of the Radioactive Waste Management Division at the NEA. She received her Masters degree in Chemical Engineering from the University of Toronto in Canada and her PhD degree in Material Science from the Imperial College, London in the United Kingdom. She has more than 15 years of experience in the nuclear industry specialising in corrosion of steel and material engineering. She is a registered engineer in Canada and has obtained her Professional Engineer License of Ontario, Canada since 1993. Prior to joining the NEA, Dr Kwong was the Chief Design Specialist at the Nuclear Waste Management Organization (NWMO) in Canada, and has good knowledge of the Canadian geological repository designs.

Annex II. Impartiality statement of the international review team

Stéphane Brassinnes

Herewith I declare that I have not been involved in person and in an important manner in the Japanese siting process for a geological disposal facility for high level waste during the last five (5) years.

Place: Brussels Date: 19 April 2016.

Your signature,

Olivier Fabbri

To whom it may concern

Herewith I declare that I have not been involved in person and in an important manner in the Japanese siting process for a geological disposal facility for high level waste during the last five (5) years.

Olivier Fabbri

Agreement received electronically on 5 May 2016.

James Rubenstone

To whom it may concern

Herewith I declare that I have not been involved in person and in an important manner in the Japanese siting process for a geological disposal facility for high level waste during the last five (5) years.

James Rubenstone

Timo Seppälä

To whom it may concern

Herewith I declare that I have not been involved in person and in an important manner in the Japanese siting process for a geological disposal facility for high level waste during the last five (5) years.

Helsinki, July 22, 2016

Timo Seppälä
Senior Advisor
Saanio & Riekkola Consulting Engineers

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Japan's Siting Process for the Geological Disposal of High-level Radioactive Waste

The Nuclear Energy Agency carried out an independent peer review of Japan's siting process and criteria for the geological disposal of high-level radioactive waste in May 2016. The review concluded that Japan's site screening process is generally in accordance with international practices. As the goal of the siting process is to locate a site – that is both appropriate and accepted by the community – to host a geological disposal facility for high-level radioactive waste, the international review team emphasises in this report the importance of maintaining an open dialogue and interaction between the regulator, the implementer and the public. Dialogue should begin in the early phases and continue throughout the siting process. The international review team also underlines the importance of taking into account feasibility aspects when selecting a site for preliminary investigations, but suggests that it would be inappropriate to set detailed scientific criteria for nationwide screening at this stage. The team has provided extensive advisory remarks in the report as opportunities for improvement, including the recommendation to use clear and consistent terminology in defining the site screening criteria as it is a critical factor in a successful siting process.

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