Siting regions for deep geological repositories

Nagra's proposals for Stage 3

nagra.

Site selection for deep geological repositories – procedure specified in the Sectoral Plan

How is the search for sites regulated?

The Swiss Federal Office of Energy (SFOE) has the lead in the process that regulates the search for sites for deep geological disposal of all radioactive waste arising in Switzerland. In 2008, the procedure to be followed was defined by the Federal Council (Federal Government) in the Sectoral Plan for Deep Geological Repositories. Nagra prepares siting proposals in each of the three stages of the process; these are reviewed by the authorities and each stage ends with a decision by the Federal Council on which siting proposals are to be carried forward to the next stage. The objective is to identify one site each for a high-level waste (HLW) repository and a low- and intermediate-level waste (L/ILW) repository or a site for a combined repository for the two waste categories. Safety always has the highest priority.

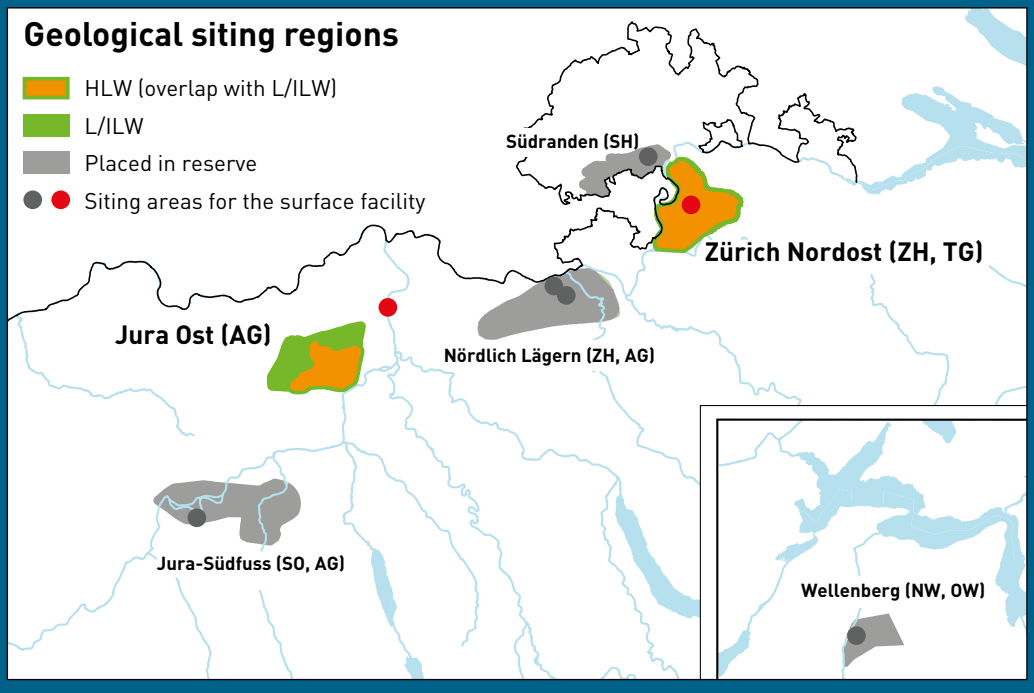
How does site selection proceed?

In **Stage 1** of the Sectoral Plan process, Nagra had to propose geological siting regions for the repositories, taking the whole of Switzerland into consideration. These proposals had to be prepared on the basis of pre-defined criteria relating to safety and engineering feasibility. In autumn 2008, Nagra proposed the following geological siting regions: Zürich Nordost, Nördlich Lägern and Jura Ost for the HLW and L/ILW repositories; in addition, the regions Südranden, Jura-Südfuss and Wellenberg were proposed for the L/ILW repository. The proposals were reviewed by several bodies, including the Swiss Federal Nuclear Safety Inspectorate ENSI and the Nuclear Safety Commission NSC. The Cantons, affected federal offices and neighbouring countries, as well as interested organisations and individuals, had the opportunity to express their views on the proposals as part of a broad public consultation process. The Federal Council then decided in 2011 to adopt all six proposed siting regions into the process.

In **Stage 2**, Nagra designated at least one siting area for the surface facility of a potential repository in each of the six siting regions; this work was carried out together with the regions and the Cantons and was completed in May 2014. The locations for the surface facilities had already been the subject of discussion by the regional conferences since 2012. Besides safe construction and operation, the aim is to integrate the surface facility as far as possible into the siting region in question. Nagra also carried out a safety-based comparison of the siting regions and, in December 2014, proposed the siting regions Zürich Nordost and Jura Ost for further investigation in Stage 3 (see below).

Proposals for Stage 3

Based on the results of the safety-based comparison, Nagra proposes the geological siting regions Zürich Nordost and Jura Ost for further investigation in Stage 3. It also recommends that the siting regions Südranden, Nördlich Lägern, Jura-Südfuss and Wellenberg be placed in reserve as part of the process. (Nagra Technical Report NTB 14-01, December 2014). The results of the safety-based comparison are summarised in this brochure.



Safety-based comparison of the geological siting regions – requirements of the Federal Government

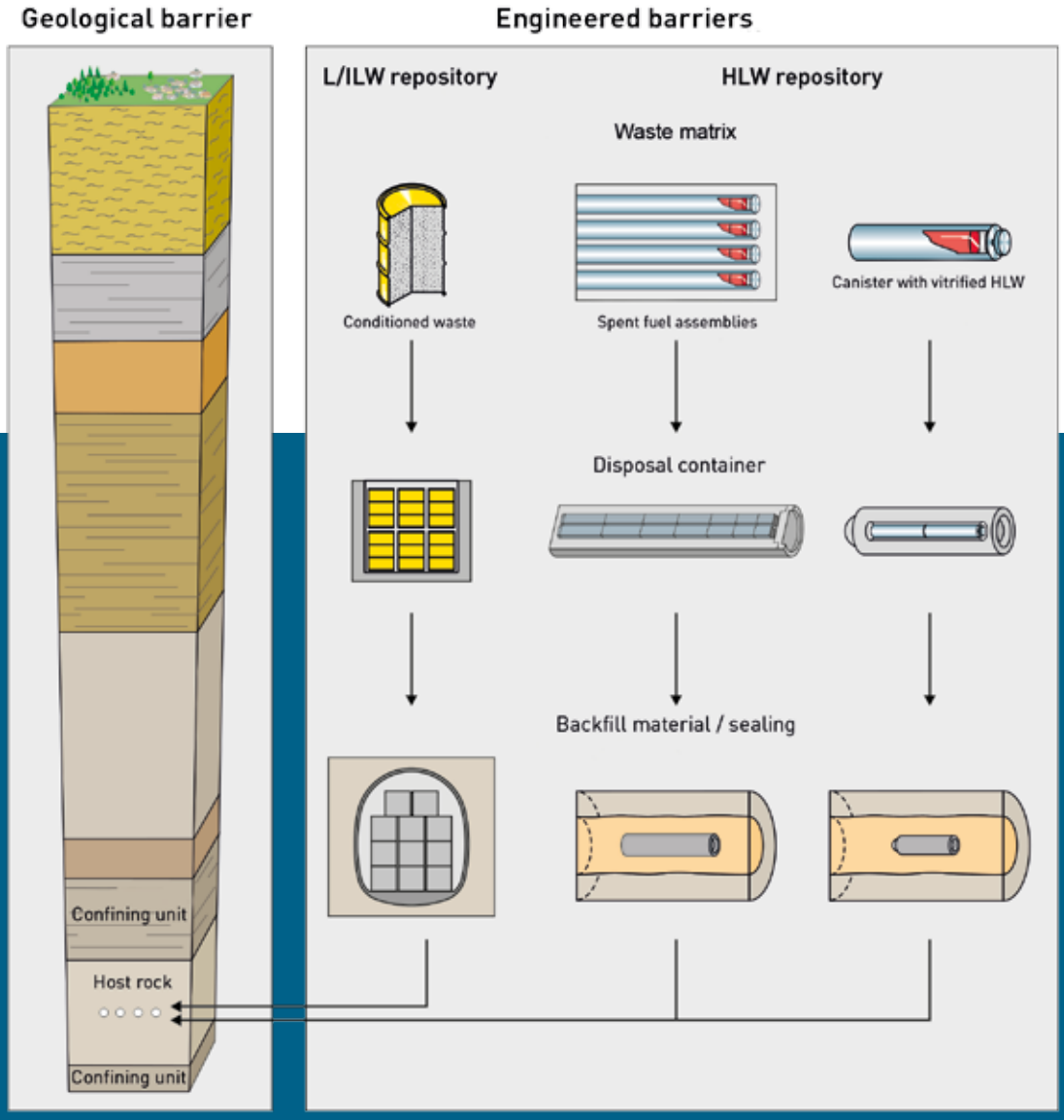
How did Nagra compare the siting regions in Stage 2?

Long-term safety is the most important criterion for decision-making as part of the safety-based comparison in Stage 2. Nagra evaluated and compared the siting regions based on the requirements set out in the Sectoral Plan and specified by ENSI. The suitability of a siting region for hosting a deep geological repository is determined initially on the basis of dose calculations. The siting regions are then evaluated in terms of their geological properties and the results are used for the safety-based comparison (see table right).

A siting region can only be placed in reserve for the next stage of the process if it shows **«clear disadvantages in terms of safety»** compared to the other siting regions.

What were the results of the safety-based comparison?

All six potential siting regions from Stage 1 fulfil the strict safety requirements and are suitable for hosting a deep geological repository. However, a detailed comparison of the siting regions shows clear and decisive differences. Compared with the other potential regions, Zürich Nordost and Jura Ost have the most favourable conditions for both a high-level waste and a low- and intermediate-level waste repository (see table and histograms right).



Multiple safety barriers provide containment of the radioactive substances in a deep geological repository and largely prevent release to the human environment. The geological barrier plays a decisive role in this respect.

Safety-based comparison of the siting regions – results

Very suitable
Suitable
Limited suitability
Less suitable

	HLW repository			L/ILW repository					
Decision-relevant features / Decision-relevant indicators	Zürich Nordost	Nördlich Lägern	Jura Ost	Südranden	Zürich Nordost	Nördlich Lägern	Jura Ost	Jura-Südfuss	Wellen-berg
Effectiveness of the geological barrier (E)									
Hydraulic conductivity									
Type of transport pathways and structure of the pore space									
Transmissivity of preferential release pathways									
Self-sealing capacity									
Homogeneity of the rock structure									
Thickness									
Length of critical release pathways									
Colloids									
Long-term stability of the geological barrier (S)									
Conceptual models of long-term evolution (geodynamics and neotectonics; other processes)									
Self-sealing capacity									
Potential for formation of new water flowpaths (karstification)									
Erosion during the time period under consideration									
Depth below the local erosion base level as relevant for formation of new ice-marginal drainage channels									
Depth below terrain as relevant for rock decompaction									
Depth below top bedrock as relevant for glacial overdeepening									
Seismicity									
Explorability and ease of characterisation of the geological barrier in the siting region (C)									
Variability of the rock properties as relevant for their ease of characterisation									
Exploration conditions in the geological underground									
Engineering feasibility (F)									
Depth with respect to engineering feasibility (considering rock strength and deformation properties)									
Geotechnical and hydrogeological conditions in overlying rock formations									
Available space underground									

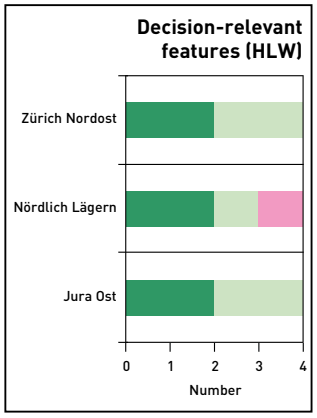
How are clear disadvantages of the individual siting regions identified?

For the safety-based comparison of the siting regions, specific decision-relevant features and indicators were defined based on ENSI requirements. These features and indicators were then used to decide whether a siting region has "clear disadvantages" compared to other siting regions (see table and histograms). The difference between the best siting regions and the following ones is decisive.

Table – Note on the overall evaluation of the four decision-relevant features (E, S, C, F):

The overall result of the evaluation of the effectiveness (W) and the explorability and ease of characterisation (E) of the geological barrier is the mean value of the evaluations of the assigned decision-relevant indicators. It is assumed that these indicators compensate one another. For the long-term stability of the geological barrier (L) and the engineering feasibility (M), the overall evaluation is derived from the lowest evaluation for an assigned decision-relevant indicator. This is based on the fact that these indicators are all equally important and independent of one another. For example, a favourable spatial extent cannot make up for poor geotechnical conditions.

Comparison of the geological siting regions for the HLW repository



Very suitable

Suitable

Limited suitability

Less suitable

All the siting regions fulfil the strict requirements defined for a HLW repository.

The geological siting regions Zürich Nordost and Jura Ost show more suitable conditions for locating a HLW repository compared to the Nördlich Lägern siting region.

Zürich Nordost: E S C F

The siting region has a sufficient spatial extent in the preferred (from a technical viewpoint) depth range. Together with its thick confining units, the Opalinus Clay host rock shows very favourable barrier properties. The geological situation is also favourable with respect to long-term stability.

Nördlich Lägern: E S C F

The space available in the siting region at the preferred depth is less suitable. Going deeper would provide more space, but it would be difficult, from an engineering perspective, to construct a repository to the desired standard at such depth. During construction, the limited suitability of the depth range could lead to significant impairment of the geological barrier.

Jura Ost: E S C F

Despite the limitations relating to the depth of the host rock, the siting region has a sufficient spatial extent in the preferred depth range. The host rock has a very favourable barrier function and long-term stability is assured by the geological situation.

Decision-relevant features according to ENSI

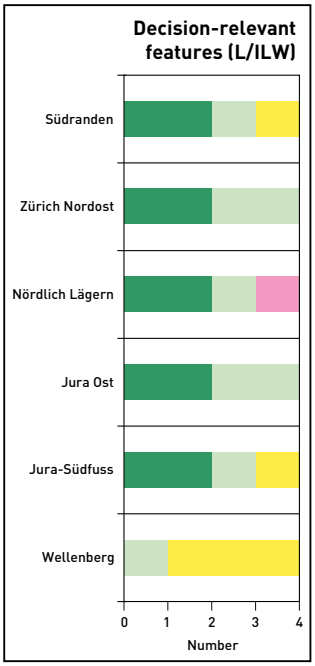
E **Effectiveness of the geological barrier:** The barrier function determines how well the emplaced radioactive substances are retained in the repository and to what extent they decay there. The geological barrier comprises the host rock and the under- and overlying confining units.

S **Long-term stability of the geological barrier:** Favourable long-term stability ensures that the required barrier function remains intact over the time period under consideration. The decrease in the radiotoxicity of the emplaced waste as a result of radioactive decay determines the length of the relevant time period: 1 million years for the HLW repository and 100 000 years for the L/ILW repository. Erosion and potential differential movements underground are important for long-term stability.

C **Explorability and ease of characterisation of the geological barrier in the siting region:** Explorability determines how accurately and reliably the location and key parameters of the safety-relevant geological features can be determined (e.g. sedimentary deposits such as hard limestone beds with increased hydraulic conductivity). Ease of characterisation describes how reliably and accurately the properties that are critical for the barrier function can be determined (e.g. individual water-bearing joints).

F **Engineering feasibility of a deep geological repository:** This considers the damage to the host rock in the direct vicinity of the disposal chambers. The barrier effect of the host rock and possible impairment of the engineered barriers as a result of constructing the disposal chambers are analysed. The access from the surface siting area to the underground disposal perimeter is also considered, as well as whether the available space within the siting region is sufficiently large.

Comparison of the siting regions for the L/ILW repository



Very suitable
Suitable
Limited suitability
Less suitable

All the siting regions fulfil the strict requirements defined for a L/ILW repository.

The siting regions Zürich Nordost and Jura Ost show more suitable conditions for a L/ILW repository compared with the siting regions Südranden, Nördlich Lägern, Jura-Südfuss and Wellenberg.

Südranden: E S C F

The long-term stability of the geological barrier is of limited suitability. The relatively shallow depth of the host rock provides only limited protection from erosion. The space available in the siting region is only just favourable as the region is divided by a bedrock channel (identified in seismic investigations in 2011/2012 as the Neuhauserwald channel).

Zürich Nordost: E S C F

The siting region is very suitable in terms of the available space at the depth preferred from a technical viewpoint. Together with its thick confining units, the Opalinus Clay host rock shows very favourable barrier properties. The long-term stability and depth in relation to engineering feasibility are also suitable.

Nördlich Lägern: E S C F

The space available in the siting region at the preferred depth is less suitable. Going deeper would provide more space, but it would be difficult, from an engineering perspective, to construct a repository to the desired standard at such depth. During construction, the limited suitability of the depth range could lead to significant impairment of the geological barrier.

Jura Ost: E S C F

The siting region is very suitable in terms of the space available at the preferred depth. Together with its confining units, the Opalinus Clay shows a very good barrier function. The long-term stability and the depth in relation to engineering feasibility are also suitable.

Jura-Südfuss: E S C F

Compared to the siting regions Zürich Nordost and Jura Ost, the space available in the siting region at the preferred depth is smaller as considerable reserves are required due to the fact that the rocks have undergone a more marked tectonic overprinting. The effective containment zone (Opalinus Clay and confining units) has a limited thickness and the lower confining units make effectively no contribution to the barrier function.

Wellenberg: E S C F

In the Wellenberg siting region, the fractured host rock - the Helvetic Marls - has a restricted self-sealing capacity and homogeneity compared to the Opalinus Clay. This means that the barrier function is less good. The conditions relating to long-term stability are less favourable than in Northern Switzerland due to the location in the Alps. The region is also difficult to explore from the surface.

Further information:

Nagra Technical Report NTB 14-01 on the safety-based comparison of the siting regions (in German with English abstract). This report has been with the authorities for review since December 2014.

Technical Report NTB 14-01 and other relevant documents can be downloaded or ordered from the Nagra website.

Site selection for deep geological repositories – decisive years lie ahead

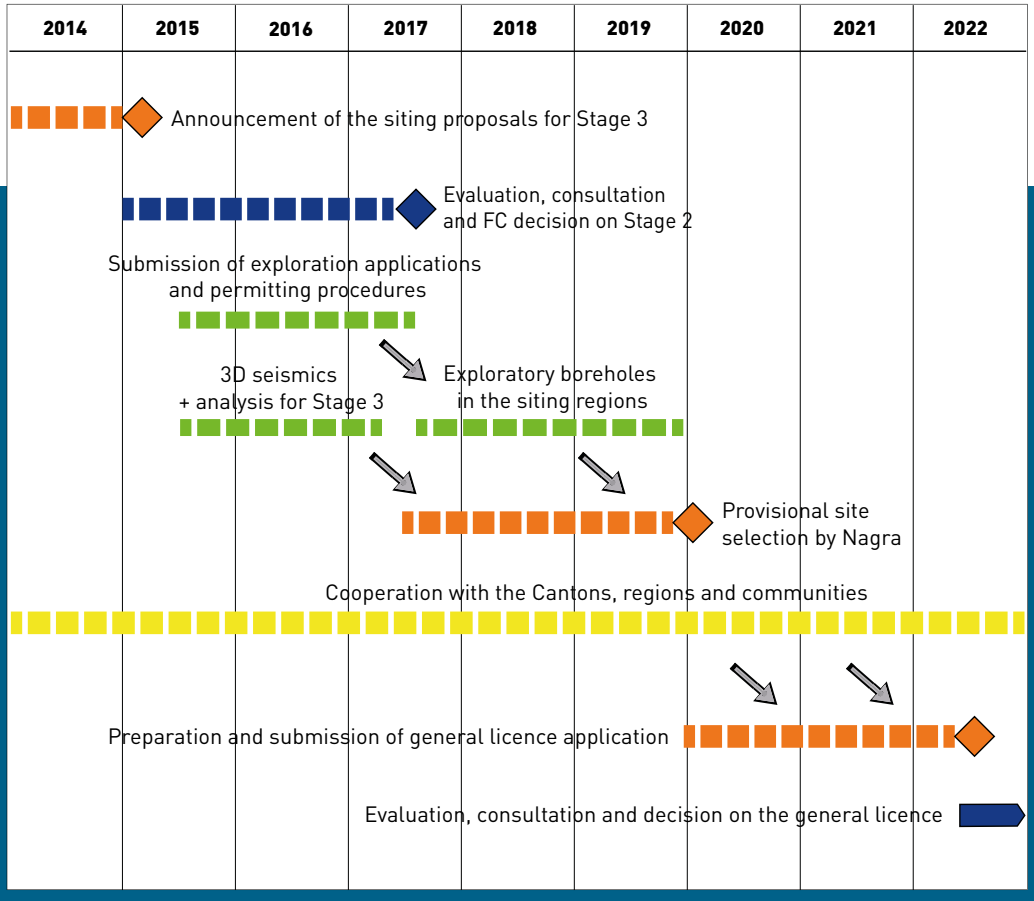
What next?

The SFOE published Nagra's reports with the proposals for the siting regions for Stage 3 at the beginning of 2015. This will be followed by a technical review by the authorities before all the documentation is submitted to a wide public consultation process in 2016. The Federal Council is expected to decide on adopting Nagra's proposals into the Sectoral Plan process in 2017.

In **Stage 3**, the proposed siting regions remaining in the process will be investigated in more depth using 3D seismic surveys and exploratory boreholes. Based on the results of these investigations, around 2020 Nagra will announce the siting regions for which it intends to prepare general licence applications for a HLW and L/ILW repository or a combined repository.

The general licence applications will then be submitted by Nagra around 2022. Cooperation with the siting Cantons, regions and communities is again foreseen with a view to concretising the projects. This will be followed by a further review by the authorities and a public consultation process. The decision of the Federal Council on the licence applications is expected for around 2027.

The Swiss Parliament has to confirm this decision and the decision of Parliament in turn is subject to an optional national referendum. If the referendum option is taken up, the Swiss voters are expected to decide on the sites for the repositories around 2029.



Timetable for the Sectoral Plan for Deep Geological Repositories – the coming years.

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