



EXPLANATORY REPORT ON THE GENERAL LICENCE APPLICATIONS

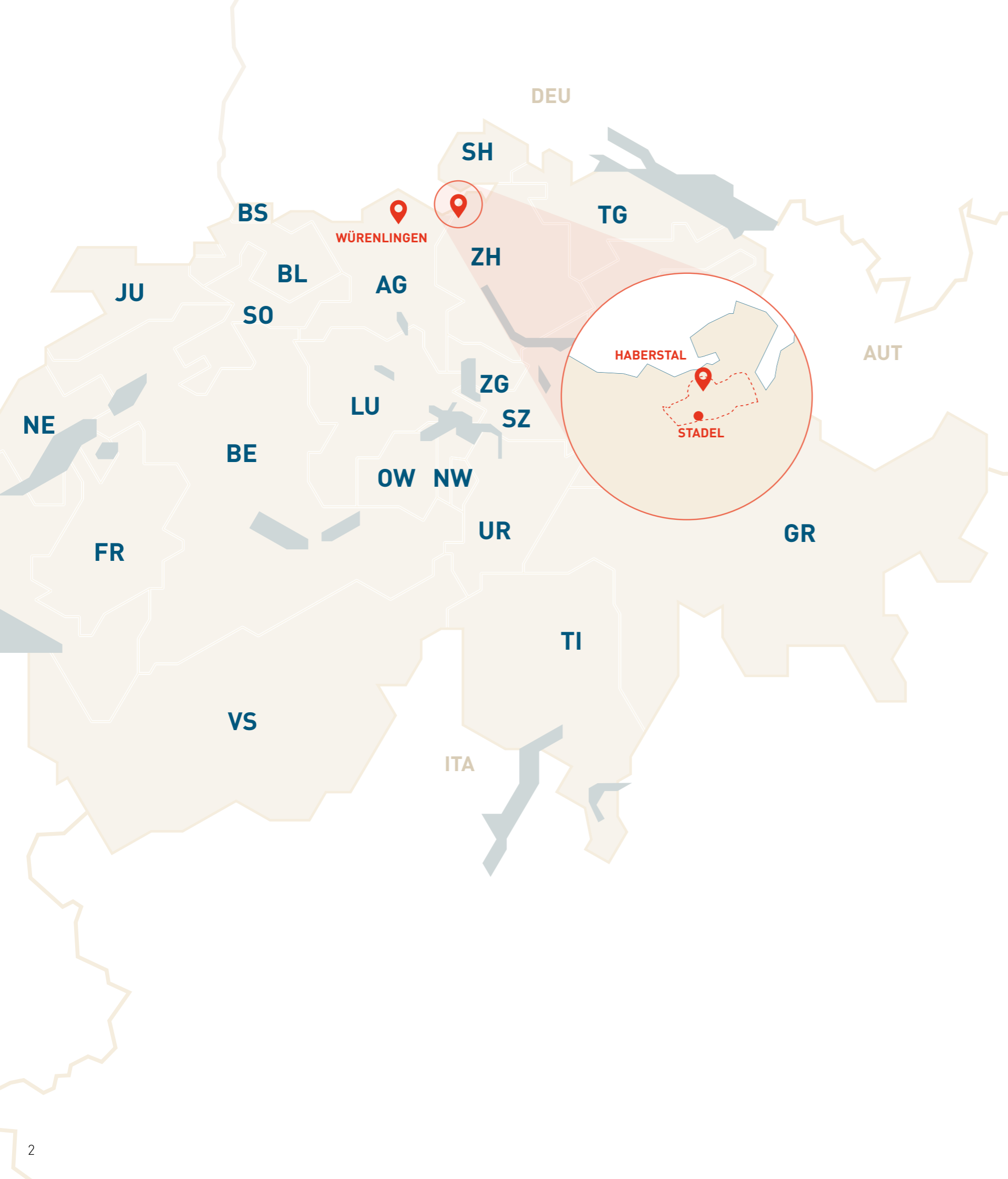
nagra ●

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This report was revised in May 2025 to include a reference for the document structure plan in the introduction. In addition, Chapter 7 now contains more detailed information on the development of the repository project, and individual numerical values and two figures (on Pages 20-21 and Page 25) were modified to correspond with the reference reports.

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INTRODUCTION

To safely dispose of its radioactive waste, Switzerland must decide on the sites for the deep geological repository and the waste encapsulation plant. In accordance with the licensing procedure set out in the Swiss Nuclear Energy Act, this decision is incorporated in a general licence.

Nagra plans to construct the deep geological repository at the Haberstal site in the community of Stadel in Canton Zürich. The site selection is based on extensive geological investigations. These revealed clear differences between the siting regions as well as the greatest safety margins for the proposed site. The encapsulation plant is to be located at the site of the Zwiilag interim storage facility in the community of Würenlingen in Canton Aargau. The two respective general licence applications were submitted to the Swiss Federal Office of Energy on 19th November 2024.

A general licence can be granted if the protection of humans and the environment can be ensured at the site. The feasibility of safe disposal in Switzerland was demonstrated several years ago and confirmed by the Federal Council following an official review. Within the framework of the site selection process, "Nördlich Lägern", including the Haberstal, has emerged as the most suitable siting region. The application documentation demonstrates that the deep geological repository and the encapsulation plant can be realised safely at the selected sites and in compliance with spatial planning and environmental legislation.

The explanatory report summarises the most important **arguments justifying the siting decision and demonstrating the safety of the deep geological repository** (argument report as per ENSI 33/649). The conclusions in the application documentation are based on extensive scientific data, analyses and findings, which are documented in numerous reference reports. The application documentation and these reference reports are openly accessible via a **web-based platform**. This platform outlines, from the reference reports to the application documentation, how the line of argumentation justifying the safety and site selection was derived.

The explanatory report also explains the most important aspects of the general licence applications and their significance in the licensing procedure up to the realisation of the deep geological repository. It provides **initial orientation and serves as a guide for reading and reviewing the application documentation**.

The general licences define the basic features of the projects, i.e. the approximate location and dimensions of the most important structures. The legislative authorities have made sure to allow sufficient flexibility for the further development of the project.

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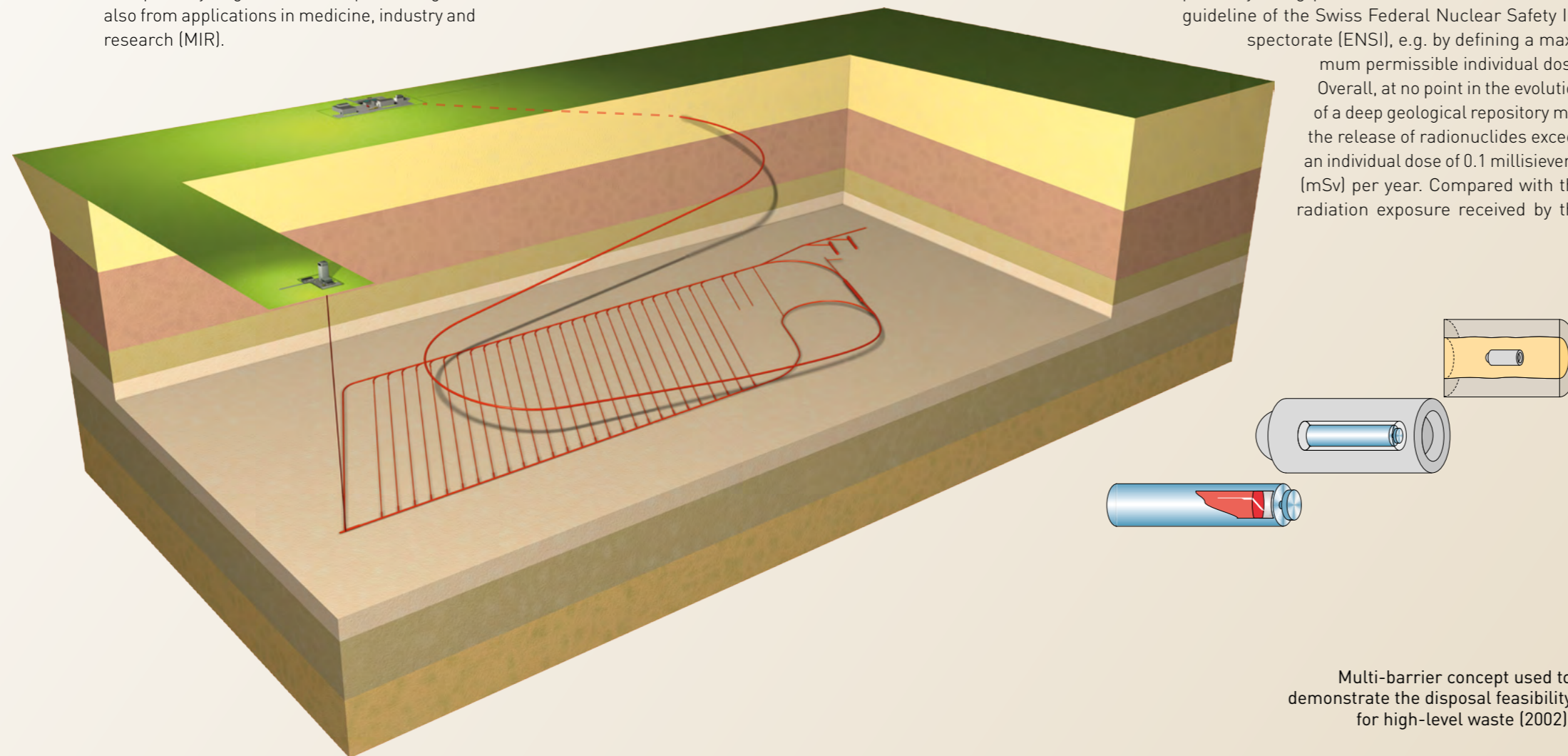
HOW DOES SWITZERLAND INTEND TO DISPOSE OF ITS RADIOACTIVE WASTE?

Switzerland has been using nuclear energy to generate electricity for over 50 years. Consequently, it has been producing radioactive waste during this period. Article 51 of the Swiss Nuclear Energy Ordinance (KEV) defines three waste categories: high-level waste (HLW), alpha-toxic waste (ATW) and low- and intermediate-level waste (L/ILW).

- HLW consists of spent fuel assemblies from nuclear power plants (NPPs) and vitrified waste from the reprocessing of spent fuel assemblies.
- ATW partially originates from reprocessing, but also from applications in medicine, industry and research (MIR).

- L/ILW mostly results from the operation and dismantling of nuclear facilities, although only a small proportion of the operational waste and dismantling materials is radioactive.

Radioactive waste from the nuclear power plants is currently stored in on-site storage facilities and in the centralised Zwiilag interim storage facility located in Würenlingen. The federal government stores MIR waste in the Swiss Federal Interim Storage Facility at the neighbouring site of the Paul Scherrer Institute (PSI).



Multi-barrier concept used to demonstrate the disposal feasibility for high-level waste (2002).

In Switzerland, the disposal of all radioactive waste in a deep geological repository is stipulated in the Nuclear Energy Act (KEG). By disposing of the waste deep below ground, it is possible to avoid potential social and technological consequences of civilisation at the earth's surface. This is a prerequisite for ensuring the necessary safety over long periods of time. The time period for assessment which, in the case of HLW, is one million years, is derived from the decrease with time of the radiological hazard potential. The complete containment of radionuclides over this long time period is not possible, but also not necessary. With the concurrent decrease of the hazard potential over time, the very slow release of radionuclides is not critical to the safety of the repository.

COMPLIANCE WITH THE PROTECTION OBJECTIVE

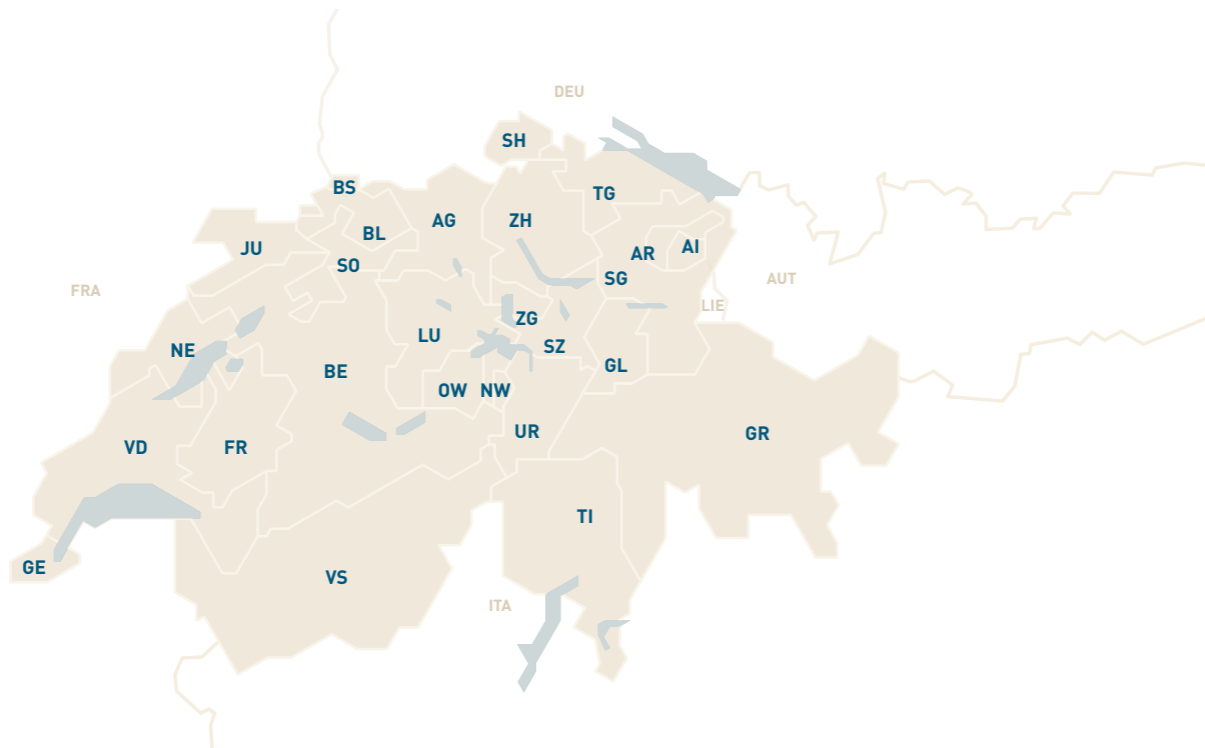
To demonstrate post-closure safety, plausible evidence must be provided that the protection of humans and the environment can be ensured (Art. 13, KEG). This protection objective is specified more precisely using protection criteria contained in a guideline of the Swiss Federal Nuclear Safety Inspectorate (ENSI), e.g. by defining a maximum permissible individual dose. Overall, at no point in the evolution of a deep geological repository may the release of radionuclides exceed an individual dose of 0.1 millisieverts (mSv) per year. Compared with the radiation exposure received by the

population of Switzerland each year, 0.1 millisieverts is a small value: two transatlantic flights would already result in a similar radiation exposure. The current average radiation dose to the Swiss population is around 6 millisieverts per year. The safety analyses for nuclear facilities must take into account irreducible uncertainties by means of conservative assumptions. This means that the radiological impacts on humans and the environment tend to be overestimated.

FEASIBILITY DEMONSTRATION

The feasibility of long-term safe deep geological disposal in Switzerland has been demonstrated for both L/ILW and HLW. These so-called "Entsorgungsnachweise" include a siting demonstration, a feasibility demonstration and a post-closure safety case. The demonstration of disposal feasibility for L/ILW in a marl formation at the "Oberbauenstock" site was confirmed by the Federal Council in 1988. The corresponding demonstration for HLW submitted in 2002 was based on the example of a repository in the Opalinus Clay in the Zürcher Weinland region and was recognised by the Federal Council following a review by the responsible authorities and numerous national and international experts.

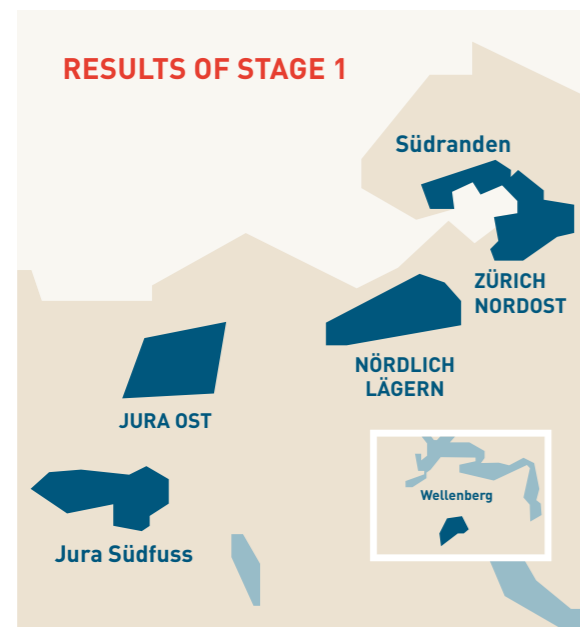
The demonstration of disposal feasibility for HLW is based on a system of geological and engineered safety barriers (**multi-barrier concept**). The disposal canisters ensure the safe confinement of the radioactive waste for a long time period, during which most of the radionuclides will decay in the canisters (around 90% over a time period of 1,000 years). After this, the remaining radionuclides will be retained by the backfill material (bentonite) emplaced between the canisters and the surrounding host rock (Opalinus Clay). The siting region ensures that, even under conservative assumptions, the conditions favourable for the retention of the radionuclides can be preserved during the time period for assessment. Besides the already established treatment and packaging of radioactive waste for interim storage, its characterisation and inventorying as well as interim storage and the associated transports, the demonstrations of disposal feasibility represent important steps in the management of Switzerland's radioactive waste. The site of the deep geological repository has not yet been legally approved. In accordance with Article 5 of the KEV, it is to be determined within the framework of the site selection process.



2 HOW IS THE SITE DETERMINED?

Sectoral plans are federal planning instruments used for the realisation of infrastructure projects of national importance, such as an airport, a high-voltage power line, a weapons range or, in this case, a deep geological repository. The Sectoral Plan for Deep Geological Repositories (SGT) was approved and initiated by the Federal Council in 2008 and defines the site selection procedure for deep geological repositories in Switzerland. The lead authority in this process is the Swiss Federal Office of Energy. The highest priority of the site selection process under the Sectoral Plan is post-closure safety: the site

selection process therefore aims at identifying the most suitable site for the realisation of a deep geological repository in Switzerland. To this end, 13 criteria related to safety and engineering feasibility were defined to guide the site selection process. These criteria are to be systematically applied in three stages. The safety of the site for the surface facilities can be ensured by their design. For this reason, the concerns of the regions, cantons and neighbouring Germany should also be taken into account when deciding where to place the surface facilities.

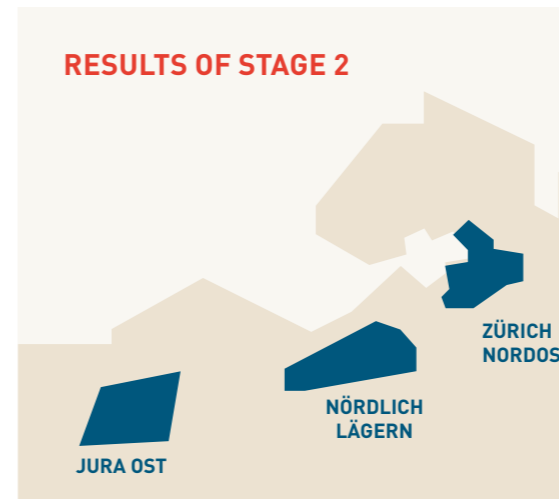


STAGE 1

Starting with a nationwide search, potentially suitable siting regions were identified in Stage 1. In 2008, Nagra proposed six geological siting regions for the L/ILW repository and three for the HLW repository. In siting regions that are suitable for both HLW and L/ILW repositories, the option to realise both repository types at the same site as a so-called combined repository was also considered. With the Federal Council's decision in 2011, the geological siting regions proposed by Nagra were included in the Sectoral Plan for Deep Geological Repositories.

STAGE 2

At the end of Stage 2, and following a review by the authorities, the Federal Council reduced the number of suitable siting regions in Northern Switzerland to three (Jura Ost, Nördlich Lägern and Zürich Nordost). The Stage 2 decision also confirmed that



the Opalinus Clay is best suited for a deep geological repository due to its rock properties and that, out of the whole country, the region of Northern Switzerland is the most suitable due to its tectonic stability and low seismic activity. In addition, proposals for the placement of the surface facility were developed in collaboration with the siting regions and cantons, resulting in the identification of potential siting areas. These proposals were discussed and reviewed by the regions and cantons and, at their request, supplemented with additional proposals on a case-by-case basis. Based on the reviews, Nagra proposed at least one location for the surface facility per siting region. These locations were approved by the Federal Council following a review by the authorities.

STAGE 3

In Stage 3, an additional in-depth geological investigation programme was conducted in the remaining siting regions. After systematically evaluating the 13 criteria related to safety and engineering feasibility and applying the ENSI requirements, Nördlich Lägern (NL) emerged as the most suitable siting region for both repository types. The layout of the surface facility was reassessed and concretised in collaboration with the siting regions and cantons. With the "Haberstal" siting proposal in the community of Stadel, Nagra is following the recommendation of the region and takes into account the opinion of the canton.

Several options were compared for the placement of the encapsulation plants. The two remaining options were either a location near the deep geological repository or at the site of the Zwiilag interim storage facility. The decision in favour of the Zwiilag site was justified in particular due to the advantages offered by the nuclear facilities that already exist there. These allow synergies to be used in connection with safety-related operational processes. In addition, less land will be required, which will reduce the impact on the landscape and environment.

The sites will be decided with the general licences.

In line with the Nuclear Energy Act, the general licences correspond to the first step in the licensing procedure and will mark the conclusion of the Sectoral Plan for Deep Geological Repositories.



3

WHAT IS A GENERAL LICENCE?

A general licence is the first step in realising infrastructure projects of national importance, such as nuclear facilities, on a political level. To this end, the submitted documentation must include the basic features of the planned project. **Anyone intending to construct or operate a nuclear facility requires a general licence issued by the Federal Council** (Art. 12, KEG). The Nuclear Energy Act (Art. 3 KEG) defines nuclear facilities not only as installations that produce nuclear materials or radioactive waste, but also those that are used to process and store nuclear products.

In particular, the general licence specifies the purpose and site of the installation (Art. 14, KEG). As the waste encapsulation plant is planned at a different site and will serve a different purpose than a deep geological repository, the Swiss Federal Office of

Energy requires two general licences for the management of Switzerland's radioactive waste. Encapsulation of L/ILW at the Zwiilag interim storage facility has already been authorised, which is why the general licence application only refers to the encapsulation plant for spent fuel assemblies (BEVA). A safety case demonstrating the long-term, post-closure safety of the nuclear facilities must be provided in order to obtain a general licence (Art.103, KEG). The basis for this is a provisional project which, for the deep geological repository, goes beyond the required level of detail needed for the general licence to properly assess safety-relevant issues and environmental impacts.

In addition to the site and purpose, the general licence specifies the basic features of the project, i.e. the approximate dimensions and locations of the

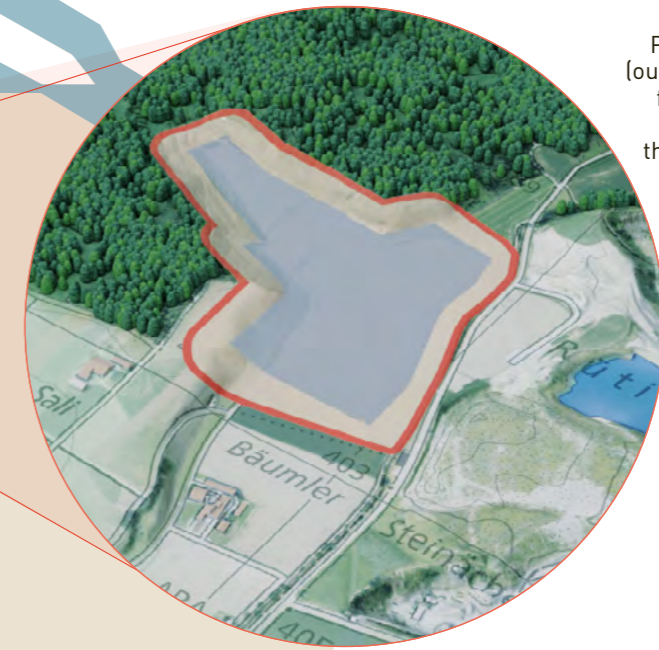
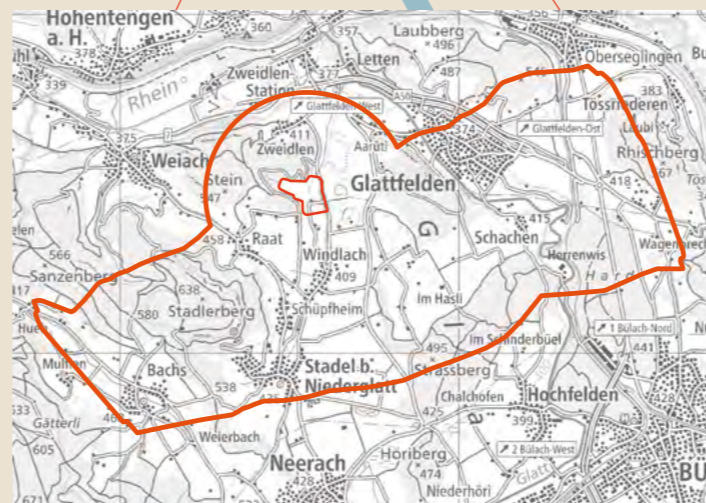
most important structures. To this end, a project perimeter is defined at the surface. Inside this perimeter is the facility perimeter, which will house the most important structures. The general licence will define the approximate ground area and maximum height above the natural terrain of these structures. The provisional facilities are used to analyse the spatial requirements as well as the procedures during construction and operation over the entire duration of the project and to ensure that the facility perimeter will be sufficiently large to house all the required structures. The project perimeter serves to secure the facility perimeter from impacts from its surroundings and, in the case of the deep geological repository, to better integrate it into the landscape. To protect the deep geological repository from human intrusion, the general licence defines a provisional protection zone for the subsurface (Art. 14, KEG). Later, the accesses and the underground repository installations (test areas, pilot repositories and main repositories) will be con-

structed in this zone. **With the project perimeter and the provisional protection zone, the general licence defines maximum spatial dimensions that must be adhered to in the subsequent procedural steps.**

SUBSIDIARY ORGANISATIONS

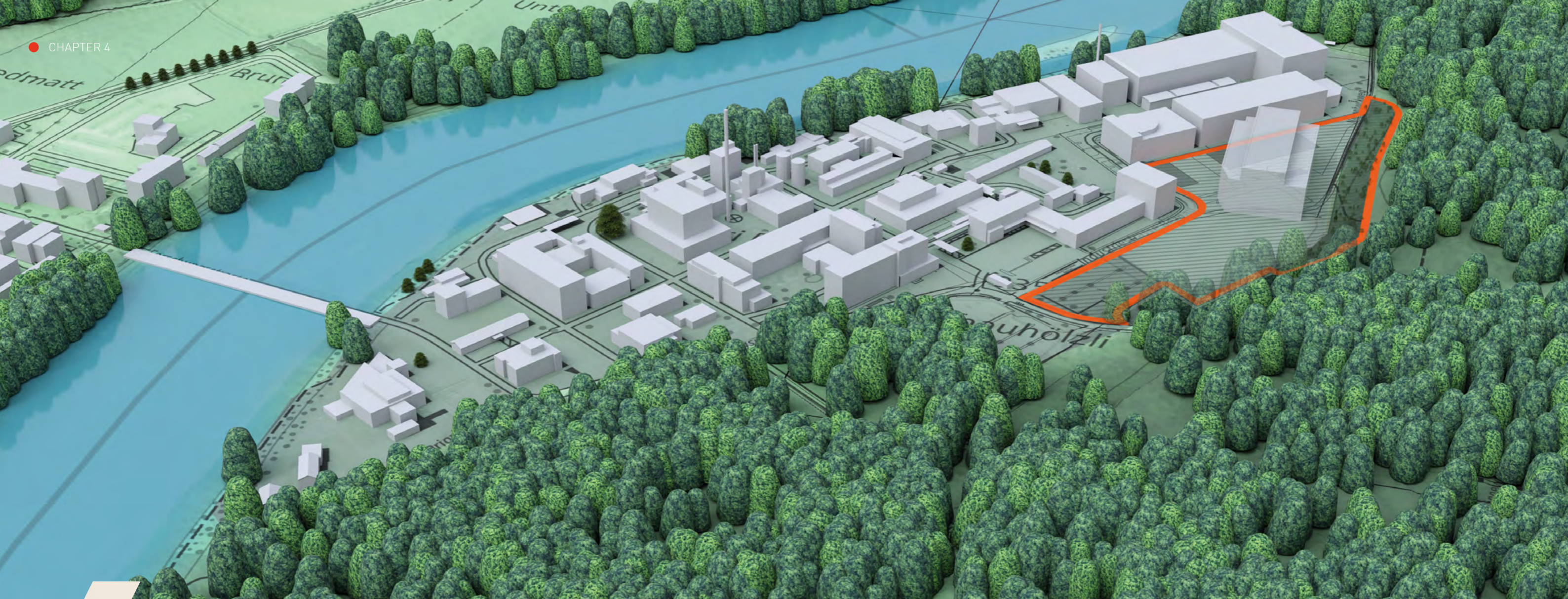
As the licence holder has to be specified for each general licence, Nagra has founded two subsidiaries for the further planning, construction and operation of the two facilities. **Nagra gTL AG**, responsible for the construction and operation of the deep geological repository, will apply for the general licence for the repository, and **Nagra BEVA AG**, responsible for the construction and operation of the encapsulation plant, will apply for the general licence for the encapsulation plant. Any reference to "Nagra" in the application documentation refers either to Nagra gTL AG or Nagra BEVA AG, depending on the respective application. These subsidiary organisations will submit their general licence applications to the Federal Council.

Project perimeter (outlined in red) and facility perimeter (grey area) for the encapsulation plant.



Project perimeter (outlined in red) and facility perimeter (grey area) for the surface facility of the repository.

Subsurface provisional protection zone for the deep geological repository.



Project perimeter with provisional illustration of the encapsulation plan.

WHAT MAKES THE PROPOSED SITE SUITABLE FOR THE ENCAPSULATION PLANT?

In line with the Nuclear Energy Act, the safety and suitability of the site where the encapsulation plant for spent fuel assemblies is to be constructed and operated has already been reviewed several times during the licensing process for the Zwiilag interim storage facility and the adjacent nuclear facilities of the Paul Scherrer Institute. With their very low external hazard potential, the site and its surroundings have proven for decades to be suitable for the operation of nuclear facilities. When preparing the general licence application for the encapsulation plant, the suitability of the site and thus the safety for the operational phase were once again reviewed and confirmed based on the state of the art in science

and technology and in line with the Nuclear Energy Act and Nuclear Energy Ordinance as well as ENSI guidelines. The range of analysed hazards includes events such as floods, extreme weather and earthquakes. The systematic assessment shows and confirms a very low hazard potential for the site and the plant caused by natural or human-driven events. In particular, the site does not exhibit any features considered unusual in connection with nuclear facilities. The encapsulation plant can be designed taking into account the corresponding site-specific hazards in such a way that any unacceptable radiation exposure of the population as a result of these hazards can be ruled out. As already implemented,

demonstrated and officially verified for other nuclear facilities, the plant is designed such as to exclude impacts resulting from rare incidents such as earthquakes or accidents such as aircraft crashes.

In analogy with the hot cell at Zwiilag, dropping a fuel assembly in the transloading cell of the encapsulation plant during transloading is considered an incident with the potentially greatest impact. For this highly unlikely event, it has already been demonstrated in the case of Zwiilag that the radiological consequences for the population will be well below the permissible dose limit. Correspondingly, in the case of the encapsulation plant, the surrounding area, population and workers can be protected from unauthorised radiation exposure during normal operation, operational malfunctions and in the event of incidents or accidents using proven nuclear safety precautions. **The suitability of the site from a safety perspective is thus confirmed.**

The site has sufficient spatial reserves to implement the encapsulation plant. The basis for demonstrating disposal feasibility in the general licence application is a conceptual description of the processes involved in repackaging the HLW from the transport and storage casks into the disposal canisters. The provisional dimensions of the encapsulation plant and other functional buildings and areas are derived from security measures and logistical processes. The projected processes and facilities in the encapsulation plant are based on many years of experience in the construction and operation of the Zwiilag interim storage facility and other comparable nuclear facilities. The proposal for the approximate dimensions and location of the plant, which are to be determined with the general licence, is also based on this. The proposal is bounding and allows for future project developments, such as technical improvements or changing circumstances, as provided for in the licensing procedure set out in the Nuclear Energy Act.

5

HOW CAN THE REPOSITORY REMAIN SAFE IN THE LONG TERM?

A safety case must be provided for the operational and post-closure phases of the repository before a general licence can be issued. To confirm the earlier, approved demonstration of disposal feasibility, the changes to the project since its approval must be taken into account. For example, the expected waste volume has decreased due to changes in the legal framework and progress in waste conditioning. For Stage 3 of the Sectoral Plan, the Opalinus Clay was determined to be the most suitable host rock in Switzerland for all waste categories. With Stage 3, Nördlich Lägern has proven to be the most suitable siting region for both repository types and offers more than sufficient space, which is why Nagra is planning a combined repository for all waste categories. The main features of the repository concept remain largely unchanged. The multi-barrier system, which consists of the engineered and geological barriers, and the selected site provide robust **arguments for demonstrating post-closure safety** (argument report as per ENSI 33/649).

THE ENGINEERED BARRIERS

The **properties of the engineered barriers** of the repository delay the release of radionuclides and restrict their transport into the surrounding rock. Waste can only be emplaced in a repository in solid, stabilised and packaged form. Both spent fuel and vitrified HLW decompose very slowly in the repository. This also applies to L/ILW, which is fixed in a solid matrix, usually as glass, cement or bitumen.

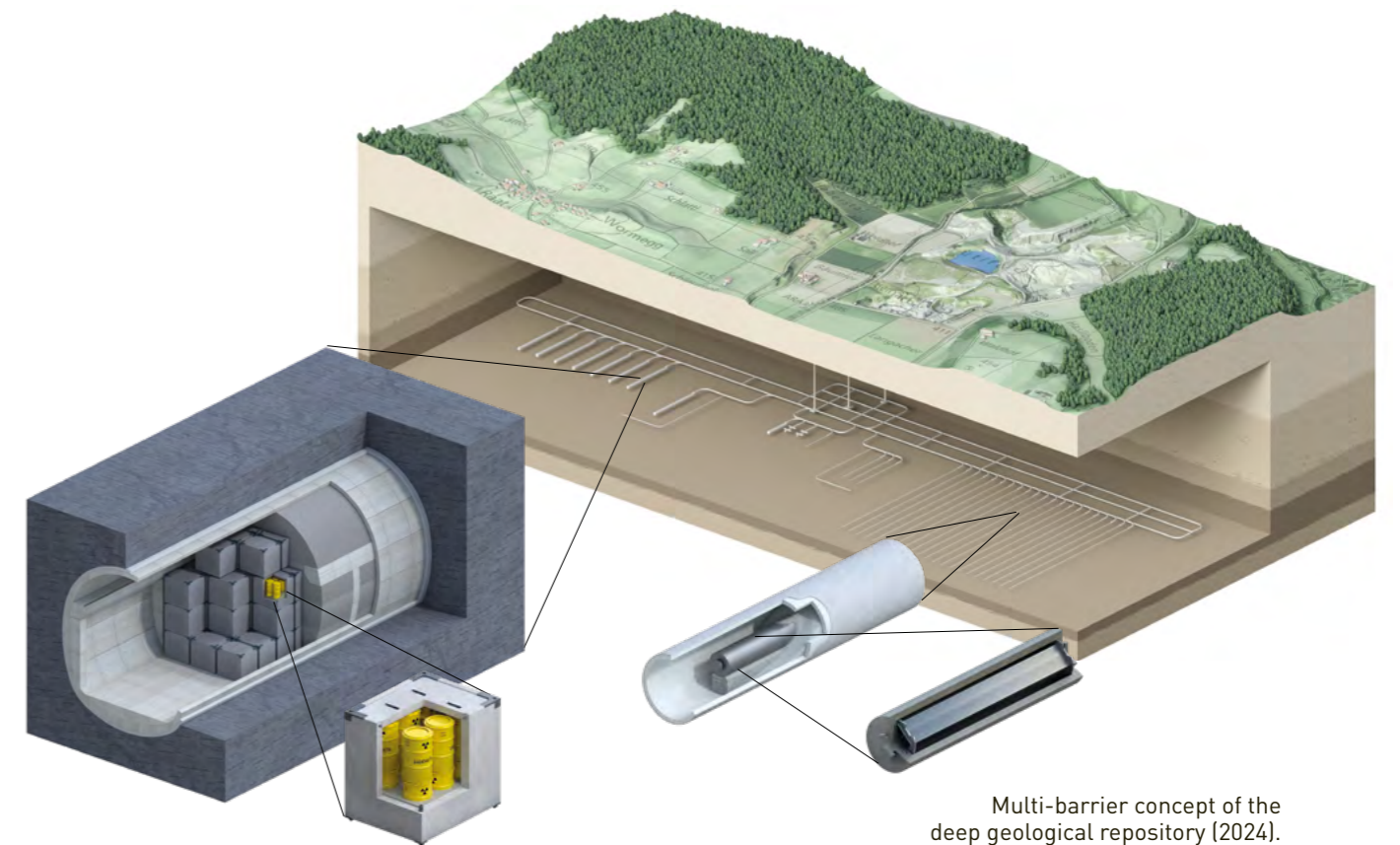
In the HLW repository section, the disposal canisters ensure that the radionuclides remain confined for a significantly longer period than the 1,000 years stipulated by ENSI. As a result, most of the radioactive substances will decay while the disposal canisters are still intact, thus ensuring complete containment.

In the L/ILW repository section, the waste will be packaged into thick-walled concrete containers, and the remaining voids will be filled with mortar. In line with the current disposal concept, the bentonite intended for backfilling the HLW emplacement drifts up to the last voids, has similar properties to the Opalinus Clay. Should cracks occur, it can self-seal, and it has a very low permeability. Most radionuclides sorb very well on bentonite. As a result, further radionuclides will decay before they can pass through the bentonite. Finally, the sealing and backfilling of the accesses to the deep geological repository ensure further retention of the radionuclides.

THE OPALINUS CLAY

The most important barrier of the repository is the geological barrier. Its transport and retention mechanisms ensure the retention and very slow release of radionuclides due to the high proportion of clay minerals. In particular, the safety-relevant **properties of the Opalinus Clay** include:

- **low permeability** for water and gas, which ensures that radionuclide transport takes place mainly by diffusion, i.e. a slow equalisation of a concentration gradient without the involvement of flowing water.
- negative charge of the clay minerals and their large surface area, which ensure that positively charged radionuclides are bound to and retained by the clay minerals (**sorption**).
- the swelling capacity, which seals cracks in the rocks (**self-sealing**), so that the low permeability for water and gas remains ensured in the long term.



Multi-barrier concept of the deep geological repository (2024).

THE SITE

Finally, the **features of the site** where the Opalinus Clay is located at a suitable depth are of central importance for post-closure safety:

- The **extent** of the layer of Opalinus Clay is more than **sufficient**.
- The long-term stability of the safety-relevant properties is ensured thanks to the **geologically stable situation**.

Extensive knowledge of the comparatively uneventful geological history of Northern Switzerland is a prerequisite for making reliable assumptions about the likelihood of future changes. Past time periods that are around one hundred times longer than the period for assessment for the deep geological repository are clearly understood. The 174-million-year-old Opalinus Clay is around 100 metres thick and was deposited in a vast, shallow sea over the – geologically short – time period of one to two million years.

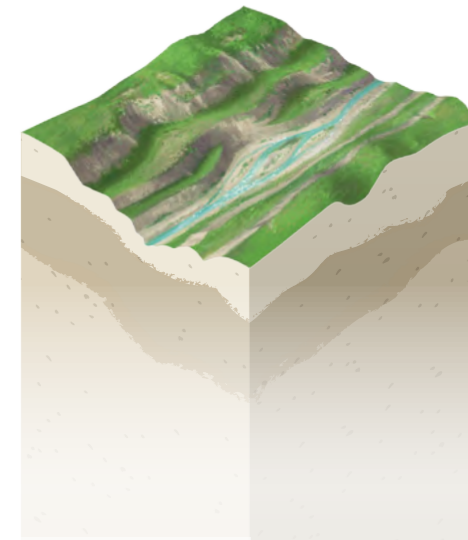
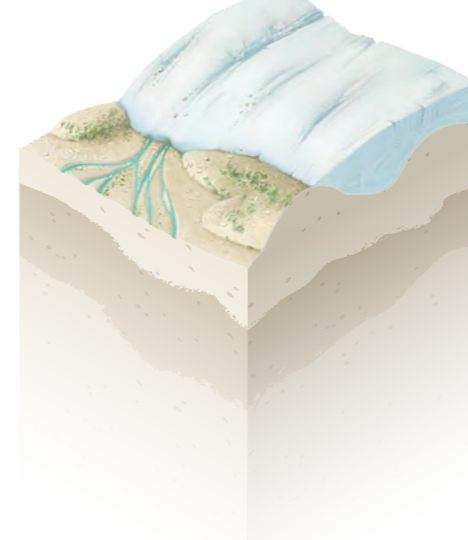
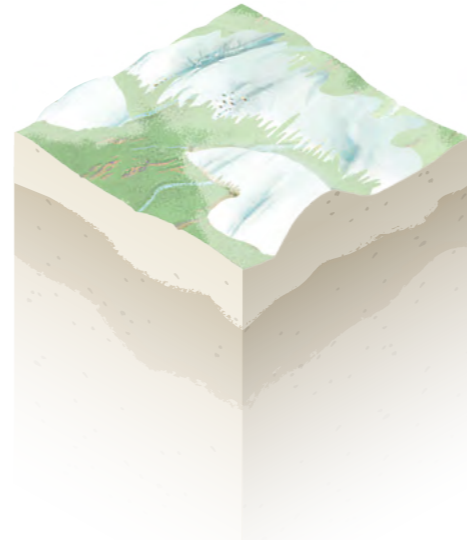
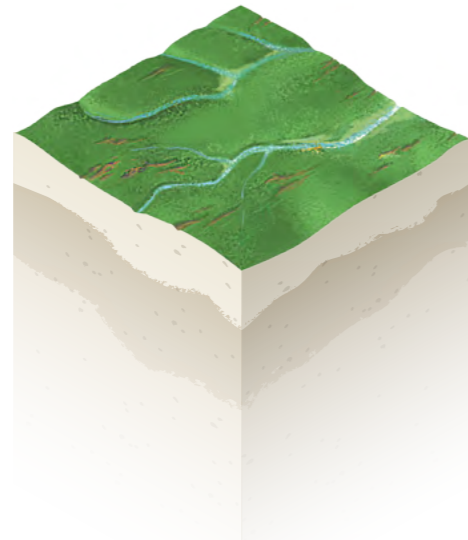
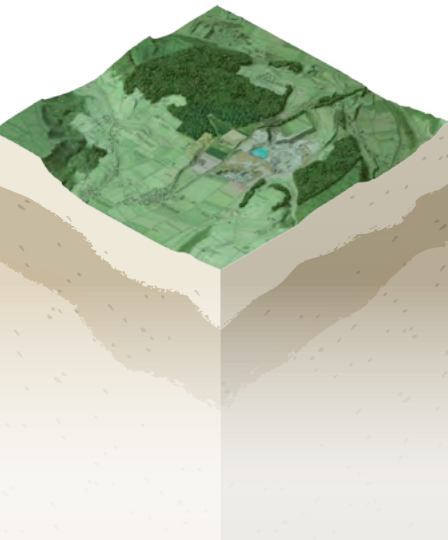
Understanding erosion processes is important because Northern Switzerland will uplift in the long term and erode subsequently. The retention properties of the geological barrier will not be impaired by decompaction and weathering as long as the clay-rich rocks do not come too close to the surface, i.e. remain at a depth of more than 200 metres. The disposal level at the site lies at a depth of 800 to 900 metres. The uplift rate expected in the long term, an isostatic levelling movement caused by the formation

of the Alps, is less than 3 tenths of a millimetre per year. Assuming constant uplift rates, an uplift of less than 300 metres can be expected over the next one million years. In addition to uplift and erosion by rivers, potential future glacial advances and the varying erosion resistance of the different rock layers are also taken into account in the safety analyses of potential impacts of future evolution. As the assessment of future barrier properties always considers bounding variants with cautious (conservative) assumptions, i.e. also with unfavourable assumptions regarding future uplift and erosion rates, the predictions always include safety margins. Even taking all aspects into account, the long-term preservation of barrier properties has large safety margins.

The analysis of the groundwater and porewater allows predictions to be made about the transport processes in the geological barrier. The porewater compositions analysed along boreholes in combination with the composition of the deep groundwaters confirm the retention capacity of the rocks. The exchange processes between groundwater and porewater mainly take place by diffusion and over very long periods of time. The safety analyses also include conservative assumptions about the hydrogeological release pathways. Above the disposal level, the nearest aquifer is located at a depth of around 400 metres. The age of the groundwater in the aquifer has been determined to be several hundred thousand years. This is a significant isolation period. Nonetheless, the assumption for the safety analyses is that, once radionuclides have reached

UNCERTAINTIES AT THE EARTH'S SURFACE ARE TAKEN INTO

ACCOUNT BY MEANS OF UNFAVOURABLE ASSUMPTIONS



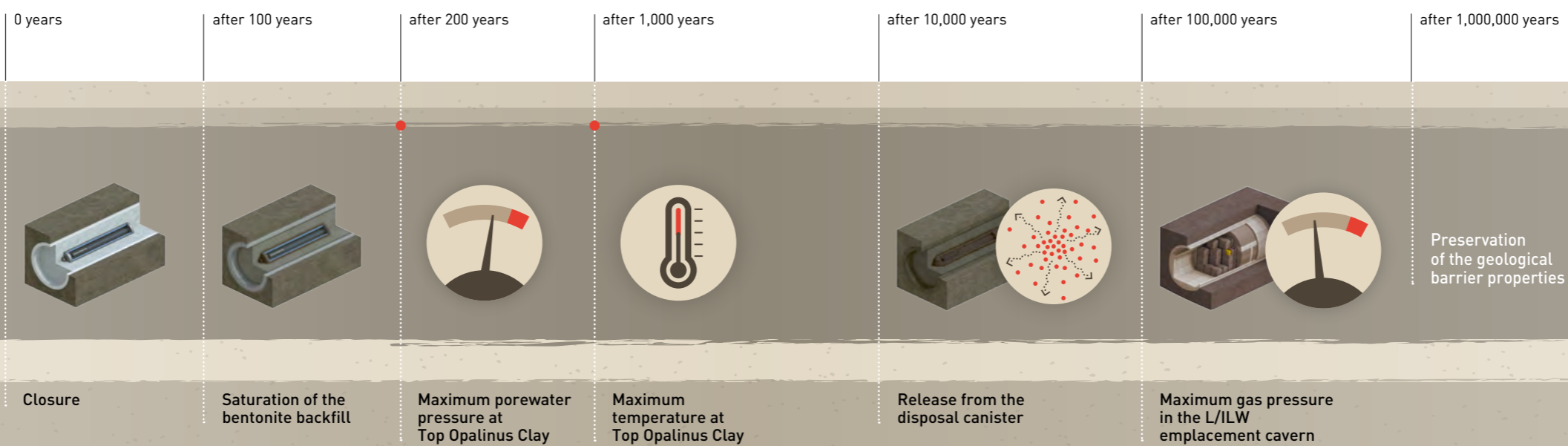
the aquifer, they will then reach the earth's surface directly and without delay. In this way, the potential radiological impacts of a deep geological repository are calculated based on the most conservative assumptions to take into account any remaining uncertainties.

The evolution of the engineered barriers, geological barriers, the biosphere and people's living habits can each be **predicted differently with regard to time**. The long-term behaviour at the disposal level is known from many years of research and can be well predicted using model analyses. At the beginning of the post-closure phase, during which the containment of the HLW in the disposal canisters is ensured, heat is generated by the radioactive decay of the

waste. When designing the repository, it must be verified that the rise in temperature does not impair barrier properties. A rise in temperature causes a change in pressure conditions, which are additionally influenced by gas produced by the corrosion of metals. Gas is also produced in the L/ILW repository section through the corrosion of metals and the decomposition of organic waste. This gas is distributed throughout the backfilled infrastructure at disposal level. System analyses confirm that the gas storage volume of the planned backfill materials will be sufficient to ensure that the gas pressure in the repository will remain below the critical values and that the mechanical integrity of the geological barrier will remain ensured with a sufficient safety margin.

The uncertainties at the earth's surface with regard to climate evolution and human behaviour are taken into account in the safety analyses by means of bandwidths and unfavourable assumptions. The results are measured against the specification of the maximum permissible additional individual dose of 0.1 mSv per year from the deep geological repository, demonstrating that safety can be ensured for the wide spectrum of scenarios considered. **In all cases, the resulting maximum individual dose remains below the protection criterion**, in most cases by several orders of magnitude. To demonstrate the robustness of the multi-barrier system, hypothetical evolution scenarios are also analysed. The system is shown to remain robust even in the event of these impossible scenarios. The know-

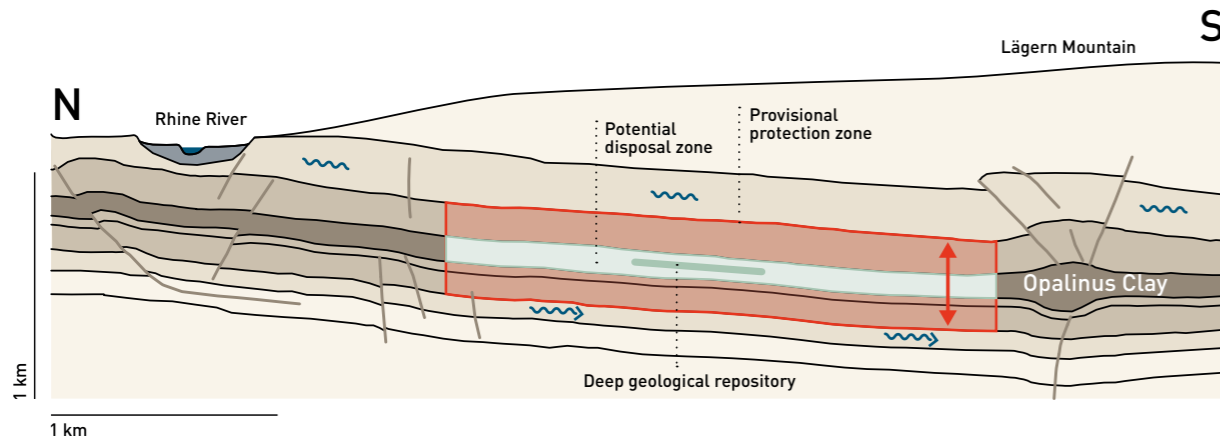
ledge gained since the demonstration of disposal feasibility with regard to the performance of the engineered and geological barriers has led to a more robust safety case. **The extensive geoscientific investigations carried out during the Sectoral Plan process have further substantiated the safety cases.** For example, the contribution to the barrier function of the low-permeability confining geological units over- and underlying the Opalinus Clay can also be taken into account. The surface facility can also be designed in such a way that it can withstand all hazards during the operational phase and protect the surrounding area, population and workers from unauthorised radiation exposure.



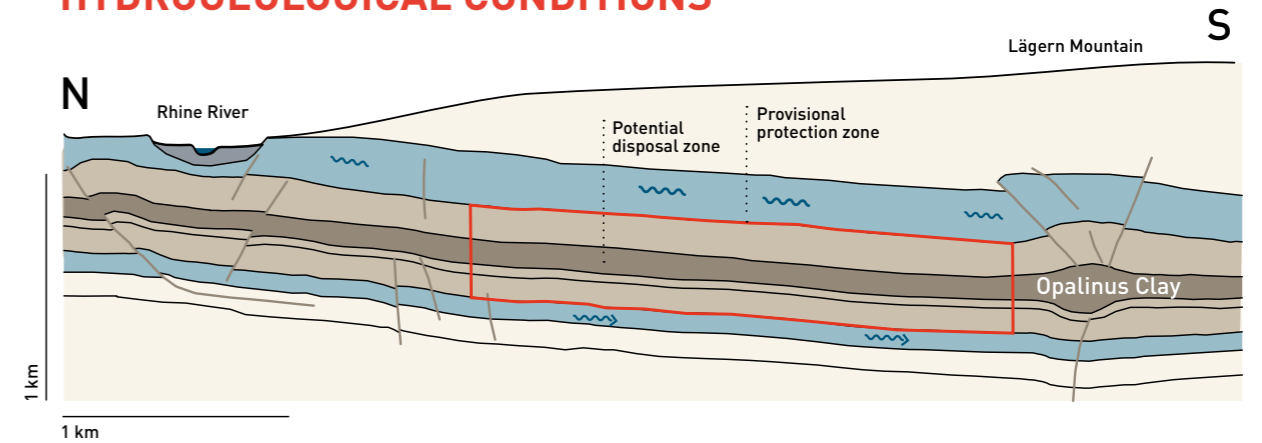
DEEP UNDERGROUND, THE EVOLUTION OF THE REPOSITORY AND THE GEOLOGY CAN BE

PREDICTED WITH SUFFICIENT RELIABILITY.

THE GREATEST THICKNESS



THE MOST FAVOURABLE HYDROGEOLOGICAL CONDITIONS



6 WHY IS NÖRDLICH LÄGERN THE MOST SUITABLE SITING REGION?

The Jura Ost (JO), Nördlich Lägern (NL) and Zürich Nordost (ZNO) siting regions are all suitable for the construction of a deep geological repository, with sufficient margins to ensure safety in the long term. In Stage 2 of the Sectoral Plan process, preliminary safety analyses demonstrated that the protection criteria can be met in all of these siting regions. The key properties of the engineered and geological barriers present in all siting regions form the basis for demonstrating post-closure safety.

The decisive features for selecting NL were determined based on extensive geological investigations carried out at the beginning of Stage 3. With a view to the preparations for the general licence applications, this led to the announcement of the most suitable repository site in autumn 2022 based on the decisive features summarised in terms of quality, stability and flexibility.

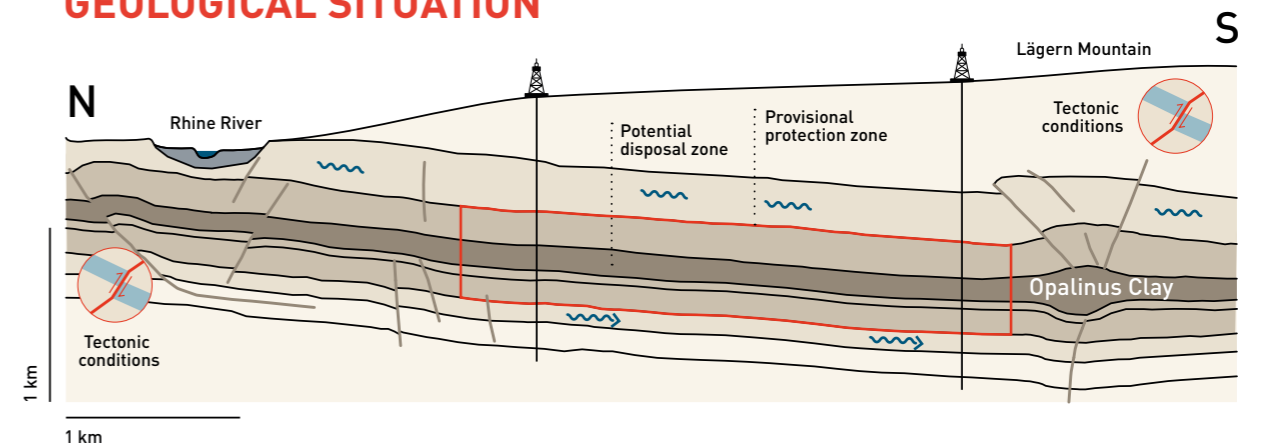
The siting regions were investigated in great detail by means of 3D seismic surveys, a deep borehole campaign and numerous Quaternary

boreholes as well as accompanying field measurements. The key decision factor for the selection of NL as the repository site are the following features of the containment-providing rock zone (argument report as per ENSI 33/649):

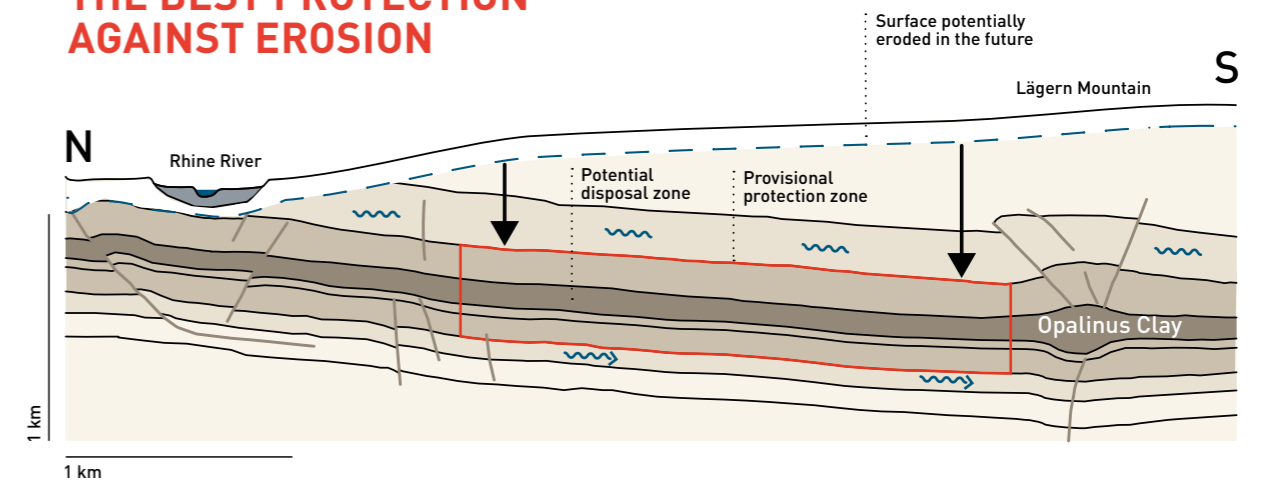
- the greatest thickness
- the most favourable hydrogeological conditions
- the most straightforward geological situation
- the best protection against erosion

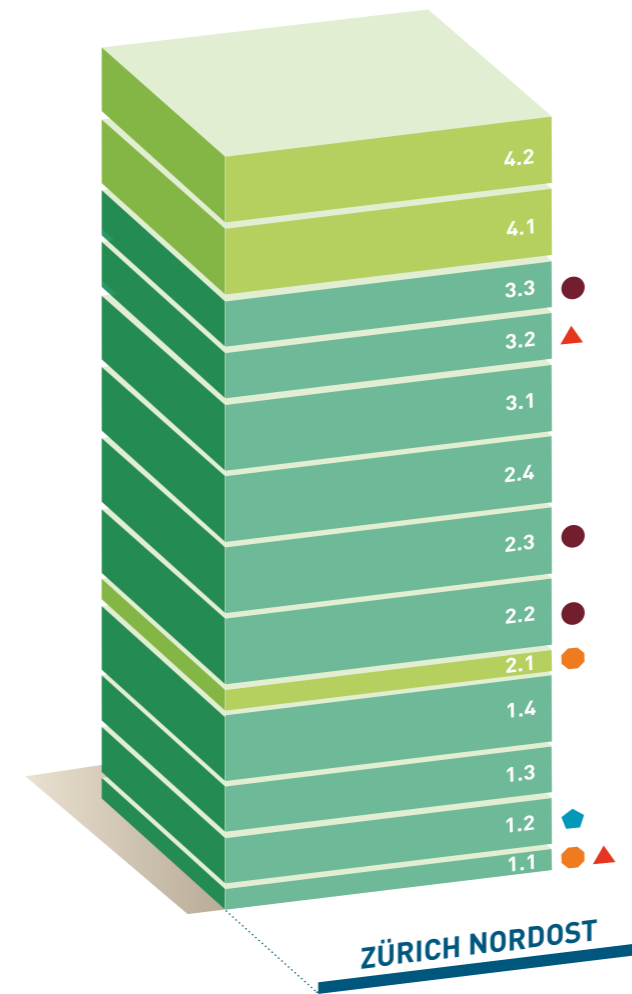
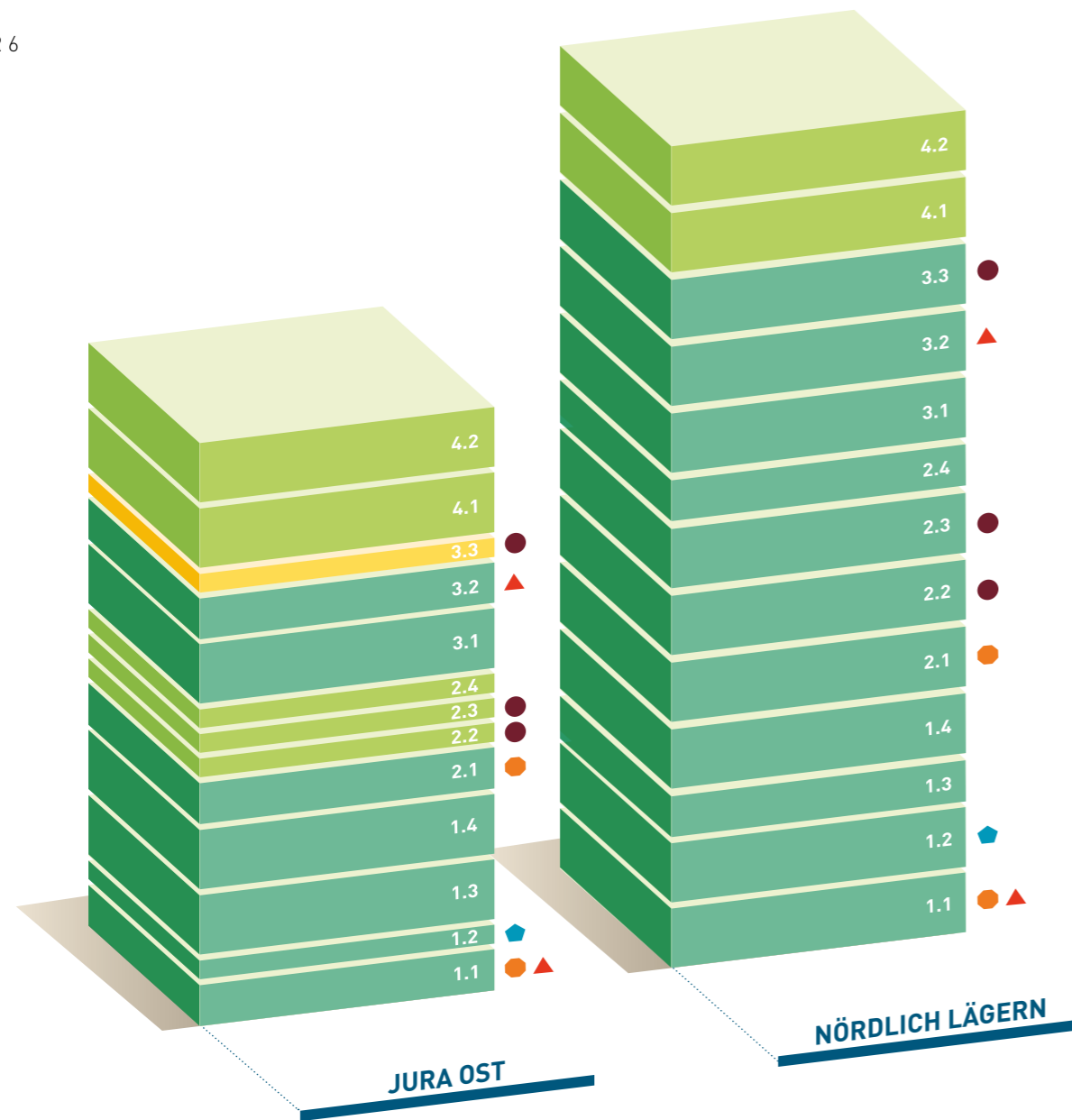
The Sectoral Plan defines 13 criteria that must be evaluated as part of the site selection process with regard to safety and engineering feasibility. The most suitable siting region for an HLW and an L/ILW repository must be determined by means of a positive selection process. As all siting regions are suitable, the focus is on **selecting the siting region that offers the greatest safety margins**. The qualitative advantages of NL are confirmed within the framework of assessing the 13 criteria, which are assigned to four criteria groups.

THE MOST STRAIGHTFORWARD GEOLOGICAL SITUATION



THE BEST PROTECTION AGAINST EROSION





Evaluation of the 13 criteria of the Sectoral Plan for an HLW repository in the three siting regions.

THE SELECTION CRITERIA

Criteria group 1 is related to the barrier function of the containment-providing rock zone. Criteria group 2 assesses how well this barrier function remains ensured over the required time periods, and criteria group 3 assesses the reliability of these geological findings and predictions. Criteria groups 1 to 3 assess the performance of the geological barrier in the siting region with regard to post-closure safety. Engineering measures can only impact these to a limited extent. The repository-induced effects are an exception (Criterion 2.3) as these can be influenced by the repository layout.

Criteria group 4 evaluates the engineering suitability, i.e. technical feasibility. To determine this, provisional repository projects were developed for each repository type and each siting region, and an integral assessment of the engineering suitability of the geological subsurface was carried out by means of construction engineering risk analyses. These confirm that the conditions for all repository

projects can be controlled from an engineering perspective and that the associated risks can be mastered with known and proven measures used in underground construction, even in the event of deviating geological conditions. In line with the primacy of safety in the Sectoral Plan process, the effort required in this respect is not assessed.

As the distance to the aquifers in NL is greatest overall and the containment-providing rock zone is thickest, there is a qualitative advantage with regard to the spatial extent (Criterion 1.1). Analyses of the chemical composition of the porewaters and the groundwater in the aquifers show that groundwater circulation in and around the containment-providing rock zone in NL is lowest. As a result, NL has a qualitative advantage in the assessment of the hydraulic barrier effect (Criterion 1.2). The geological situation is the most straightforward in the potential disposal zone of NL. The rocks, for example, are the most stably bedded. With one possible exception below the Stadlerberg, there are no indications

for faults large enough to be mapped with 3D seismic surveys, which is why the spatial extent in NL (Criterion 1.1) is rated best. Since changes in the geological underground generally take place where weak points already exist, the absence of faults results in an advantage with regard to the stability of the site and rock properties (Criterion 2.1). The straightforward geological situation is also an advantage for geoscientific investigations and the realisation of the deep geological repository, in particular due to the lower uncertainties when developing long-term predictions and safety analyses. NL, for example, also has the greatest likelihood of additional confining geological units, i.e. a greater safety margin for the underlying confining geological units (Criterion 3.2). The safety margins with regard to future evolution are greatest in NL. This applies, for example, to repository-induced effects (Criterion 2.3). With regard to protection against erosion, this issue is important both with a view to the expected future evolution (Criterion 2.2) and to less favourable assumptions (Criterion 3.3).

DECISIVE BARRIER PROPERTIES

The properties of the geological barrier that are decisive for site selection show clear advantages for NL, regardless of the repository type. As the time period for assessment for an L/ILW repository is ten times shorter than for an HLW repository, not all criteria are as relevant in the case of the L/ILW repository. The greater protection against future erosion is therefore not relevant, but the preservation of long-term barrier integrity with increasing gas pressure is of greater importance than in the case of the HLW repository. Assuming the same repository layout, the greater repository depth in NL provides a greater safety margin when considering repository-induced effects (Criterion 2.3). Negative interactions between the two disposal areas for HLW and L/ILW in the combined repository can be ruled out due to the generous spatial reserves. Regardless of the repository type, the NL siting region has clear safety-related advantages for post-closure safety due to its geological properties.

HOW MUCH WASTE WILL BE DISPOSED OF IN THE REPOSITORY?

In accordance with ENSI requirements, the general licence application is based on the Model Inventory for Radioactive Materials (MIRAM). MIRAM comprises the waste that exists today and a prediction of the waste that is still expected to be produced, assuming an operating lifetime of 60 years for the nuclear power plants currently in operation. The provisional dimensions of the disposal areas are also based on this assumption. To ensure that the scope of the licence, which must comply with subsequent procedural steps, covers the temporal uncertainties connected with a century-long project, the general licence solely specifies the “approximate” dimensions of the most important structures and the “maximum disposal capacity”.

MAXIMUM DISPOSAL CAPACITY

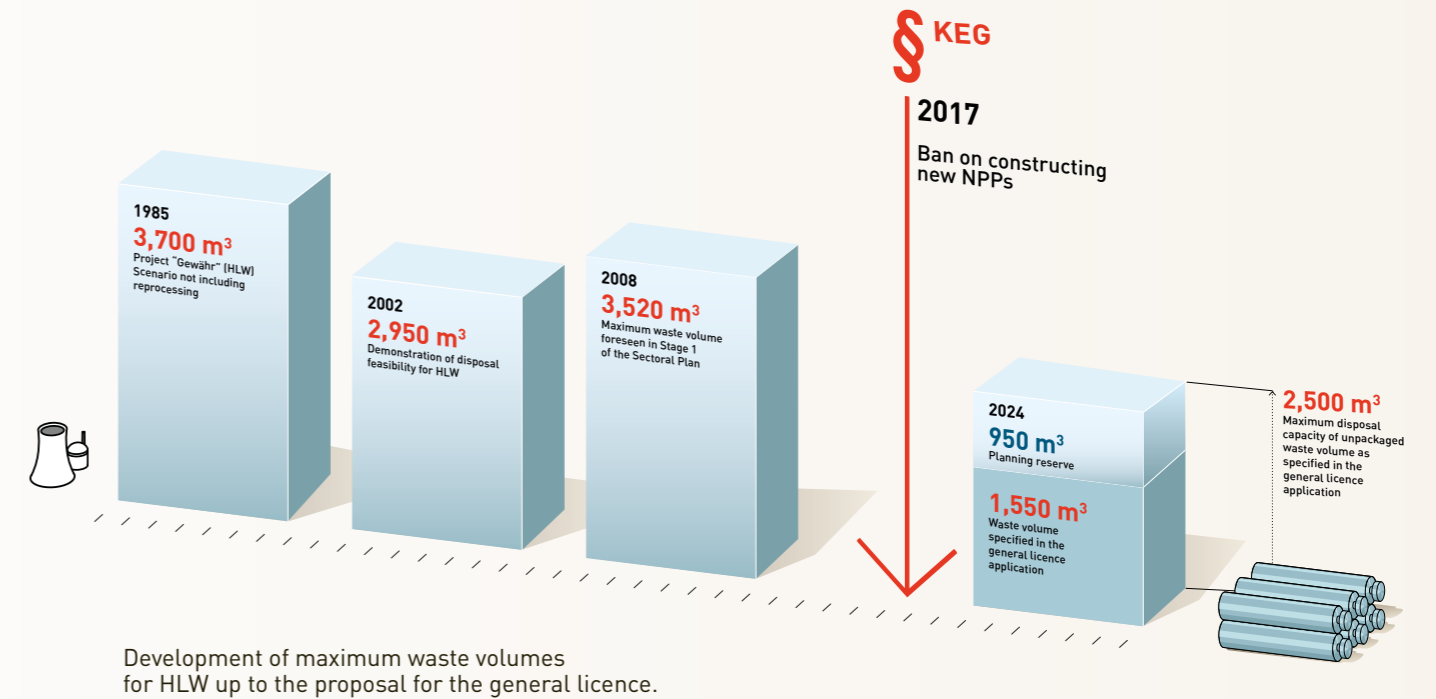
The maximum disposal capacity specifies the maximum amount of waste that can be disposed of in the deep geological repository within the scope of the general licence. In addition to other time-related uncertainties, the fact that the operating licences for the Swiss nuclear power plants were granted for an indefinite time period and can thus produce electricity for as long as they are safe, must also be taken into account. It is not possible to obtain a comparable licence for the deep geological repository as the Swiss Federal Office of Energy stipulates that the maximum disposal capacity must be specified in terms of volume. To ensure that this volume does

not include other variables, Nagra proposes to define the maximum disposal capacity as unpackaged volume:

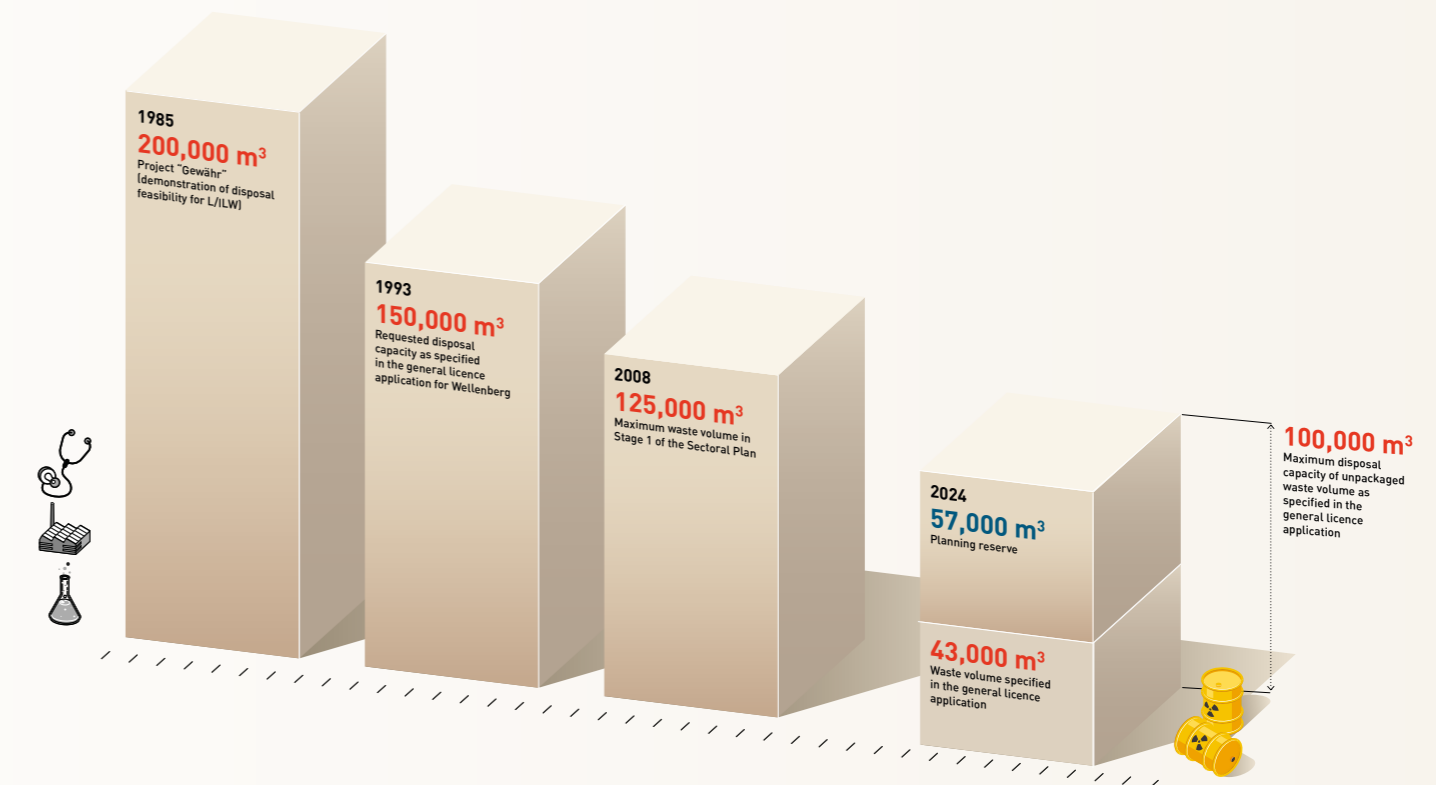
- **For HLW**, the proposal involves a maximum disposal capacity of 2,500 m³. This volume is around 1.5 times larger than in MIRAM and is based on the extended operation of the nuclear power plants currently in operation.
- **For L/ILW**, the proposal involves a maximum disposal capacity of 100,000 m³. This volume is around twice as large as in MIRAM and takes into account uncertainties regarding the volume of the decommissioning waste, an extended emplacement period for waste from medicine, industry and research and any changes in waste treatment procedures.

The justification of the maximum disposal capacities was developed in accordance with legal stipulations, in particular the ban on granting general licences for new nuclear power plants (Art. 12, KEG), which has been in force since 2017. The proposed maximum disposal capacities are significantly below the volumes on which the repository project was based in earlier project phases.

If the waste volume increases, the number of required HLW emplacement drifts and L/ILW emplace-



Development of maximum waste volumes for HLW up to the proposal for the general licence.



Development of the maximum waste volumes for L/ILW up to the proposal for the general licence.

ment caverns must increase correspondingly. The **potential disposal zone (around 22 km²)** has far more space available than that specified in the **current spatial requirement (around 2 km²)**. This means that, even if the spatial requirement increases to the point that the maximum disposal capacity is reached, large spatial reserves remain to optimise and adapt the layout of the repository.

The impacts of increasing gas pressure can be countered independently of the waste volume or the size of the repository, e.g. by ensuring a sufficient gas storage volume. In general, the size of the repository and thus the gas storage volume increase roughly in proportion to the volume of the waste. When considering the impact of heat on the barrier properties, the focus must be on the near-field, as heat generation primarily affects the immediate vicinity of the disposal canisters. The preservation of the barrier properties can thus be regulated by loading the disposal canisters in such a way as to limit the thermal output and by controlling the distance between the disposal canisters and the emplacement drifts.

Not all conclusions on post-closure safety are exactly proportional to the waste volume, but due to the large spatial reserves for the layout, qualitative statements using proportional assumptions are justifiable. Since the radiological consequences based on the expected waste volume are many times below the stipulated protection criterion, this criterion will be met even if the maximum individual dose were to increase proportionally to the waste volume.

CONCLUSIONS

Conclusions on the safety of the deep geological repository in the event that the maximum disposal capacity is reached are therefore already possible today. **Due to the large spatial reserves for the repository layout, post-closure safety will remain ensured even if the maximum disposal capacity is reached.** In addition, the licensing procedure stipulates that the safety case must be confirmed in future project phases, taking into account project developments featuring an increasing proportion of existing waste and a decreasing proportion of predicted waste.



WHAT IS INCLUDED IN THE GENERAL LICENCE APPLICATIONS?

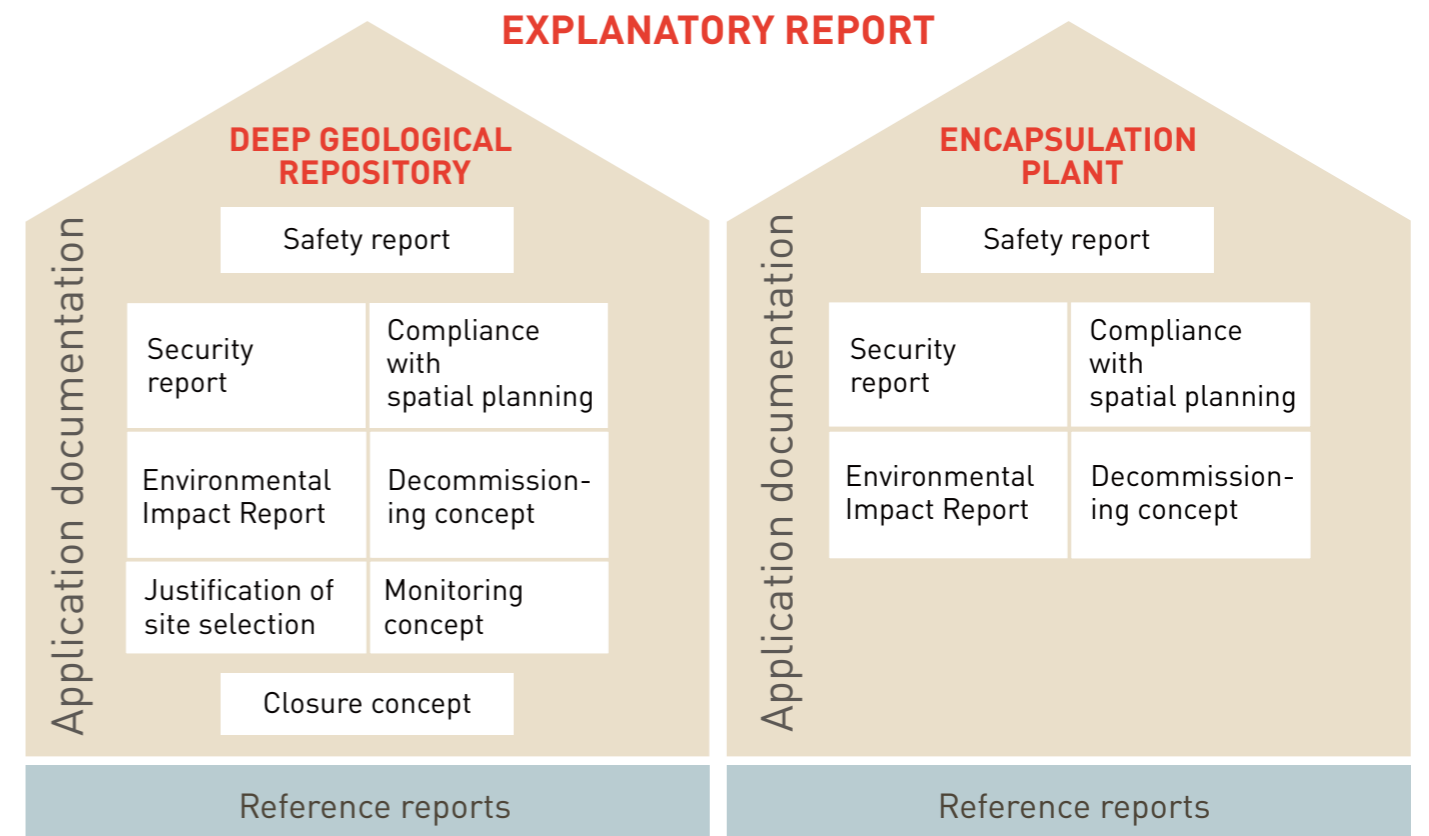
The documentation required for the general licence applications is specified in the Nuclear Energy Ordinance (Art. 23 and Art. 62, KEV):

- The **safety report** shows why the sites are safe for the purpose of the two nuclear facilities. For both sites, safety during the operational phase must be assessed, with the purpose of highlighting which characteristics of the site and which aspects of the project are to be considered when determining the design and dimensions of the facilities. In the case of the deep geological repository, a provisional repository project is used to demonstrate that the long-term protection of humans and the environment can be ensured. For the safety assessment, the evolution of the repository and the barriers is evaluated taking into account all conceivable events.
- The Environmental Impact Assessment for nuclear facilities is divided into two stages. For the general licence application, Stage 1 of the **Environmental Impact Report** must be submitted. This outlines how the projects can be realised in compliance with environmental legislation. To this end, an assessment is conducted to determine whether and how the project could affect assets worthy of protection. To assess the impacts, the projects and facilities are based on bounding assumptions, and the process for subsequent procedural steps is defined in the form of requirement specifications.
- The project perimeters required for the realisation of the deep geological repository and, in

part, the encapsulation plant are located outside the construction zones. By granting the general licence, the Federal Council confirms the spatial planning framework for the surface facility and its corresponding use. The **report on coordination with spatial planning** explains how, within the context of the Sectoral Plan process, a suitable site for the surface facility was determined as a result of the collaboration with the regions, cantons and neighbouring Germany.

- The **security report** shows that unauthorised access, interference and theft of nuclear materials can be prevented. As only conceptual security considerations are required for the general licence application, these reports are public, as opposed to the security-related documents for subsequent procedural steps.
- The **decommissioning concept** outlines how the nuclear facility buildings will be decommissioned and dismantled after the operational phase.
- In accordance with Art. 62 KEV, the general licence application for the deep geological repository also contains a **report justifying the site selection**, including an assessment of the geological properties that were decisive for the selection of the site. In line with ENSI's specifications, the documentation also includes a **closure concept** and an integral **monitoring concept**.

Both general licence applications are based on various complementary reference reports which are



Application documentation for the deep geological repository and the encapsulation plant for spent fuel assemblies.

publicly accessible via a web-based platform. This extensive documentation has been compiled over a long period of time, during which the project and the interpretation of facts have evolved. In the event of

any contradictions, the application documentation and more chronologically recent reports are to be prioritised.

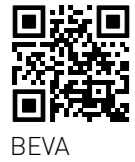
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HOW IS THE INFORMATION MADE OPENLY AVAILABLE?

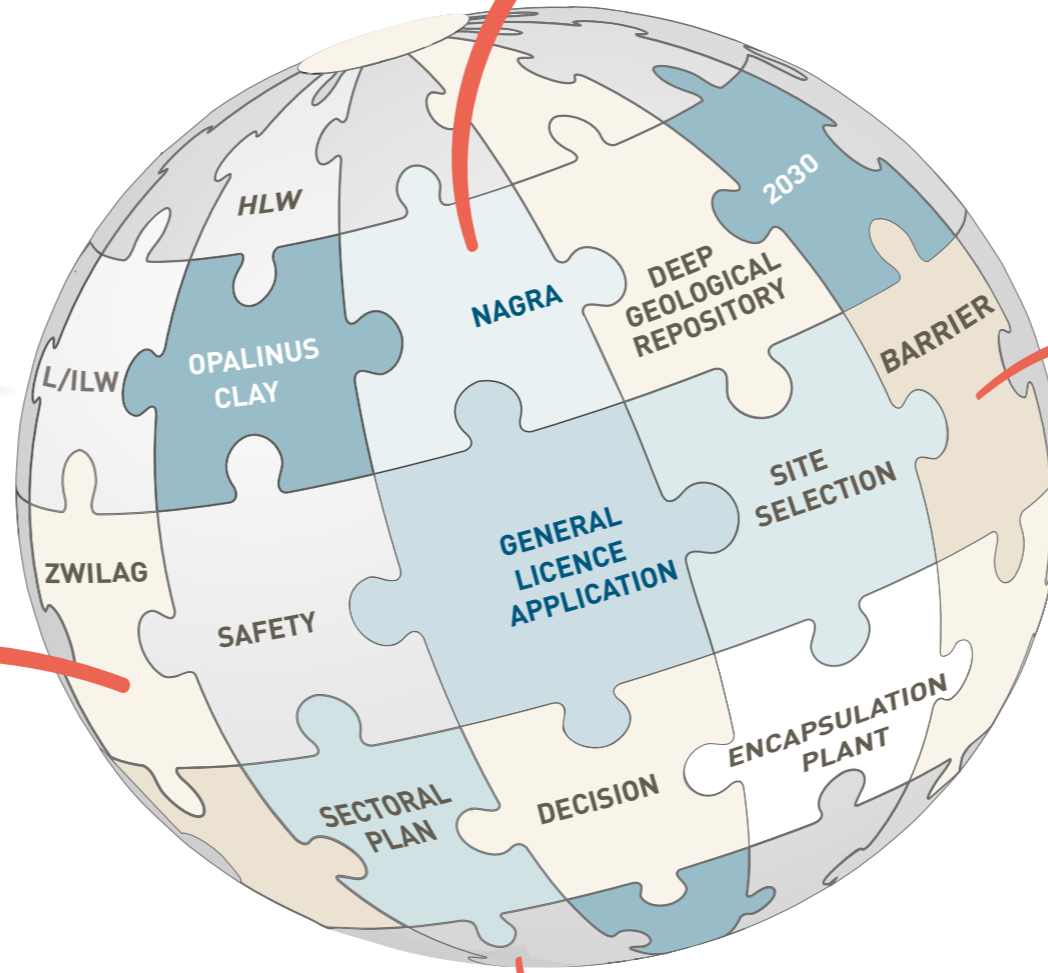


DIGITAL REFERENCE BOOK

The explanatory report, the documentation for the general licence applications for both the deep geological repository and the encapsulation plant as well as six key reference reports for the general licence application for the repository are uploaded at chapter level and provided with hyperlinks. Similar to using an encyclopaedia, users can browse through the different topics to obtain an overview.



BEVA



SEARCH FUNCTION

The platform allows users to search for terms and delivers hits from the application documentation and reference reports, which can be filtered according to relevance.



ARGUMENTS UNDERLINING GENERAL LICENCE APPLICATIONS

This area allows users to understand how the arguments were derived (document structure plan as per ENSI 33/649).



PDF LIBRARY

The reference reports for the general licence applications, generally relevant Nagra reports and important documents from the authorities are available in digital PDF libraries. Users can read the summaries, search for keywords and download relevant documents.



LIST OF ACRONYMS

ATW	Alpha-toxic waste
BEVA	Encapsulation plant for spent fuel assemblies (<i>Brennelementverpackungsanlage</i>)
DETEC	Federal Department of the Environment, Transport, Energy and Communications
ENSI	Swiss Federal Nuclear Safety Inspectorate (<i>Eidgenössisches Nuklearsicherheitsinspektorat</i>)
gTL	Deep geological repository (<i>geologisches Tiefenlager</i>)
HLW	High-level waste
JO	Jura Ost (siting region)
KEG	Nuclear Energy Act (<i>Kernenergiegesetz</i>)
KEV	Nuclear Energy Ordinance (<i>Kernenergieverordnung</i>)
L/ILW	Low- and intermediate-level waste
MIR	Medicine, industry and research
MIRAM	Model Inventory for Radioactive Materials
mSv	Millisievert
NL	Nördlich Lägern (siting region)
PSI	Paul Scherrer Institute
RBG	General licence application (<i>Rahmenbewilligungsgesuch</i>)
SFOE	Swiss Federal Office of Energy
SGT	Sectoral Plan for Deep Geological Repositories (<i>Sachplan geologische Tiefenlager</i>)
STENFO	Decommissioning and Waste Disposal Funds (<i>Stilllegungs- und Entsorgungsfonds</i>)
ZNO	Zürich Nordost (siting region)
Zwilag	Interim storage facility (<i>Zwischenlager</i>)

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