United Kingdom Nirex Limited

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2.6: Repository Design and Construction

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FOREWORD

This Context Note is one in a series, prepared by United Kingdom Nirex Limited (Nirex), that summarises the issues, experience and status in each of 30 topic areas that are relevant to the phased development of a geological facility for the long-term management of intermediate-level and certain low-level radioactive waste in the UK – the Nirex Phased Geological Repository Concept (PGRC).

It is the view of Nirex that sufficient work has been done to demonstrate the viability of the generic Nirex Phased Geological Repository Concept: to support packaging advice; and to provide enough confidence to proceed with a site selection process in the UK. The aim of the Context Notes is to provide the documentation to support this view.

The starting point for the notes has been an identification of issues based on extensive examination of reviews and published scrutiny of Nirex work and programmes over the past 20 years. This has been supplemented by more recent discussion meetings with knowledgeable and concerned organisations and discussion meetings within Nirex. The issues have been analysed according to their importance with respect to the future implementation of a geological repository in the UK, screened and sorted into topic areas. Then, for each topic, a Context Note has been prepared that presents the key issues, relevant experience, directions for further development and overall status in the topic area.

The Context Notes are intended to provide a focus for discussion of issues and priorities of future work within Nirex, and as a means of communication to stakeholders. The Notes provide support to Nirex Report N/122, which presents an overview of the viability of the Nirex Phased Geological Repository Concept.

CONTENTS

CONTEXT NOTE 2.6: REPOSITORY DESIGN AND CONSTRUCTION

1 THE IMPORTANCE OF REPOSITORY DESIGN AND CONSTRUCTION

The engineering principles applied to the development of the Nirex Phased Geological Repository Concept (PGRC) [1] have been based on the provision of a technically feasible, safe and cost effective long-term management of the United Kingdom's intermediate level and certain[1] low level wastes [2].

For Nirex to give packaging advice to waste producers it is necessary to be able to demonstrate with a high degree of confidence that the generic design concepts are capable of meeting both regulatory and Company health and safety performance standards. To achieve this Nirex has developed a reference design to a level suitable for the necessary assessments. The reference design is focused on strong crystalline rock overlain by sedimentary rocks and has been developed around the use of proven technology in mining, construction, waste management and associated industries. The reference design is generic and would be broadly compatible with igneous and metamorphic rocks and also strong sedimentary rocks in the UK. The development of a repository in weak sedimentary rocks and evaporites would present different challenges, and would require a different repository design.

To isolate this hazardous waste from the environment, waste is emplaced in deep underground storage vaults. The vaults would be constructed in a stable geological environment that offered conditions necessary to provide geological containment at a later date. The storage vaults would be similar in design to existing surface stores with carefully controlled environmental conditions. This in itself would provide a significant barrier of several hundred metres of rock so the waste is less vulnerable to natural disasters or terrorist attack.

An integral part of the design process, at all stages, will be 'design optioneering', i.e. a systematic review of the implications of alternative design proposals with the objective of establishing the best way of meeting the standards.

The following sections briefly describe the general approach to the design and construction of the Nirex PGRC.

1.1 General Approach to Design

The design has been developed employing proven technology and the using the principals of sound engineering and best practice. The operational safety has been assessed [3] to ensure that it meets Nirex's Environmental and Safety Policies [4]. Fundamental to this is the incorporation of design features that eliminate or mitigate the consequence of possible unplanned events and accidents and maintain the facility in a safe condition. To do this Nirex has followed an iterative approach whereby a design is developed, and faults and hazards are identified and then either eliminated or controlled within the design. Pursuing this process from the early stages of design development helps to ensure that key safety considerations are addressed and provides a robust foundation for continued development of the design.

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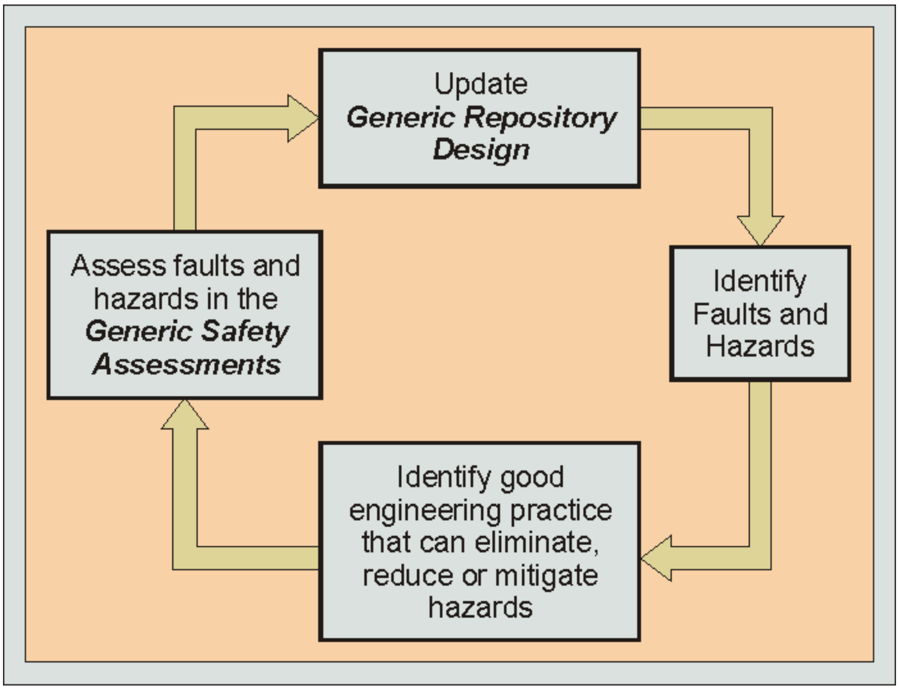
[1] Defined as low level wastes unsuitable for disposal at Drigg, reported in the 2001 Inventory and that arises in the period up to and including 2089/90.

The environmental impact of the design and operation of the repository would be addressed at all stages to ensure that effective measures are taken to reduce the impact. Environmental impact is also an important consideration in the selection of sites suitable for the construction and operation of a repository. The Nirex Generic Repository Design [5] introduces the key factors which would be taken into account as the design develops.

This strategy and approach is in line with the Nirex Health, Safety and Environmental Policy and the overall strategy of achieving safety for the PGRC which is discussed in Context Note 1.2 “Environmental and safety policies and strategy”, [4].

Figure 1 Design Development and Safety Assessment



The Nirex Engineering Foundations Report [6] describes the development of engineering solutions for the Nirex PGRC. It describes how the concept has been based on sound engineering practice, and it identifies the following key aspects:

- A brief ‘walk-through’ of a repository as it would operate from the receipt of waste at the surface, its transfer underground and emplacement within the vaults.
- A summary of the requirements and constraints for each functional area, and a description of the engineering that has been incorporated into the concept.
- How the equipment, systems and techniques are drawn from well developed practice within the nuclear, mining or construction industries.
- The provision of safety during the operational period, and how flexibility has been addressed to ensure that future decisions can be taken with the confidence that the wastes can be retrieved safely, should that be required.

The aim of the Engineering Foundation Report is to provide the reader with an understanding of the basis for the engineering and an appreciation of the underlying objective of developing a simple, flexible and robust concept. It identifies those key elements that Nirex believes have been sufficiently developed at the concept level to provide confidence that they can be detailed at some future stage.

The design responds to the requirements for long term safety. The key emphasis at this stage is to design for safety and robustness but it is acknowledged that further work will be required to optimise the design to demonstrate Best Practical Means (BPM).

The Nirex Health and Safety Policy Statement [7] (currently under review) applies to all the Company's activities. This lays down the health and safety framework within which all the Company's activities, including design and engineering are to be undertaken. In particular, design activities must comply with the following principles::

> *"The Company will establish and maintain management arrangements that ensure high safety standards are achieved in the design, development, construction, operation and closure or disposal of the facilities for which it is responsible."*
>
> *"Where potential hazards cannot be eliminated by design, good industrial practice is followed to achieve as a minimum the standards identified in the appropriate HSE Code of Practice. Similarly, where substances are used that may be harmful to health, precautions specified in legislation or advised in HSE Guidance Notes will be applied."*
>
> *"The Company's radiation protection policy sets down criteria to ensure that the risk presented by its facilities is as low as reasonably practicable during all operational and post-closure phases. It embodies the basic principles of radiological protection established by the International Commission on Radiological Protection (ICRP): justification, optimisation and limitation, and is in line with the fundamental principles set down in HSE's assessment principles for nuclear plants and NRPB guidance.*
>
> *This will ensure that no person will receive doses of radiation in excess of the appropriate limits as a result of the normal operation of its plant and facilities and that all reasonably practicable steps will be taken to prevent accidents and to minimise the radiological and other consequences of any accident."*

In addition, Nirex has set out the Nuclear Design Safety Principles (NDSPs) [8] that it considers are applicable to a repository. They are based on the general principles set out in the NII's Safety Assessment Principles [9]. The NDSPs relate primarily to the operational safety of a repository and incorporate nationally and internationally recognised principles of sound engineering design for nuclear facilities. The NDSPs complement the standards for radiological protection set out in the Company Radiological Policy Manual [10].

1.2 General Approach to Construction

The UK Construction (Design & Management) Regulations (CDM) [11] & [12] apply to the following:

> *"All demolition and structural dismantling work, except where it is undertaken for a domestic client";*
>
> *"Most construction projects…"*

The Regulations require that the designer shall ensure that:

> *"the health and safety of those who are to construct, maintain or repair a structure are considered during the design process. The most important contribution a designer can make to improve health and safety will often be during the concept and feasibility stage when the main considerations will be about the different design options which are open so that potential hazards can be avoided."*

The Generic Operational Safety Assessment (GOSA) [3] addresses the viability of the Nirex Phased Geological Repository Concept (PGRC) for emplacement operations. An extended period of 'care and maintenance' will rely on management/inspection and maintenance of all activities and action would be taken to remove/replace/refurbish well in advance of failure of any component. This would also be the case for any storage concept. The impact of an extended care and maintenance will be assessed in the development of the GOSA. Within this, the *Conventional Safety Assessment*, *Part 8* gives a high level overview of the hazards and control measures for conventional safety associated with construction of the facility and the methods that would be employed to mitigate these. At this stage of the project this is a suitable level of review to meet the CDM regulations. However, it is recognised in Section 1.3 of the *Generic Operational Safety Report* (Part 1 of the GOSA) that this will need to be addressed further in the future.

2 RELEVANT EXPERIENCE

Nirex has developed a generic design for a deep geological repository for the phased disposal of solid intermediate level wastes (ILW) and certain low level wastes (LLW) [2]. The long-term safety of the repository is based on a multi-barrier safety approach, which makes use of engineered and natural barriers to contain and isolate the wastes. As part of the work programme, a series of documents has been produced to define and describe the Nirex PGRC [1], [3], [13], [14], [15], & [16].

The Nirex PGRC envisages emplacement of wastes in a facility constructed at depth within a suitable host geology. The Nirex PGRC is not specific to any one location or type of geology, however, certain assumptions are made about the ability to excavate and maintain underground openings that are generally applicable to good quality strong crystalline rock, based on internationally accepted rock mass classification systems. Nirex is also working on concept designs in a range of other geologies (see Section 3.1.2)

It is envisaged that the repository could operate as a deep underground store, where waste would be monitored and could be retrieved if required. In a similar way to managed storage, the Nirex PGRC provides for continued management and intervention which gives flexibility to future generations on the timing of backfilling, sealing and closure of the facility.

The Generic Repository Design (GRD) [5] has been developed to meet the requirements of the Generic Disposal System Specification [13]. In turn, the GOSA [3] identifies safety systems and provisions to address identified hazards within a deep repository.

A key element in the general approach to developing the Nirex PGRC is to use engineering solutions which, where possible, are based on existing available technology that has been tried and tested in other applications. In view of this, a review [17] was undertaken of the technologies that would need to be employed in all phases of the construction, operation and closure of the Nirex PGRC, and their availability. The main areas of the review were:

- Waste packaging and handling. This included the methods for packaging low and intermediate level radioactive wastes that are currently in store or those likely to arise in the future and any additional requirements for temporary shielding during transport to the repository.
- Construction and operation of the underground repository. This included the surface facilities, access routes underground and emplacement in the two

types of vaults, i.e. those for waste packages that require shielding and remote handling and those that do not.

- Closure and monitoring of the repository over the longer term and the facilities for retrieving the waste, if required.

The main findings of the review are summarised as follows:

"Construction of the repository[2] would employ standard techniques that are used in the mining and tunnelling industries.

Initial emplacement and further construction operations would take place in parallel. Construction would include systems for ventilation and drainage of the vaults and underground facilities. Such systems are already employed in the major mining and tunnelling industries.

Surface facilities at the repository would be broadly divided into designated and non-designated areas which are consistent with the current practice on current licensed nuclear sites. Transport packages[3] would arrive by rail or road to be checked in and monitored. They would then be unloaded from the road or rail wagons onto drift wagons for transport into the underground facilities using a rack and pinion railway [18]. This would also be used for personnel and some equipment. The methods would be analogous to those used for drift mineral mining operations. Any construction activities would continue to use the main access shaft.

Once underground, the LLW and SILW packages would go into a buffer store before being transferred on a forklift truck to the emplacement area. The procedures would be analogous to those being currently employed for underground emplacement of radioactive waste packages at for example, Forsmark in Sweden.

Once underground, the RSTC's would be transferred to the shielded inlet cell to allow for removal of the UILW packages inside. The UILW packages would then be handled remotely using techniques that are analogous to those currently used for surface storage of ILW waste at existing sites at Sellafield and Dounreay. They would be transferred to the emplacement area on a remotely controlled bogie and stacked in the disposal vault using a remotely controlled crane. The empty RSTC's would be returned to the surface for checking and dispatch to the waste producers for re-use with the next load of UILW, in a manner similar to the current re-use of spent fuel flasks.

In all periods of the operation of the repository, ventilation air and liquid effluents leaving the emplacement and other active areas would be treated to remove radioactivity using methods that are currently used in the process and nuclear industries. These are sufficient to clean and purify liquid or gaseous

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[2] No purpose built deep repository exists in Europe, however underground facilities have been or are being developed at Äspö (Sweden), Mol (Belgium), Mont Terri and Grimsel (Switzerland) and Bure (France) for experimentation and demonstration of construction and emplacement technology. In addition the development of deep repository within existing mines at Morsleben and the licensed facility at Konrad, both in Germany, and the facilities at Asse have all developed experience in underground construction work specific to their use as repositories or demonstration facilities. There is also considerable experience derived from the construction of transport tunnels and underground hydroelectric facilities.

[3] Shielded Intermediate-Level Waste/Low-Level Waste (SILW/LLW) containers for emplacement in the SILW/LLW vaults or Reusable Shielded Transport Containers (RSTC's) containing the Unshielded Intermediate Level Waste (UILW) packages for emplacement in the UILW vaults.

> *effluents and allow them to be discharged to the environment in accordance with any requirements laid down by the relevant regulatory authorities. Compliance with the discharge limits and all other aspects of repository operations would be supported by monitoring programmes that currently operate in all licensed industrial premises.*
>
> *Ventilation and humidity control would ensure that corrosion of the waste packages over the operational life of the repository will be as low as possible. During this and any subsequent care and maintenance period retrieval of the waste packages could be carried out using the same equipment as used for emplacement*.
>
> *Backfilling of the vaults would immobilise the waste packages in a homogeneous cementitous grout, forming the next barrier against the long-term corrosion of the waste containers and migration of radionuclides from the waste. Nirex have demonstrated that, after backfilling, the retrieval of packages could still be carried out using robotic water jet cutting methods that are currently used for cutting concrete in civil and nuclear decommissioning operations.*
>
> *Closure of the repository would involve sealing all access points after which retrieval of the waste packages would require methods analogous to those used in both the mining and nuclear decommissioning industries."*

Overall, it was concluded that the Generic Repository Design applied technologies which have been proven in other applications. In applying these to the proposed design there would necessarily be some development and testing to appropriately scale the use of these technologies to this particular application.

Additional work has been carried out [19] to advance the development of the sealing requirements for the Nirex PGRC. The report is the work of an engineering specialist, drawing upon sound engineering practice and experience of seal construction for underground plugs, dams and other relevant structures in deep mine construction. Further work has also been undertaken to consider the likely backfilling and sealing requirements and how these might be met by the use of various materials and geotechnical engineering designs. This work is reported in [20].

The results of these will enable a robust specification of sealing requirements to be prepared. This will form the basis of design concepts to demonstrate that sealing of the repository is feasible and post-closure performance requirements are achievable. The concepts will help to identify material testing requirements, assist model development and validation of model predictions, and give confidence in the design.

Following on from [19] further work was carried out to assess the logistics of sealing a repository. The report [21] describes and demonstrates what practical and sensible timescales can be assigned to the backfilling, sealing and closure operations at a repository following a decision to move to that phase. It further identifies what additional measures could be undertaken to accelerate the programme of backfilling, sealing and closure, should a need arise for the repository to be closed as quickly as possible.

The report concludes that using standard equipment, the 'base case' programme indicates that the repository could be backfilled, sealed and closed within 11 years following a 'care and maintenance' period. With additional equipment and varying levels of personnel, the accelerated programme indicates that the backfilling, sealing and closure period could be reduced, reasonably, to 5 years. Further reductions in time are considered to be feasible, which could give a minimum total sealing and closure time of 2 years. Detailed operational planning would be required to achieve these further reductions in time below the accelerated case, and it is probable that partial pre-installation of seals (either during construction or during the ‘care and maintenance’ period) would be required.

3 FUTURE WORK

On-going and planned work provides for further repository engineering studies, to build confidence in the concept by addressing outstanding engineering issues and uncertainties, and to consider potential improvements. The outcome from this work will undergo safety and environmental assessment before being incorporated into future enhancements to the concept. The future work programme for the next three financial years concentrates on engineering development.

The overall objectives and key deliverables within this area are set out in Section 3.1.

3.1 Engineering Development

3.1.1 Generic Repository Design

An update of the Generic Documents, based on the 2001 National Inventory was issued for publication in July 2003. Certain aspects of the engineering require further development to improve the understanding of key aspects of performance in order to consolidate the robustness of the concept. This work will feed into the next revision of the GRD.

Whereas the Generic Documents were updated in 2003 to reflect the changes in the nature and quantities of waste published in the 2001 National Inventory, design changes have been identified for a future revision in the light of recent studies. Proposed design changes are recorded in the Change Control Database [22]. All proposed changes to Generic Documents are recorded and assessed, and will be implemented at an appropriate time, in a consistent way and in accordance with the Company Management Procedure for Change Control of Generic Documents [23].

The Generic Repository Design is revised and updated at appropriate stages to reflect updates in the UK Radioactive Waste Inventory and to include potential design changes identified in recent studies and any changes in UK and European regulatory requirements for a project of this type.

3.1.2 Design for Retrieval in Other Geologies

The reference repository design described within the current GRD is specific to construction of a repository in strong crystalline rocks. It is necessary that designs for other geologies are considered and developed to an appropriate level of detail to define the concept for that rock type. The current GRD considers the implication for other rock types in terms of the impact on scale of underground openings that would be viable and capable of accommodating the types of waste packages developed or envisaged. For emplacement in other geologies, such as clay or evaporite systems, openings may need to be smaller and different handling systems may be required. Design schemes for these options will be developed in advance of the 2006 Generic Document revision.

Two reports [24] & [25] have been produced, aimed at providing information on the implications on the generic repository design of constructing a facility in a range of different host geological environments. The first report considered four principal rock mass types:

- Igneous and metamorphic rocks that can be considered to be at the top of the strength scale for construction and include such rocks as granite, basalt, quartzite, and slate.
- Strong sedimentary rocks such as sandstone, limestone and dolomite.
- Weak sedimentary rocks such as mudstone, siltstone and stiff clay.
- Evaporites that can be strong to weak sedimentary rocks and include rock salt, potash, gypsum and anhydrite.

The report demonstrated that some form of repository could be constructed in most rock types. The more competent rock masses would support larger repository excavations at greater depth. As rock quality decreases, then generally so does the vault size and maximum excavation depth.

The second report was developed from the first, and examines in more detail the basis of design for geological repositories constructed in clays and evaporites, and develops some conceptual designs in some representative rock types. These include bedded and massive halites (rock salts) and both plastic and indurated clay. The report outlines the potential repository configuration, design provisions and operational factors, including retrievability for different host rocks (e.g. clay and evaporites).

The report covers such areas as:

- **Rock support** - The requirements for rock support in different rock types, and commensurate with the proposed life of the excavations.
- **Construction** - Construction methodologies are discussed, identified and justified appropriate to the rock mass characterisation.
- **Repository Layouts** - A number of underground repository layouts have been prepared for the chosen rock mass characterisation.
- **Design Description** - The underground layouts, their facilities and method of operation are described.
- **Waste Package Specification** – The report identifies the impact the repository design has on the current waste package specifications.
- **Retrievability** – The repository designs highlight issues that relate to the viability of retrievability.

The report highlighted retrievability as an area where the concepts for other geologies would, in some cases, be unable to match the flexibility of the reference case design in strong crystalline rock. This report will feed into work on design for retrieval in other geologies, and will support the next revision of the generic design.

3.1.3 Recovery from Malfunction

The assessment of faults and hazards in the generic design indicated a need to ensure the ability to effect recovery when operational problems occur. A systematic assessment of the faults and hazards has been conducted within the operational safety assessment and this has helped identify where potential malfunctions might occur. These in turn would be considered within the design with the aim, where feasible, of eliminating or reducing the risk of malfunction. Where the malfunction cannot be eliminated, scenarios for recovery would be addressed. Work is in progress and safe recovery methods have been developed for several scenarios, but further work is still required to complete the required detail for recovery scenarios. The work has demonstrated that safe recovery methods can be developed for identified malfunctions and the possibility of these occurring can be reduced, or recovery can be simplified by the incorporation of certain design features that have been identified. Continued iteration with operational safety assessment [3] will help to enhance the robustness of the design and operational provisions and this process will continue throughout all phases of design development.

There are a number of recommendations for design changes that could enhance recovery from malfunctions. The design changes need to be assessed for inclusion in the next revision of the GRD.

3.1.4 Construction and Operation

Nirex recently commissioned an independent review of the implications of carrying out excavation activities (currently envisaged to be by drill and blast) concurrent with operations in adjacent vaults.

The precedence around underground blasting was examined and an assessment of a typical blast design presented. Ground vibration and air blast levels were predicted at appropriate distances from blasting and an assessment carried out of the likely risks and consequences on plant, equipment, vault construction/fit-out activities and emplacement operations. Vibration criteria were recommended in order to address the need to minimise vibration and safeguard vaults during both fit-out and waste emplacement operations. The report concluded that with the vibration criteria recommendations implemented, and exercising best practice engineering control, blasting operations could be safely carried out whilst safeguarding vaults undergoing fit-out and waste emplacement operations, and containing previously emplaced waste.

4 CONCLUSION

Nirex have developed a simple, flexible and robust concept, in strong crystalline rock, for the safe and cost effective long-term management of the United Kingdom's intermediate level and certain [4] low level wastes [2].

The aim of the engineering development has been to minimise environmental impact and to apply systematic assessments in order to ensure that radiological risks and non-radiological hazards are as low as reasonably practicable. The Nirex Phased Geological Repository Concept (PGRC) has been developed at concept level to provide sufficient detail to allow key systems and operations to be understood, and to be assessed by Nirex as viable. The robust solutions have been based, as far as is practicable, upon established, proven and reliable technology.

Many detailed issues relating to the development of the Nirex PGRC have been identified from independent reviews of both Nirex's past work and the current Nirex Generic Repository Design, as well as reviews and discussion within Nirex [26]. The key issues fall into five principal areas:

- Void Migration - The concern raised related to retaining an open crown space in the vaults after backfilling, and whether this could lead to void migration. The key issue raised was whether this could result in a pathway that bypasses the vault seals.
- Other Geologies - The concern raised related to the flexibility in the concept for constructing in other geologies, for example clays and evaporites.

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4 Defined as low level wastes unsuitable for disposal at Drigg, reported in the 2001 Inventory and that arises in the period up to and including 2089/90.

- Construction and Operations - The concerns raised related to vault blasting during concurrent construction and waste emplacement operations, and the requirement for the storage, maintenance and replication of records.
- Fault Recovery - The concerns raised related to the review of potential failure modes and how Nirex will approach these in the design.
- Repository Sealing - The concern raised related to the ability to construct long lasting repository seals.

Table 1 summarises the key issues under the five principal headings and evaluates their status in relation to the Nirex PGRC.

Table 1 Potential Threats to the Viability of the Concept

Issue	Evaluation	Status
1. Void space in the vault crowns The concern raised related to retaining an open crown space in the vaults after backfilling, and whether this could lead to void migration.	This key issue raised was whether this could lead to void migration by creation of a pathway that bypasses the vault seals.	The current status is that Nirex have concluded that filling the void space should reduce the potential for void migration, but the effect on overall system performance needs to be fully evaluated. This will be taken forward as a design change control issue.
2. Other Geologies The concerns raised related to the flexibility in the concept for constructing in other geologies, for example Clays and Evaporites.	The key issues were the implications on groundwater chemistry, gas migration and rock mass stability.	The current status is that Nirex is actively engaged in considering the design and cost implications for a range of host rocks. It has been stated [24] that concepts for other geologies are viable but do not overall provide the same operational flexibility, scale of excavation and retrievability offered by the reference concept chosen in a strong crystalline rock [25].
3. Construction & Operations The concerns raised related to vault blasting during concurrent construction and waste emplacement operations, and the requirement for the storage, maintenance and replication of records.	The key issues were the effects of vibration induced shock waves on the packages, and the inadequacy of records leading to loss of waste package information.	The current status is that Nirex recently commissioned an independent review of blasting precedence. Ground vibration and air blast levels were predicted at appropriate distances from blasting and an assessment carried out of the likely risks and consequences on plant, equipment, vault construction/fit-out activities and emplacement operations. The Nirex design, both for surface access and underground operation, totally separates construction and waste emplacement operations.
4. Fault Recovery The concerns raised related to the review of potential failure modes and how Nirex will approach these in the design.	The key issues were being able to mitigate unidentified hazards within the design.	The current status is that Nirex have a robust approach to operational safety as dictated by the Generic Operational Safety Assessment [3], where assessment of the design has been carried out. As the detailed designs develop, further Hazard and Operability Studies (HAZOP) and fault schedule analysis will be carried out to assess the impact of that development and any appropriate mitigation measures identified.

Issue	Evaluation	Status
5. Repository Sealing The concern raised related to the ability to construct long lasting repository seals.	The aim is to develop conceptual design options which can be assessed in post-closure modelling of the repository system, leading to selection of the preferred strategy.	Work has been carried out [19] to advance the development of the sealing requirements for Nirex PGRC. The report is the work of an engineering specialist, drawing upon sound engineering practice and experience of seal construction for underground plugs, dams and other relevant structures in deep mine construction. Further work [20] has also been undertaken to consider the likely backfilling and sealing requirements and how these might be met by the use of various materials and geotechnical engineering designs. The results from these will enable a robust specification of sealing requirements to be prepared. This will form the basis of design concepts to demonstrate that sealing to repository post-closure performance requirements is achievable. The concepts will help to identify materials testing requirements, assist model development and validation of model predictions, and give confidence in the design.

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