Strategic Considerations for Developing Future Underground Research Facilities – 15114

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ABSTRACT

The suite of existing underground research facilities (URFs) and their various operational histories and contexts provides useful insights to consider when deciding a particular URF location and approach (generic or site-specific) for new disposal facility research programmes. Even the smallest URF represents a large capital investment and a significant ongoing operational mortgage when recognizing the typically decades-long site characterization and data collection thought necessary to support a defensible safety case or safety assessment. Thus making such investments should be approached with an understanding of the short- and long-term implications for such factors as cost, location, data quality, public acceptance, operational risk, opportunity for design optimization, etc. and with an understanding of the potential risk management issues to help ensure the URF programme achieves the intended objectives.

INTRODUCTION

A primary purpose of a URF is to provide high-confidence data from conditions relevant to the deep geologic disposal facility siting and to enable the development process to progress. The characterization and practical demonstration of key technical processes relevant to disposal facility performance (operational and long-term) is instrumental to establishing the degree of confidence in that performance and in the robustness of the design. The more advanced nuclear waste management programmes (e.g. France, Finland, Sweden, the United States) have made extensive use of URFs in their respective programmes; some are *site-specific* URFs located at the potential or actual disposal facility, and others are *generic* URFs located in similar geologic regimes that are typically excluded from disposal facility development by a-priori agreement with the host community or state. As national waste management programmes begin or renew their efforts to pursue deep geologic disposal facilities, the need for and benefit of URF programmes remains clear.

Much has already been written regarding URF experience with their siting, design, and operation; see e.g. Blechschmidt et. al, 2010 [1], Mazurek, M., et al. 2008 [2], McCombie, C., W. Kickmaier 2000 [3]. The recent Nuclear Energy Agency (NEA) document on Underground Research Laboratories (URLs) (NEA, 2013) [4] provides a comprehensive review of the strategy and planning of a URL but with an emphasis on reflecting the research needs for a repository development programme. However, a review of experience to date with existing URFs suggests there may be additional factors to consider from the perspective of risk management when embarking on the development of a URF. Some of these factors are explored below with the intention of improving the probability a URF fulfils its intended objectives.

DISCUSSION

Assuming a primary objective of a URF (or URL, little distinction is given here between URF and URL, the concepts apply equally) is to provide high-confidence data that ultimately supports a licensing decision (and collaterally enhances stakeholder confidence), then the notion of risk management refers to taking those actions necessary to enhance the probability that the URF will fulfil that objective, and to do so in a cost/time efficient and deliberate manner. As the development and operation of a URF presents an on-going trade-off between the desired research activities and the associated cost/benefit, it is prudent to consider how, beyond careful planning, to ensure the benefits toward a repository development are realized and the risk to same are minimized. Experience suggests that URF costs issues are ubiquitous and certain, while the benefits are often subjective. Managing key development issues and risks is intended to better ensure tangible benefits are realized for a given unavoidable cost of a URF development. Some of these development issues (and the possible aspects of cost) and risks are elaborated below.

Generic or Site-Specific URF

An essential first decision point is whether to pursue a generic or site-specific URF. A primary consideration will be the issue of the technical and regulatory acceptance over the transposition (or extensibility) of data from a generic site to the site-specific safety case. Acceptance by the regulator will likely depend on factors affecting the degree of transposition and the applicability to establishing confidence in the site performance; e.g. homogeneity of rock properties vs. distance, comparability of the regional setting, etc.

For example, the US Permian Salado bedded salt formation of the WIPP is noted for its uniformity over large distances, as is the French Callavo-Oxfordian clay formation at Bure. Such generally uniform conditions allow the actual repository siting to be readily transposed within a certain domain. The volcanic terrains comprising the Yucca Mountain site in the US are much less forgiving in this regard; a transposition of the site even one ridge away would likely call for additional site characterization. Likewise, even in granitic terrains where the rock body may be large and compositionally similar, the properties of interest to a repository, namely the fault and fracture network and its transmissivity / hydraulic conductivity, are generally more difficult to predict over some distance. As might be expected the geologic conditions necessary for the formation of extensive salt and clay formations point to expecting a degree of uniformity (not withstanding subsequent conditions affecting the rock mass). In contrast the tectonic conditions and rock mass anisotropies that control the development of a fracture network in granitic terrains are often episodic and/or stochastic which make for some difficulty in reliably predicting conditions further from the point of investigation.

This is not to say that a particular geology, or that a particular approach to a URF (site-specific or generic) is better or worse than another. Indeed, the WIPP site-specific characterization, even in a very uniform geology, still had to address certain conditions such as brine pockets and karst features. The point is that planning a URF for a particular geology to support a repository development (and its subsequent safety case review) should strive to anticipate the effects of possible issues on data transposition, wherever the data comes from. Anticipating the site characterization and probable scope of work, and the potential risks or difficulties in data transposition, will better inform the repository development timeline. In most circumstances, the issue of data transposition (or data representativeness with respect to the repository site) will likely affect the degree of data / performance confirmation necessary to support an accepted safety case.

Data Qualification

In the early evolution of several of the established URFs [4], especially those that advanced toward direct support of the safety case for licensing, the issue of data qualification arose. The history of several extant URFs suggests that URF operation can often begin before the regulatory framework for a repository development program is matured, and thus expectations or requirements for data qualification (and similarly for model development, peer reviews, etc.) are applied after data collection has begun.

A not uncommon experience is that site characterization activities, often designed with standard geoscience investigation approaches (e.g. hydrogeology testing, rock mechanic tests, etc.), are thought to be sufficient if performed to usual industrial QA standards (e.g. the supporting of geoengineering reports). However, as repository safety case development and licensing can be a decades-long process, the technical basis (i.e. the data and models derived from the URF or URL experiments) may be challenged many years later to often higher regulatory QA standards. It must be recognized from the outset of a URF implementation that the quality and *regulatory defensibility* of a future safety case is heavily contingent on the quality and defensibility of the technical basis that is rooted in the data collected from the URF's earliest efforts. Data quality and data management challenges are supposed to be precluded by adoption and adherence to a quality assurance programme geared to support repository programmes (e.g. ASME NQA-1, ISO 9001), but even advanced URF and repository development programs continue to receive feedback on the need to bolster QA efforts to avoid later regulatory challenges [5][6].

Inadequate data quality can sometimes be addressed retroactively; for example the U.S. NRC has a regulatory guideline [7] to establish data qualification post-facto to an accepted QA programme, but such efforts are labour and cost intensive and can be readily avoided by establishing a regulator-accepted QA programme in advance of URF operations. The cost-benefit of a rigorous QA program are not limited to the regulatory environment of a repository development program and it's URF; indeed other highly regulated industries (i.e. biotechnology, aircraft manufacture, pharmaceuticals) have similar challenges, but their scale of operations lends itself to well-supported commercial solutions for robust data management systems. Early repository development programmes with associated URFs tended to have more custom or operator-built data management solutions, but there is evidence this has changed in recent years with several URF programmes now using more standardized or commercial systems.

Beyond the notion of establishing confidence that data is 'fit for purpose', it is vital to understand that the actual purpose (i.e. value of the data) is ultimately to support a demonstration of compliance with the licensing criteria, and that may be assessed by the regulatory body many years later and without the benefit of the original researcher who generated the data. As experimental data, especially that from URFs, are often very difficult and expensive to re-create or re-qualify, mitigating the future risk of losing data defensibility with a robust should be an essential prerequisite to a well-implemented URF.

Number of Repositories or Candidate Sites
As a function of candidate site selection processes or for other reasons such as geographic equity, some national authorities may encourage or require multiple sites to be evaluated (e.g. the U.S. Public Law 97-425 of January 1983 was to provide for the development of repositories for the disposal of high-level radioactive waste and spent nuclear fuel). Pursuing multiple candidate sites may be viewed as a risk-management function in the case that one candidate site is deemed unsuitable or unacceptable (technically, politically, or socially). Obviously the significant cost of a single candidate site investigation (and a URF development if it proceeds to that stage) is compounded if two or more such sites need to be investigated simultaneously. Beyond the cost considerations are more subtle issues regarding the possible, or likely, need to down-select from multiple sites to one as the designated site.

International experience in multiple geologies and settings strongly suggests that from a purely technical standpoint, many sites can be seen as viable, while among stakeholders there is often the desire to pursue only “the best” site. Given the large number of contributing factors (engineering, geologic, cost, social) the notion of a “best site” is highly subjective and consensus on a “best site” would be elusive. Most nations only pursue a single site for URF development when designating a single site for repository development, but even when only one site is pursued, social and political consensus on the site suitability may still be elusive.

A few nations have pursued multiple site investigations, but the experience base with multiple site investigation in differing geologies is much smaller. Considering the potential for future site selection processes could call for multiple site investigations in different geologies and stakeholder participation processes, the issue of the down-selection process will be complicated by the desire of stakeholder to identify the “best site” of two or more sites under investigation even if all candidate sites can be shown to be adequate (i.e. demonstrated compliance with long-term performance requirements).

With regard to the issue of multiple site investigations for URF development, the implementing or authorizing organization would be wise to consider how to establish and maintain a sense of “technical equity” among multiple investigations. The intent is to avoid future accusations of institutional bias and that a particular site is deemed the preferred site (or “best site” in simple parlance) because it may have received greater support (technical and financial resources, a longer development time, etc.) from the same authorizing organization and which somehow then fostered bias in the organizations preferences for one site over another. Secondly in multiple simultaneous site investigations (with or without an associated URF), one site is almost certainly to be found ‘numerically better’ than another site (e.g. the calculated dose projections vary). Even if that numerical difference is insignificant, the issue of adequate versus best site will need to be addressed, and again the implementing organization should proactively avoid the potential for perceived or real bias affecting the results. In short, the down-selection processes when considering multiple candidate sites are ripe for charges of unfairness or bias, and these can be enhanced or diminished by the URF development programmes and policies that supported the site investigations.

Dedicated or Multiple Use Facilities and Operating Facilities

Many generic URFs are co-located with existing infrastructure, and further, are supportive of operating as a multiple-use geotechnical laboratory, hosting other organizations in conducting studies and tests and supporting multiple technical missions. Besides the greater international collaboration opportunities and benefits, the implementing organization can realize some offset in the cost of operations. URF overhead and infrastructure costs tend to be large and fixed mostly irrespective of the size or number of supported test activities (i.e. the fixed costs of keeping the URF open are the largely the same whether there is 1 or 10 test activities). Thus sharing or offsetting these costs of operations is desirable.

In site-specific URFs which are often authorized for a specific purpose by a national government, the situation of supporting multiple missions can be the same to a point, but avoiding logistical or technical interference with the primary mission (i.e. the development of the repository facility safety case) is usually paramount. Once a site-specific URF becomes attached to an operating facility (e.g. in the case of the WIPP), other factors such as security and radiological safety come into play that were not as prevalent before waste operations began.

As the costs of new URFs is high, there is a strong desire to use whenever possible existing infrastructure, whether for site-specific or generic URF purposes. As several site-specific URFs approach repository development in the coming decade, the issue of using the facility for additional testing (beyond confirmation test supporting the original licensing) will naturally arise, and questions of whether (or how best) to support waste disposal operations and other testing will need to be confronted. In this regard, the U.S. WIPP facility and the German Gorleben facility (coincidentally both in salt), provide some indications of risks inherent in locating test activities (not specific to the waste disposal operations) in an operating repository; whether through accident or government action, access to both facilities is presently not available and may be expected to remain so for some time. Had tests or experiments been emplaced prior to the present closures, access to them would have been lost, with the commensurate loss of sunk cost and schedule. This is not to suggest testing in operating repositories should be avoided, but rather to impart the notion that planning of test activities in such situations may benefit from and a healthy risk management perspective, and especially so for larger-scale multi-year tests. Test and operational concepts such as facility modularity, remote data access, systems engineering to reduce test maintenance, or using smaller-scale, shorter tests, etc. could help in deriving at least partial benefit of an emplaced test if facility access is unexpectedly lost.

CONCLUSION

As part of its effort to build competences in nuclear waste management among the member states, the International Atomic Energy Agency supports a forum of underground research facility (URF) organizations interested in sharing their expertise on geological disposal and specifically URLs and URFs. Additionally the development of Agency safety guides and other documents capitalizing on this international resource and experience-base are intended to facilitate the successful development of a URF. While there are several Agency and other resources describing many aspects of URF or URL development, there are other subtle considerations from a standpoint of risk management that may be taken into account in planning a URF development. Some of these considerations have been presented above. Others considerations are the subject of additional and ongoing efforts by the IAEA such as; succession planning and talent acquisition for a potentially multi-generational workforce, test program and research agenda prioritization, and the effects of changes in political will or stakeholder support for URF over repository development timeframes. There are a number of social, political, economic, and technical considerations that need to be made in deciding a URF strategy and its expression, but in all cases the primary objective of a URF should be to support the development of a safety case for a geologic repository. Whether site-specific or generic, the primary value of a URF is to provide high-confidence data from conditions relevant to a deep geologic disposal facility (proposed or sited) and to better enable the repository development process to progress. The discussion provided is intended to develop sensitivity for risk management referring to those actions necessary to enhance the probability that the URF will fulfil its objective, and to do so in a cost/time efficient and deliberate manner.

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