The Role of URLs in the Repository Implementation Phase

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EXTENDED OUTLINE

What is done in URLs and when?

Underground Research Laboratories (URLs), for the practical exploration of issues to do with deep disposal for long-lived radioactive wastes, have been in use for almost 40 years. The earliest work dates back to the mid-1960s, when the Asse salt mine in Germany was used for the trial demonstration of LLW/ILW disposal. Major experimental R&D programmes commenced in several countries in the late 1970s, notably in salt at Asse and in granite in Sweden (Stripa) and the USA (Climax). Since that time, more than a dozen URLs have been in use world-wide, with Japan starting work at Tono in 1986.

The NEA (2001a, b) defines two main categories of URL:

1. **Generic**: at locations that will not be used for a repository
    - in extensions of existing mines or tunnels
    - purpose built generic (PBG-URL), at a previously undeveloped site
2. **Site-specific**: at sites intended for development as repositories (SS-URL).

The NEA sub-division of generic URLs does not reflect any difference in scientific or technical concepts: it is merely a matter of practicality and convenience. If a programme wishes to explore a particular rock type or geological environment, then it can be most efficient to gain access through an existing underground facility, provided the environment is analogous to those being sought for a repository, and provided the existing facility does not grossly disturb the rock-groundwater system to be used in the URL. If, on the other hand, a suitable facility does not provide ready access to a useable volume of rock (for example, if a rather specific type of formation is to be investigated in a specific geological setting), then it may be necessary to start constructing a URL from scratch (PBG-URL).

Within the two NEA categories, it is useful to classify the type of work carried out according to its purpose:

- **Experimentation:** To investigate, and to develop and test models for processes that affect repository evolution (e.g. water, heat and gas transport) in a particular geological environment and rock type. In the past, most of this type of work has been carried out in generic URLs and is generally experimental R&D.
- **Rock characterisation:** To develop, test and deploy rock and groundwater characterisation techniques and strategies for different rock types and environments. It can be carried out in generic URLs (technique and strategy development) or site specific URLs, where it can be used to investigate the particular characteristics of a specific rock formation and geological environment at a site being investigated for, or developed as a repository. Site-specific URLs, are sometimes called rock characterisation facilities (RCFs). Both generic and site-specific rock characterisation involve using underground site investigations to extend and supplement those

carried out from the surface, in order to gather data for the design and safety assessment of either a conceptual or an actual repository.

- **Test and Demonstration (T&D):** To develop, test and demonstrate the engineering aspects of repository operation, including excavation, EBS and waste emplacement (and retrieval), closure and sealing, and monitoring. This type of work can be carried out in either generic or site-specific URLs: in the latter case, some programmes refer to the URL as a Pilot, or Demonstration and Validation facility.

As can be seen, there is a wide range of potential (and confusing) terminology: URL, PBG-URL, RCF, SS-URL, Pilot Facility, D&V Facility, etc. In this presentation, I shall just use the general term URL, but discuss how the different types of work that generate this diverse terminology fit into different stages of a Repository Development Programme (which, at the risk of introducing yet another acronym, I refer to as an RDP).

The Table below illustrates the different ways that URLs can contribute to a repository development programme from the **implementor's** viewpoint. For simplicity, the Table refers to four phases of an RDP:

- **early stage:** generic concept development and exploration of alternative designs and rock formations;
- **middle stage:** when reference concepts have been identified in reasonable detail (although alternatives are still being considered for optimisation) and a site selection process is underway;
- **late stage:** when one or more sites has been identified, work is taking place on these sites and a final design(s) is being optimised in detail;
- **operational stage:** when the repository is operating and waste is being emplaced.

The Japanese HLW programme is about to enter the middle stage, in these definitions.

	Generic URL	Site-Specific URL
Experimentation	**Early Stage**: To explore key issues in design and safety, such as heat transfer, controls on nature and extent of the EDZ, solute and colloid transport. Now, almost an historical usage, although there are still a number of important generic issues that are being explored (e.g. gas movement). **Middle to late stages:** Resolving outstanding (long-standing problem) issues, or issues that have arisen during mature generic studies. Also, very long experiments might be embarked upon, to gather decade-long data sets that will be used as validation during repository licensing	**Late stage:** To verify generic models under actual site conditions and populate them with real data, thereby reducing the range of uncertainty.
Rock Characterisation	**Early to middle stages** To develop underground site investigation techniques (e.g. fluid sampling, pilot drilling and remote sensing of major features ahead of excavation, patterns of water movement) and to test and develop models for rock physical and chemical properties.	**Late stage:** To measure the distribution and variability of actual rock properties in and around the potential repository volume and link underground observations (generally more extensive and simpler) with those from surface investigations (generally more limited). In addition, the URL can be used to spearhead what will eventually be a system-wide monitoring system

Test & Demonstration	**Middle to late stages:** To develop and test engineering aspects of repository implementation (excavation, emplacement, sealing, monitoring, retrieval, QA), including both techniques and machinery. **Late stage:** In the mature stages of an RDP, when technology has been largely decided upon, long-term (decades) demonstration projects might be planned. It is conceivable that (as at the US Climax mine) these could be 'fully active', using real waste packages that are retrieved at the end of the demonstration – although few programmes would care to surmount the political and regulatory problems of doing this at a non-repository location.	**Late stage (actual site):** In a *pilot* facility, to demonstrate how certain activities will be carried out, possibly before the repository is constructed (e.g. in support of a construction or operation license). If no generic T&D facility has been available, then some engineering testing and development (see box to left) may be needed first. In a *pilot disposal* facility, to show the complete emplacement (and, possibly, backfilling or retrieval) process before full scale disposal commences. **Operational stage:** to demonstrate sealing and post-closure monitoring technology.

From the **regulator's** viewpoint, the ability to evaluate information from all types of URL, at all RDP stages, will be important and useful. This is because the regulatory authorities also have to build up a parallel understanding of the disposal systems being considered in order to understand the reasoning behind the implementers decisions and proposals. Generally, regulators would have no direct influence on the early and middle stages of an RDP, but some national regulations require the implementor to use URLs in the later, site-specific stage, to assist with characterising the chosen site(s). The regulators might also wish to specify that certain types of T&D work are carried out as part of a licensing process. For example, in the late stage of an RDP, there may be a requirement to demonstrate emplacement (and retrieval) procedures before an operating license is given. Much further into the future, the regulator may ask for a demonstration of seal emplacement and overall monitoring technology before a closure license is given. In both these cases, the value of a pilot facility of some kind, with a long record of observations throughout the pre-closure life of a repository, is clear.

Both implementor and regulator benefit from an open, **public demonstration** of method and technology at all stages of an RDP, but particularly from the middle stage onwards, when there are developed concepts to be illustrated, using real underground environments. The majority of people are completely unfamiliar with the deep underground. As many national URLs have shown, even in the early stage, well before there is any tangible repository engineering to be demonstrated, there is huge value in taking people underground and showing them what the environment is like and how science is being used to aid design and safety studies. Later, full-scale demonstrations are essential in showing that paper concepts can actually be achieved. The early US programme was even able to provide a full-scale, fully active demonstration. The ability to stroll freely down a tunnel at the Climax mine, with real spent fuel containers emplaced in the rock a few metres beneath, provided an impressive experience, even for those technically involved in disposal projects.

Is there still a need for generic experimentation?

URLs have been operating for decades. They have contributed immensely to our understanding of deep hydrogeology, geochemistry and rock engineering. In a generic sense, most of the understanding that we need to structure design and safety assessment projects has already been gathered. URLs have acted as test-beds and as validation, in particular for theories about how water and solutes move, and about how rocks respond at the micro-scale to excavation and stress adjustment. In many senses, the 'learning' period is over: in the 1970s there was really very limited understanding of the controls on groundwater movement and radionuclide mobility in deep, low permeability rock formations. However, we have not solved everything yet, even at a generic level.

There are several topics where a better generic understanding would be of wide value to national programmes:

- the movement of gas through clays and very low conductivity rocks with sparse fracture networks;
- time dependent, spatially variable resaturation of clay buffer and backfill materials;
- the medium to long-term function of the excavation damaged zone (EDZ) in transporting water to tunnel and borehole backfills and buffer;
- techniques for characterising the 'flow-wetted surface' in fractured rocks;
- experimental evidence for efficient colloid filtration in fractured rocks;
- the development of high pH plumes in cement-based repositories and their impact on rock properties and radionuclide migration.

Continued work in these areas is likely to feature in a number of URL programmes over the coming ten years, even though the emphasis is now beginning to turn to test and demonstration activities.

Showing we can do it

Repository design concepts have existed on paper since the 1970s. As several countries move closer to realising spent fuel or HLW disposal facilities, it is becoming increasingly important to show that these conceptual designs are workable in practice, for day-after-day emplacement of waste packages, year after year. Already, experience in URLs in Sweden and Switzerland has shown that managing EBS and canister emplacement is not yet a matter of simple routine. Several practical issues, such as handling pre-formed bentonite in humid excavation atmospheres and remote handling of EBS components need a lot of practical development. There is little doubt that paper concepts will be further optimised to take account of these developments during the next few years.

Showing that emplaced waste packages really will remain safe, secure and inert, even if we can only provide a demonstration over a few decades, will also be an important aspect of winning public support for full-scale waste disposal. We should not forget that, although we may have become entirely used to the geological disposal concept after many years of exposure, it is not real: no-one has yet put a HLW container into a final repository .

Consequently, we should expect to see the emphasis of URL work moving away from experiment, to test and demonstration, particularly once sites are chosen.

Building confidence and propagating expertise

The discussion above has concentrated on resolving technical issues for design, safety and operational purposes. URLs have other functions during an RDP. Their role as test beds during the early stages of a programme is well established: the Stripa, Whiteshell, Grimsel and Mol URLs, in particular, were central in developing understanding of granite and clay formations during the 1980s and early 1990s. Over 10 – 20 years, those who worked in these projects (which acted as focal points for scientists from many countries) progressively built up their own confidence in understanding these geological systems and, in particular, in their ability to characterise them. In the case of Japan, entering into two major new URL projects, this element of progressive confidence building prior to going underground at a potential repository site, sometime after 2010, will be invaluable.

URLs have long lifetimes – typically measured in decades. Those who instigated some of the most famous URLs have long since moved on to managing other projects. But the long-term projects have acted as permanent training centres for passing growing experience on to younger generations of scientists and technologists. A key aspect of this education and training is that URLs comprise diverse, multidisciplinary projects, and they act as the focus for much of the front-line thinking and development of ideas about specific disposal concepts, both from a scientific and an engineering viewpoint. Anyone working in such an environment is exposed to many of the central problems in an RDP. In short, URLs, properly managed and with comprehensive programmes, comprise ideal centres for training those who will eventually implement repositories.

The new Japanese URL programme

Japan is starting work on construction of two major new PBG-URLs, one (nearby the existing Tono mine and URL) in granite – the MIU project, the other in sediments, at Horonobe. As the national HLW disposal programme enters the middle RDP stage, what might these projects be expected to contribute, bearing in mind the discussion above? The following aspects will likely be important:

- A useful facet of new URL projects is the need to characterise the URL rock volume and put it into its regional context. Thorough knowledge of the rock properties and of the flow, stress and geochemical boundary (and baseline) conditions is essential for any work that will be carried out in the URL. This is analogous to the staged surface-to-depth site characterisation programme that would be carried out at a repository site, although the scale is smaller at a URL. Consequently, the surface-based, followed by shaft and underground investigations will be useful practical experience for designing later repository site characterisation programmes. Among other things, working in an integrated programme such as this will enable investigation strategies and associated quality assurance procedures to be developed. Developing QA methodologies will also be an important aspect of any T&D work later on.

- Apart from addressing some of the 'residual' generic issues mentioned above, the new projects will be the main platform over the next few years for building up and training teams to carry out field investigations. These groups will develop hands-on experience of drilling, testing and excavating in hard rocks and sediments. Some of the methods they may need to deploy are likely to build on, but go beyond, approaches already developed in other national programmes, particularly for Horonobe, where the types of sediments encountered reflect specifically Japanese geological and tectonic conditions. Transferring international experience to local conditions will be a key role for the URLs.

- All of this will build confidence, both inside and outside the radioactive waste community in Japan, that when NUMO comes forward with its proposed detailed investigation areas, there will be the technology and the experience to set up comprehensive site characterisation programmes.

- Although the national HLW programme is only just about to enter its middle RDP stage, it is not too early to begin thinking about both engineering testing and demonstration projects in the Horonobe URL, and possible long-term experiments in both URLs. Long-term experiments may be most readily accomplished at MIU, where the environment is already reasonably well understood. It is likely that further characterisation will be needed before either engineering or long-term experimental projects can be fitted to the particular characteristics of the Horonobe URL. Internationally, whilst there is much talk in favour, there is limited movement towards development of large-scale demonstration projects. This is an area where Japan, with its strong engineering base, could take a lead and attract other national programmes into shared, long-term, high-profile tests and demonstrations of repository engineering.

References

NEA, 2001a. The role of underground laboratories in nuclear waste disposal programmes. OECD Nuclear Energy Agency, Paris. 42 pps.

NEA, 2001b. Going underground for testing, characterisation and demonstration. NEA/RWM(2001)6/REV, OECD Nuclear Energy Agency, Paris. 69 pps.

(参考)

【地下研究施設（**URL**）の分類】

(1) 処分予定地以外の場所に設けられるもの(**Generic URL**)
① 既存の坑道を活用するもの［例；釜石鉱山，東濃鉱山，モンテリ(スイス)など］
② 地上から新たに建設するもの(**PBG-URL**)［例；瑞浪超深地層研究所計画，幌延深地層研究計画，ホワイトシェル(カナダ)など］

(2) 処分予定地に設けられるもの(**Site-specific URL**)［例；ユッカマウンテン（米）など］

【略語】

D&V：Demonstration and Validation （実証と確証）
EBS：Engineered Barrier System （人工バリアシステム）
EDZ：Excavation Damaged Zone （掘削影響領域）
MIU：Mizunami Underground Research Laboratory （瑞浪超深地層研究所）
RCF：Rock Characterisation Facility （岩盤特性評価施設）
RDP：Repository Development Programme （地層処分計画）
PBG-URL：Purpose Built Generic URL （処分予定地以外の場所に地上から新たに建設する地下研究施設）
SS-URL：Site-Specific URL （処分予定地に設けられる地下研究施設）
T&D：Test and Demonstration （試験と実証）
URL：Underground Research Laboratory （地下研究施設）