Application of Knowledge Management to the UK's Radioactive Waste Management Programme – 14651

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ABSTRACT

The delivery of a geological disposal facility (GDF) for radioactive wastes in the United Kingdom (UK) is inevitably a long-term project. It will require specialist scientific and engineering skills to be applied across successive generations of employees and contractors. The Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority is developing and applying methods to transfer knowledge from retirees and other experienced leavers, to ensure that the project can be delivered successfully and efficiently. Following its closure, the hazard presented by a GDF would remain significant for millennia, and on these timescales support for reliable active knowledge transfer systems cannot be guaranteed. Therefore thought is being given to other methods of providing information, including design features that can alert future generations through passive marking of the site. This paper describes the techniques applied by RWMD, together with the lessons learned and emerging themes for the future, all of which are aimed at supporting the safe deployment of geological disposal, underpinned by a reliable legacy of accessible records.

INTRODUCTION

Current planning for a geological disposal facility (GDF) for radioactive wastes in the UK shows first waste emplacement in 2040 and final closure not before 2130. In order to comply with site licence conditions set by safety regulators, RWMD should act as both as a 'Capable Organisation' and as 'Design Authority'. This means that RWMD must have arrangements to learn from experience and to preserve design integrity, respectively [1, 2].

There is currently no requirement or formal process for RWMD employees to share expertise or pass on knowledge before they leave the organisation, and as this project is unique to the UK, the knowledge of individuals with many years experience is often irreplaceable. Without appropriate planning, this knowledge may be lost, leading to duplication of work and resulting in programme delays and increased costs.

For employees who are identified to have unique expertise or key knowledge of the GDF design, safety and operations, RWMD has used shadow working. This is not possible for all technical employees due to time and cost constraints. To address this issue, RWMD has adopted a 'Knowledge Harvesting' approach, derived from the Retention of Critical Knowledge (RoCK) Process in use at Sellafield Ltd., to capture knowledge from employees before they leave. To date this has been used to capture combined experience totaling more than 100 years.

Looking further ahead, it is essential to provide information that could be used to protect future generations who did not benefit from the processes that generated the waste, but who may live in proximity to the disposal location. This is based on the development of a dual track strategy of actively planned record transfers (generation to generation) and passive interpretation of archive materials and other markers (direct to a more distant future).

EXTERNAL REQUIREMENTS

In 2011, the Nuclear Decommissioning Authority corporate strategy [3] identified knowledge management and information management as critical enablers (i.e. critical for delivery of all nuclear decommissioning and disposal activities). In 2013, the NDA published its Information Governance Strategy [4], which sets out requirements for each Site Licence Company (SLC) to maintain and improve the confidentiality, integrity and accessibility of its information assets. The NDA Knowledge Management Roadmap [5] is a programme of work to support these strategies and includes:

- **Sharing Knowledge -** through creation of communities of practice and facilitating peer-to-peer collaboration and inter-project learning;
- **Managing Knowledge Risk -** identification of knowledge that is at risk; both collectively in teams, projects, departments, and as individuals where the risk is realised through staff moving jobs or retiring;
- **Knowledge Enablers -** including briefings, awareness, training, promoting and sharing good Knowledge Management (KM) practices, at this and subsequent conferences;
- **ICT Infrastructure -** including an NDA Knowledge Hub (an electronic 'portal') and an estate-wide search capability.

RWMD currently operates as a 'Prospective SLC' and in order to be granted a Site Licence it must act as GDF 'Design Authority' and formal process to understand and maintain design knowledge, integrity and accessibility throughout the full GDF lifecycle (see Figure 1) [1].

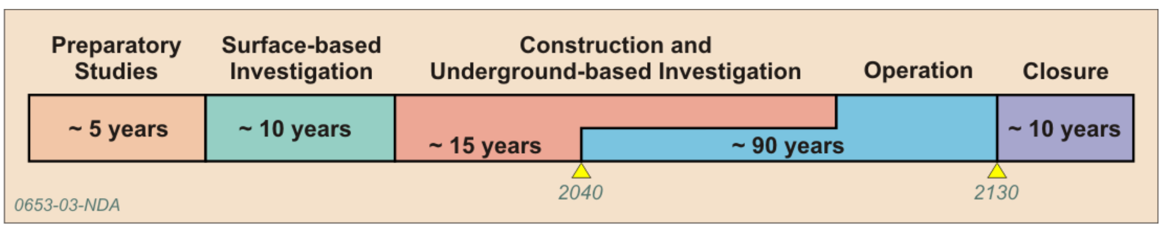

Figure 1 Lifecycle of a UK Geological Disposal Facility

This is also reflected in the following regulatory requirement [6]:

> *"The organisation needs to demonstrate to us that it is fully capable of assuring environmental safety by implementing a management system that includes … a commitment to continuous learning and proper arrangements for succession planning and knowledge management."* (Guidance on Requirements for Authorisation, 6.2.8)

As the GDF programme is funded in the public sector (i.e. by central Government), RWMD also has to comply with the UK Government requirement of fully 'collaborative 3D Building Information Modelling'. This requires all project and asset information, documentation and data to be held electronically by 2016 [7].

The engineering team at RWMD is developing its 'Building Information Modelling (BIM) environment' for the GDF design [8], which will address both regulatory and UK Government requirements for knowledge, information and data management. In order to foster a knowledge management culture, there must be a conscious desire to create, use, share and transfer knowledge using a combination of people, processes and tools. The next Section describes a practical trial to demonstrate the value of a knowledge management technique.

MAINTAINING EXPERTISE

In 2011, the RWMD initiated an exercise to identify whether it could manage knowledge risk by 'harvesting employee knowledge'. This was based on a process called 'Retention of Critical Knowledge' (RoCK), adopted by Sellafield Ltd to facilitate an employee sharing their knowledge before they leave the organisation. The approach utilized by RWMD is illustrated in Figure 2, which shows that as employees develop specialist expertise their knowledge and understanding becomes more vital to nuclear and environmental safety. The aim of this exercise was to codify expertise in an easily accessible form to: avoid unnecessarily repeating work; share and document the context of previous work, and; enable future work to be specified in an informed, structured manner.

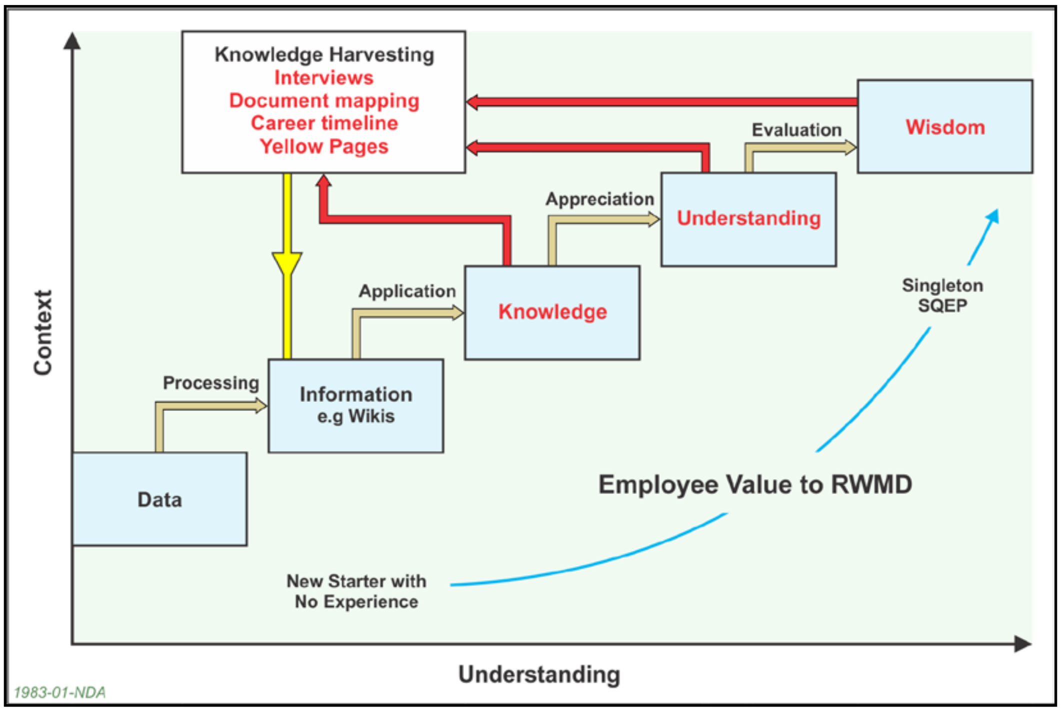

Figure 2 RWMD's 'knowledge harvesting' approach to managing knowledge risk

This knowledge harvesting approach is applicable when the time before an employee leaves is limited, or if shadow working is impracticable. The approach taken is outlined in Figure 3. After this initial trial, which was judged highly successful, the technique has been used more routinely in RWMD, especially where staff deemed to occupy 'singleton' Suitably Qualified and Experienced Person (SQEP) roles are due to retire or leave, potentially resulting in the loss of these skills and knowledge.

It is anticipated that information from the resulting transcripts could be maintained as a series of 'wiki' pages on the NDA's 'Knowledge Hub', which is intended to be a single point for retention and access of knowledge for the completion of the NDA mission. At some point in the future, these ‘wikis’ may become the front end to RWMD’s document management systems, providing the contextual information for published reports and work in progress. For example, the engineering wikis may become the collective home page, linked to the more detailed engineering ‘BIM environment’, which holds specific design data and information.

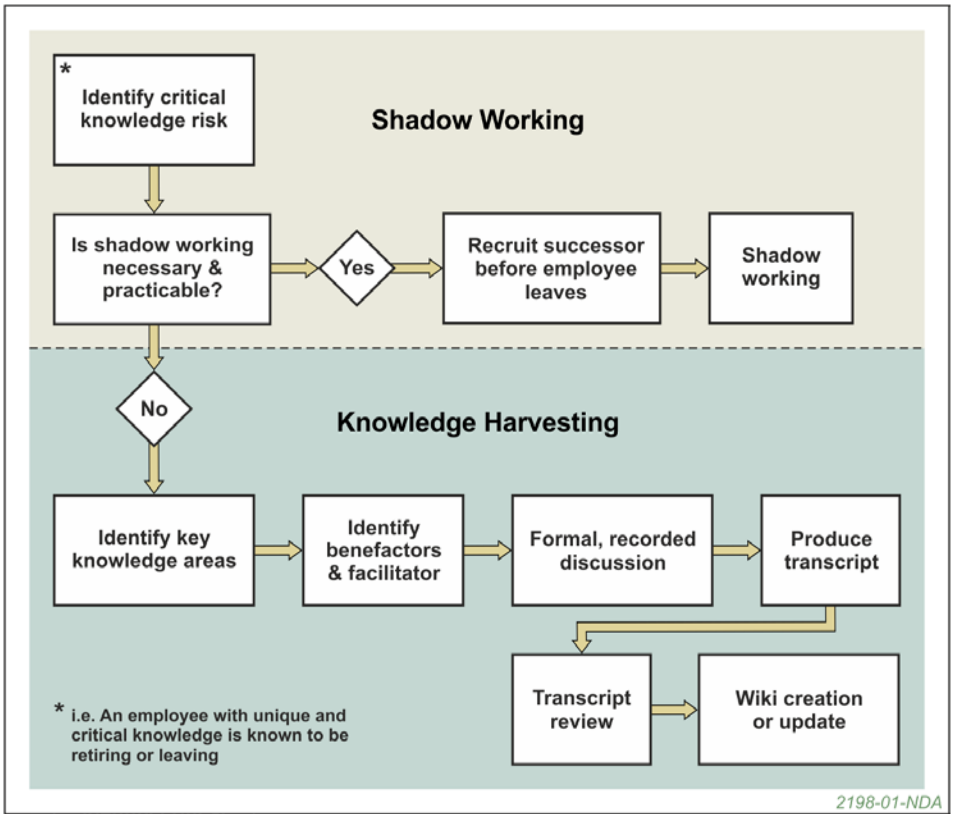

Figure 3 Outline of knowledge harvesting approach

Knowledge retention can be a significant challenge as technology changes. Even with fully recorded details the information often needs the unique experience of individuals to be useful. A recent example that came to light near the RWMD office in Oxfordshire involved a steam train preservation society. Although they had fully reconditioned the engine they did not have the experience to confidently and safely set up the valves and gauges that control the system, and were fortunate to identify a retired engineer who had done the job for years. Such ‘happy endings’ will not always be the case.

THE NEED FOR LONG-TERM RECORDS

The UK nuclear industry has a long and complex history, with its origins in the earliest academic research. After playing a key role in the Allied wartime efforts to develop nuclear weapons, subsequent research and reactor development was conducted independently, resulting in unique technologies based on a range of diverse designs. Applications of nuclear materials in the UK have covered military uses (weapons and submarines), power reactors (gas and water cooled), industrial and medical applications, and extensive academic interest. Each of these applications produces wastes that will need to be carefully managed through to disposal.

This diversity means that the history of the waste could not realistically be re-created by logical means, nor by comparison with other national nuclear programmes. Furthermore it is likely that the nuclear industry itself is likely to be 'transient', at least by comparison with fundamental and established industries such as agriculture, construction and manufacturing. Therefore it is vital that adequate records are prepared, to provide appropriate context for the nature and origin of the waste, and to support waste disposal.

UK NATIONAL ARCHIVE AND NUCLEAR RECORDS

The UK national archive is located at Kew in west London. It is open to the public, with free admission. The digital catalogue covers more than 11 million government documents, stretching back almost 1,000 years to the Domesday Book, originally produced in 1086. It received more than 600,000 original documents in 2010/11, and receives more than 100 million internet 'hits' per month. It is designed for the permanent retention and accessibility of public records. Specialist records are also held in other approved locations, defined as 'places of deposit', which are subject to the same controls and standards as the main archive.

Following creation of the Nuclear Decommissioning Authority (NDA) in 2005, a project was initiated to prepare for a dedicated archive, to be known as the National Nuclear Archive (NNA). This archive will serve the entire UK nuclear industry, from its initiation by statute in 1946, storing paper and microfilm records in a purpose-built facility located near Wick in Caithness, north-east Scotland. The NNA is designed with a total of 27km of shelf space, and will meet the environmental standards for temperature and humidity as defined in British Standard PD5454:2012 [9] and the archive conditions standards set by the National Archives. It has received designation as an approved 'place of deposit' from the national archive in Kew.

Financial and planning approvals have been obtained and the 'design and build' project is due to start in late 2013, with a planned opening date in 2016. The NNA is designed for 100+ years, and will be co-located with the North Highland local authority archive. Open public access will be provided for the North Highland archive but some of the nuclear archive material will be security controlled, and the design of the NNA provides for a clear division between the two archives. Access to records will be in-person or by digitized record, to be supplied on demand.

In common with other organizations, RWMD has identified that digital continuity is a very significant risk. For example, RWMD has recently had to employ experts to recover data and information from magnetic disks. There are numerous challenges in doing so, including identifying a device to read the media, fading magnetism, and software to interpret the data. In this context it is acknowledged that databases are particularly difficult to recover. A growing body of opinion suggests that anything identified as a vital record should have copies kept in three different forms: paper, digital and film.

CAUSES OF LOSS OF KNOWLEDGE – CASE STUDIES

A detailed study of conventional waste disposal sites that have operated over the last century [10], has shown that it is rare to lose all information about past practices, although the details tend to be lost first, and that once lost, records are very difficult to re-construct. It is clear that the failure to make primary records, or to keep them updated, is likely to result in the most rapid loss of memory. Other key factors identified in the study are the absence of a budget to cover the costs of record-keeping, and changes of personnel, especially where accompanied by poor handover arrangements. Both of these factors are likely to result in rapid loss of memory.

Although they occur more rarely, two other reasons that are considered to be particularly significant were identified: unlawful activities and societal discontinuities. The first involves the deliberate loss or destruction of records, usually motivated by the prospect of reducing financial liability. The second relates to major societal upheavals, such as war and the shift of national boundaries, which are likely to be accompanied by a transient change of priorities from professional responsibility to personal survival. The preliminary conclusions from the study are that there is a need for a culture and awareness of the importance of preservation of records and memory, and that replication of information, geographically and between disciplines, is important.

A further example that identifies the vulnerability of records to organisational change comes from the UK public library service [11]. Due to economic pressure and on-going decline in usage, many local libraries are threatened with closure, and are being offered to local communities. The implications are clear, with local records being dispersed to private ownership or even lost completely. These changes can occur rapidly, and without adequate consideration of the wider, long-term impacts.

MAKING SENSE OF THE PAST – PLANNING FOR THE FUTURE

On the basis that records can be lost, and that the more time that elapses since establishing the original record the more likely that loss is, it is necessary to consider a situation in which the records have actually been lost. It is not important to try to predict how or when this might occur, just to accept that it has. In this situation, future inhabitants of the region would not have the benefit of historic knowledge when considering whether to develop land or to explore the sub-surface for resources. It may also be reasonable to assume that these future inhabitants would not recognize messages produced using 21st century language, and may mis-interpret symbols and pictograms (cf. 20th century attempts to decipher ancient Egyptian hieroglyphics).

Archaeological evidence for the actions and lifestyles of humans on Earth extends for more than 5,000 years into the past. It can be assumed that our ancestors did not plan for the longevity of their structures or artifacts, but the materials they used, or the density of the human population at the time, coupled in many cases with favourable environmental conditions, led inevitably to their preservation. The purpose of the structures and the motivations of those who built or used them may be unclear, in whole or in part, but the key conclusion from the discoveries is that they are man-made. In this way it is possible for past civilizations to ‘speak’ directly to us today.

With this in mind it is possible to consider designing features to be associated with disposal facilities that will be recognised as man-made. Furthermore, by using resistant materials and insulating them from the weathering effect of the environment, there should be a reasonable degree of confidence that they will survive for very significant lengths of time. It may or may not be possible to convey a specific message about the nature of the disposal facility, but the fact that the feature is man-made would, on its own, be sufficient to allow future populations to explore the discovery in an informed manner, making suitable provision to protect individuals involved in any exploration.

It is clear that a buried structure containing radioactive waste will represent an anomaly in the environment. The original excavation and construction of the facility is likely to reduce the density of the rock volume, but increase its iron content (steel is a common material for waste containers). Therefore, in the long-term future, if records were to be lost, surface-based surveys may find clues to the existence of the waste disposal site without drilling or excavation. For example, surface-based surveys may detect gravitational and magnetic signatures. Such clues may provide a link to other evidence or provide input to anthropological theories, or they may inspire a search for any remaining records.

Geophysical surveys are commonly conducted using airborne detectors to cover large areas quickly. A useful response depends on host rock characteristics and the thickness of Quaternary deposits, and it is unlikely that shapes can be resolved. However, low density regions will be seen as cavities, and are likely to attract attention. Simple 2D models can be constructed to test the instrumented response from the use of today's technology. An example is presented in Figure 4, which shows that tunnel voids can be clearly detected at moderate depths. The sensitivity of this gravitational signature could be exploited to provide an enduring 'marker' to future surveyors, drawing attention to anomalies in the geology.

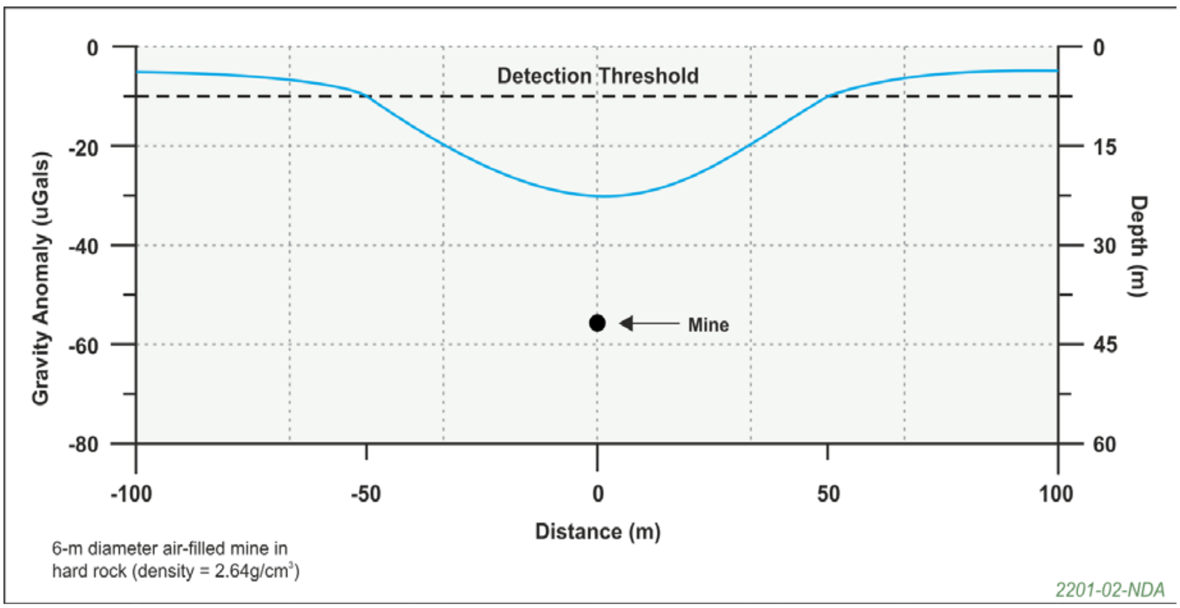

Figure 4 Modelled gravity survey

The detection of induced magnetic fields is a technique commonly used in geophysical surveys. Magnetic signatures may be particularly promising as a method to provide an enduring marker in the ground, because most waste packaging in the UK makes use of ferritic alloys, which would provide a detectable response at hundreds of metres depth. Taking this one step further, the burial of strong permanent magnets would provide a highly anomalous signal, which would provide a lasting reminder of the presence of the GDF while records remain, and would spark interest when detected at a later time in the absence of records.

The dimensions, profile and geographical extent of underground structures will be constrained by the inventory of wastes for disposal. The use of dense materials, especially cast iron and steel, will result in density differences and ensure induced magnetism, leading to potentially measurable responses from surveys. As noted above, the emplacement of strong permanent magnets with the radioactive wastes, perhaps at the outer limits of the facility, would ensure that its existence is detectable. These design-specific issues will be considered as the UK's GDF project progresses.

A similar approach that does not require instrumented surveying is the concept of 'self marking' sites. Residual surface features will leave scars on the landscape, and will represent visual clues to previous activity. Such features of a GDF may include bund walls built to preserve visual amenity, altered water courses or access routes for road and rail. There are many examples, scattered all over the world, where similar visual clues remain, pointing to human activities several thousands of years ago. A good example, showing ramparts and entrance ways, and preserved in the UK landscape for more than 2,500 years, is shown in Figure 5.

Figure 5 Aerial view of Maiden Castle in southern England

The detailed design of a GDF in the UK will not be progressed until a site and host rock has been identified. Conditions associated with building permission may constrain the restoration of the site at the end of its working life, although careful design and local negotiations may allow surface features to remain or to be adapted, for the key purpose of preserving knowledge of the site. With careful planning, it may be possible to engineer key surface features, designed to communicate that it was once operated as a major industrial site, into the design of new geological facilities.

In every case, whether above or below ground, the intent would not be to provide a detailed message, describing the full hazard, but to state clearly that the 'feature' was man-made. Once that was established, it would be reasonable to assume that any further investigation, including deep drilling or even excavation, would be undertaken in the context of deliberate intrusion. Such activities are undertaken today with application of appropriate safety precautions, such as blowout prevention and 'behind-the-bit' radiation monitoring. Thus the responsibility, or moral duty, to inform future site occupiers of the presence of a potential hazard would be satisfied.

SUMMARY AND CONCLUSIONS

A successful outcome to the implementation of a GDF programme in the UK will largely be determined by the application of good knowledge management practices over several generations. Thus, RWMD must continue to embrace the role of effective and sustainable knowledge and the need for it to be managed. This will require the vision and enthusiasm to develop and maintain the necessary culture. Knowledge harvesting is one example of a technique which can be used to facilitate the sharing and transfer of knowledge.

The preservation of long-term records, with appropriate contextual information, is an important element of safety for the geological disposal of radioactive wastes. Dedicated national archives can clearly play a role, but there is ample evidence that records can be lost, with causes ranging from withdrawal of funding to major societal discontinuities. Methods are being explored to determine whether it is possible to provide future generations with enough information to interpret a 'lost' facility as man-made, and then to proceed with caution as they undertake any subsequent exploration. These ideas represent emerging trends that will be further explored as the UK disposal programme evolves.

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