Nuclear
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NDA Report no. NDA/RWMD/013

Geological Disposal

Steps towards implementation

March 2010

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Executive summary

Introduction

Our Radioactive Waste Management Directorate (RWMD) is responsible for managing the delivery of geological disposal for higher activity radioactive wastes, as required under UK Government policy. This policy also states that the siting of a geological disposal facility will be based on a voluntarism and partnership approach.

In this summary of our published report (Geological Disposal – Steps towards implementation) we describe the preparatory work that we have undertaken so far, including the planning of our future work programme and the management arrangements to deliver it. This report is intended to provide information to a wide range of interested parties on the steps we believe will be required for successful implementation of geological disposal. It will also explain how the various activities and outputs of our work programme are designed to achieve a safe, secure, sustainable and publicly acceptable outcome.

As the development of the implementation programme is at an early stage there are inevitably many uncertainties; these are outlined in the report and explanations given of how they are accommodated in our planning. It will be some time before a site is selected, but while this is happening we need to develop plans, with the support of others, as to how we ultimately will deal with the waste and get it safely underground.

In this report, we consider what we currently know or those things we currently assume which are important in planning the development of a geological disposal facility, including in particular:

- the amount of radioactive waste requiring geological disposal;
- the types of rock that potentially could host a facility; and
- the potential geological disposal concepts.

The radioactive waste

Our first consideration is the amount of waste that needs disposal. The Managing Radioactive Waste Safely (MRWS) White Paper sets out what is known as the Baseline Inventory of the higher activity radioactive waste that is a legacy from nuclear activities that have been undertaken or committed to up to now. This includes radioactive materials which have not yet been classified as waste, such as spent nuclear fuel from power stations which has not been reprocessed; plutonium and uranium extracted from spent fuel that has been reprocessed; and uranium from the nuclear fuel manufacturing process.

A programme to build new nuclear power stations would produce more waste for disposal. The Government believes it is technically possible and desirable to dispose of both new and legacy wastes in the same geological disposal facilities. We have carried out technical assessments of the disposability of the new wastes that would be produced that support this view.

The geology

Based on the research that we and others have undertaken in the past three decades or so, we believe that there is geology in the UK that is suitable to host a geological disposal facility. For our preparatory work we have considered three broad (generic) host-rock types. This helps us explore potential conceptual designs for a facility in any of these rock types.

These rock types are:

Higher strength rocks: These rocks, for example granite, themselves generally have a very low permeability to water flow so that any water flow that does occur is in open cracks, or fractures, that have formed in the rock mass. This type of rock is planned to be used in Finland and Sweden at the sites chosen for their geological disposal facilities for spent nuclear fuel.

Lower strength sedimentary rocks: These rocks are generally physically uniform and any flow of water occurs through the overall rock mass. The Swiss Opalinus Clay geological disposal concept is designed for this type of rock.

Evaporites: These rocks, for example rock salt, may contain water that has been trapped within them ever since they were formed, but they are isolated from water flow that could dissolve them. In the USA this type of rock is used for the Waste Isolation Pilot Plant, where waste has been disposed of for more than a decade, in New Mexico; Germany has also developed a concept for this type of rock.

Multi-barrier approach to geological disposal

A range of generic geological disposal concepts is available that can provide safe and secure geological disposal of higher activity wastes for each of the potentially suitable UK geological settings identified above. Typically a different range of disposal concepts needs to be considered in relation to different geological settings. However, each concept will utilise a ‘multi barrier’ approach.

This approach involves engineered and natural barriers working together to prevent radioactivity being released to the surface in amounts that could cause harm to life and the environment. It works as follows:

The waste form: This is the form into which the waste is conditioned to make it suitable for disposal. This form might be chosen so that it is very resistant to the leaching of radionuclides by groundwater, as in the example of converting high-level waste into a glass waste form.

The waste container: The conditioned waste is placed in a container, creating what is referred to as the waste package. The container is constructed to have sufficient strength and corrosion resistance that the waste will be safely contained during its initial, interim storage and its eventual transport to the geological disposal facility and transfer underground. The material and design of the container can be chosen to subsequently provide reliable physical containment under disposal conditions for extended periods of time.

The buffer or backfill: When waste packages have been placed underground in a disposal facility, at an appropriate stage according to the design and taking account of societal considerations of retrievability, they will be surrounded with buffer or backfill materials. In addition to providing physical support for the waste packages, the buffer or backfill can be designed to provide qualities such as physical and/or chemical protection of the waste container, and physical and/or chemical controls on the migration of radionuclides away from the waste packages.

Mass backfill: In addition to the buffer or backfill around the waste containers, all access tunnels and shafts will be filled in with mass backfill, prior to closure of the facility. The mass backfill might simply be required to ensure other engineered barriers are retained in place but could also be designed to control groundwater flow.

Sealing Systems: Engineered seals will be used to prevent the flow of fluids in the excavated tunnels. Seals may also be used where appropriate on parts of the rock that are more permeable.

Geology: The rock formations themselves will act as a barrier in a number of ways that could include limiting the flow of groundwater or of any gas released from the waste packages, limiting the movement of radionuclides towards the ground surface, and protecting the wastes deep underground from extreme changes (human or natural) that may take place on the Earth's surface.

Phases of work in our programme for implementing a geological disposal facility

We have defined a number of phases in our programme of work for successful implementation of a geological disposal facility that run from its initial planning through to its closure and beyond. The earlier phases are aligned to the stages of the site selection process set out in the UK Government's MRWS White Paper.

Preparatory Studies Phase: This is the current phase of our work and it coincides with the UK Government's MRWS Stages 1 to 4 of the site selection process. Purely as a planning assumption we assume that this phase will be about five years in duration. Our work supports the UK Government and communities who have expressed an interest in participating in the site selection process. We are developing conceptual facility designs and the safety and environmental assessments for those designs. Areas deemed unsuitable following screening by the British Geological Survey will be ruled out during this phase. Communities with potentially suitable sites may opt to move to a decision to participate in the site selection process although they will continue to have a right of withdrawal until construction is about to begin, just before the construction and underground investigations stage. On behalf of the UK Government, we will work with the communities who take a decision to participate to undertake desk-based studies of any candidate sites identified in their areas. The studies will inform decisions about proceeding to the next stage in the site selection process.

Surface Based Investigations Phase: This phase of our work coincides with the UK Government’s MRWS Stage 5 of the site selection process. If communities decide to proceed, the UK Government will agree candidate sites for surface-based investigations. At this time we will need to obtain the necessary environmental permits and planning permission to carry out borehole drilling to investigate the geology more closely. A monitoring programme for the geology during the entire life of the project will also be established at this time. We currently assume this phase will take about ten years to complete and ultimately will help inform UK Government's decision on a preferred site. We will work closely during this phase with the Community Siting Partnership that the UK Government expects will be set up in communities who take a decision to participate.

Construction and Underground Based Investigations Phase: This phase will begin once the UK Government has decided on a preferred site in accordance with the MRWS process. This phase of our work coincides with the beginning of UK Government’s MRWS Stage 6 of the site selection process. For planning purposes we assume that this decision could be made around 2025 and is fully dependant on the outcome of discussions between the UK Government and the local community. Following this, we will seek planning and regulatory permissions. Procurement and contractual arrangements for construction of the facility will be finalised. We will undertake long-term investigations from underground to confirm the site is suitable. We will work closely with the regulators and once planning permission is given, construction and investigations from underground will begin. Tunnels and vaults for the waste will be excavated and surface facilities built. If UK Government and the

regulators have been satisfied that the programme should proceed following the underground-based investigations, the required permissions and authorisations will be sought to operate the disposal facility. We currently assume that this phase will take about 15 years to complete.

Operation Phase: For planning purposes this phase is assumed to begin around 2040. It would continue until all the waste designated for disposal in the facility had been placed underground, assuming that the UK Government and regulators remained satisfied with the safety of the disposal facility and in particular that it would provide a sufficient level of containment. There will be a rigorous system of checking all waste packages sent to the facility for disposal. The system for transporting radioactive wastes from the sites where it is stored to the disposal facility will be developed to minimise potential environmental impacts and will be designed to operate in a safe and efficient manner.

Closure Phase: The decision on when to close the facility after all of the waste has been placed underground for final disposal will take into consideration the views of the local community. Leading up to closure of the underground facilities, disposal vaults and deposition tunnels will have been backfilled, the underground openings sealed and the access ways backfilled and closed. It is anticipated this step will take about ten years. Records from the geological disposal facility will be placed in a national archive and any permanent marking for the site will be agreed by the UK Government, the regulators and the local community. A period of post-closure monitoring could be undertaken by the authority responsible for institutional control of the site.

Schedule for gaining permissions

We are working with the UK Government and regulators to develop a schedule that is consistent with the policy commitments set out in the MRWS White Paper. Currently the schedule describes the proposed process that we plan to follow when the time comes to seek the required permissions, rather than being a timetable for such applications to be submitted.

Engaging and communicating with the public and stakeholders

We cannot do this alone. The implementation of the geological disposal programme will proceed in partnership with other organisations. Amongst the most important of these are UK Government, local decision making bodies, Community Siting Partnership, regulatory bodies and current and prospective waste producers.

Our work involves sharing information and learning through feedback we receive from others. Following consultations, we have developed and published a public and stakeholder engagement strategy that outlines the aims and objectives of the strategy and how we propose to engage and communicate with stakeholders about our work programme on geological disposal.

Costs

The current estimate of the NDA's share of the cost for the geological disposal programme for currently identified wastes and spent fuel is £3.7 billion using the UK Government's discounting method, or about £12 billion without discounting. We have estimated a further cost of about £2 billion, without discounting, for the inclusion of existing stocks of separated plutonium and uranium if it were required to dispose of these materials.

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1 Introduction

The Nuclear Decommissioning Authority (NDA) has established the Radioactive Waste Management Directorate (RWMD) to manage the delivery of geological disposal for higher activity wastes, as required under UK Government policy published in the Managing Radioactive Waste Safely (MRWS) White Paper (Ref. 1). The purpose of this report is to describe the preparatory work that we in RWMD are undertaking in planning our future work programme and the management arrangements that we will need to deliver that programme.

We hope that this report will provide useful information for a wide range of stakeholders and interested individuals. We have tried to write the report so that the reader will not require a detailed knowledge of the science and technology of radioactive waste management. We want to explain the current status of our planning for geological disposal and how the various activities and outputs of our work programme are designed to achieve a safe, secure, sustainable and publicly acceptable outcome. As the development of the implementation programme is at a very early stage there are inevitably many uncertainties; these are outlined in the report and explanations are given of how we deal with them in our planning.

As the implementation programme progresses some of the uncertainties that we have to deal with will be resolved and our planning will not rely so heavily on assumptions such as we have to make at present. Therefore we expect to publish new versions of this report at appropriate points in the programme to reflect significant developments in the status of our planning as firmer information becomes available and key decisions are made.

This approach was set out in Paragraph 4.17 of the MRWS White Paper (Ref. 1):

"During the course of 2008-9, the NDA will undertake early planning for the implementation of a geological disposal facility. This will include provision for a staged implementation approach, with clear decision points, that allows design and development, cost, affordability and value for money, safety, and environmental and sustainability impacts to be reviewed at the end of each stage before a decision to move on to the next stage is agreed with Government. This planning will be progressively refined and costed as the implementation programme proceeds."

This report describes how the early planning has progressed since publication of the MRWS White Paper. In particular we want to explain how we plan to support the MRWS site selection process, how we plan to develop into an effective delivery organisation and how technical activities and supporting research are likely to be progressed. This report is not intended to present a plan for implementing geological disposal, however we are progressing the development of provisional implementation plans for our internal use in managing the geological disposal programme.

UK Government policy is that geological disposal is the way higher activity radioactive waste will be managed in the long term: this will be preceded by safe and secure interim storage until a geological disposal facility can receive waste. The NDA also has responsibility for the safe and secure storage of its waste. This responsibility is discharged by other parts of the NDA and is not discussed in this report. In our work we do take full account of storage arrangements for higher activity wastes and also try to ensure optimised solutions for the management of higher activity wastes and nuclear materials through coordination with the relevant activities in the NDA's work programme.

The definition of geological disposal given by the UK Government's advisory Committee on Radioactive Waste Management (CoRWM) in its recommendations to UK Government in 2006 (Ref. 2) has been followed through in the UK Government response to those recommendations (Ref. 3) and in the MRWS White Paper. This is "*burial underground (200-1,000m) of radioactive waste in a purpose built facility with no intention to retrieve*…." This definition applies to all references to geological disposal made in this report.

In the MRWS White Paper, the UK Government considers the issue of retrievability of waste in a geological disposal facility. It notes that decisions about whether or not to keep a facility (or vaults within it) open once operations cease can be made at a later date in discussion with the regulators and local communities and that in the meantime the planning, design and construction of a facility can be carried out in such a way that the option of retrievability is not excluded. This is taken into account in the planning outlined in this report.

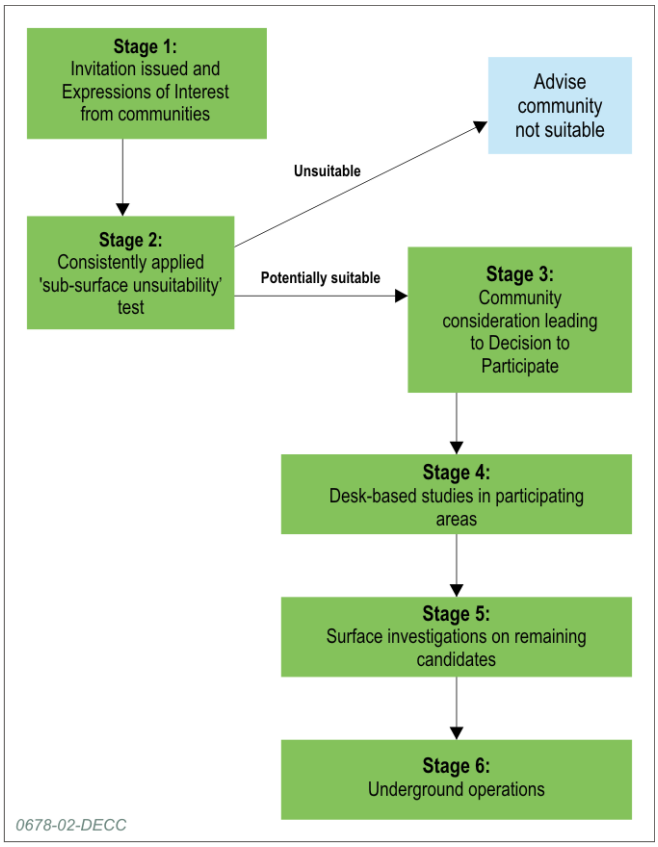
Prior to issuing the MRWS White Paper the UK Government consulted on its framework for implementing geological disposal. Following this, the Government set out that it remained of the view that it formed in responding to CoRWM's 2006 recommendations, that geological disposal and an approach based on voluntarism and partnership as a means of siting a facility is the right way forward. The MRWS White Paper states that during the early stages of the process there will be two key local decision points, defined in the White Paper as:

- Expression of Interest – the decision point at which local communities register their without commitment interest in discussions with the UK Government about potential involvement in the siting process.
- Decision to Participate – the decision point at which a Decision Making Body (ies) makes a formal commitment to participate in the geological disposal facility siting process, but without commitment to host the facility.

The MRWS White Paper sets out that the site selection process will be conducted in parallel with discussions between the UK Government, the NDA and a local community from the point at which a community has made an Expression of Interest to open up discussions with the UK Government. The invitation to make an Expression of Interest was included in the MRWS White Paper. The MRWS site selection process will progress in stages, allowing all those involved to take stock before deciding whether or not to move to the next stage at a particular site. It is represented diagrammatically in Figure 1.1.

Overall both the policy and the process are markedly different from those pursued previously. The policy covers all higher activity wastes and nuclear materials potentially requiring geological disposal, rather than just one category of wastes (intermediate-level waste). The siting process now rests on decisions on involvement and participation by local communities, rather than on the generation of siting proposals by a waste management organisation acting in concert with central Government.

Figure 1.1: Stages in the MRWS site selection process



As noted in the MRWS White Paper, the NDA has established a new Radioactive Waste Management Directorate (RWMD), incorporating expertise and information from the former United Kingdom Nirex Limited, which it will develop into an effective delivery organisation for geological disposal. In due course, ownership of the organisation could then be opened up to competition in line with the arrangements for operators of NDA sites. For the remainder of this report RWMD and its possible successor organisations will be referred to as “we” and the use of “NDA” will refer to the Nuclear Decommissioning Authority as a whole, being the organisation which has responsibility for managing the UK’s civil nuclear legacy and that owns much of the legacy higher activity waste in the UK.

Our stated mission is, “To deliver a geological disposal facility and provide radioactive waste management solutions.” Our objectives are as follows:

- Engage with national and local governments and communities to identify a geological disposal facility site.
- Develop the specification, design, safety case and environmental and sustainability assessments for the disposal system and obtain regulatory support.
- In conjunction with waste producers, identify and deliver solutions to optimise the management of higher activity waste.
- Develop and maintain an effective organisation and secure resources to deliver the geological disposal facility programme.

- Obtain and maintain stakeholder support for our activities.
- Deliver a focused R&D programme to support geological disposal and optimised packaging solutions.
- Seek sustainable, innovative and cost effective solutions that have public support and are in the best interest of the UK.

This report explains how we are delivering these objectives at the current stage of our programme.

We will work with a number of organisations to implement geological disposal. This is recognised in relevant parts of the report but the work of these organisations is not presented in detail. Paragraph 2.3 of the MRWS White Paper identifies the key roles and responsibilities for implementing geological disposal as follows:

- Government is responsible for the policy, will take final decisions and engage with stakeholders to ensure that the objectives of the MRWS programme are met.
- The NDA is the implementing organisation, responsible for planning and delivering the geological disposal facility and, as part of this process, will engage with communities and other stakeholders. NDA already provides interim storage of waste on its sites and will continue to do so for as long as it takes to site and construct a geological disposal facility. The NDA will also undertake a programme of research and development to support optimised delivery of geological disposal and interim storage.
- Communities with a potential interest in hosting a geological disposal facility will have the opportunity to work with the NDA and others in a partnership approach during the process.
- Local government will be fully engaged in a partnership approach and will play a part in local decision-making during the site selection process.
- Independent regulators will ensure robust, independent regulation in relation to statutory responsibilities for ensuring that national, European Union and international safety, security and environmental legislation and standards are met.
- Committee on Radioactive Waste Management (CoRWM) will provide independent scrutiny and advice to Government on the plans and programmes for delivering geological disposal including interim storage.

Currently the UK Government Department having responsibility for policy is the Department for Environment and Climate Change (DECC).

The MRWS White Paper envisages that communities and local government will engage with the site selection process through a Community Siting Partnership (CSP). Following Expressions of Interest by local authorities in the area, a West Cumbria MRWS Partnership has been established to lead its local community engagement with the siting process. If the process continues in this area to the later stage of identifying one or more

candidate sites for assessment, it is envisaged that a CSP will be established and be central to the agreement of such sites with DECC.

For reasons explained later in this report there are now, and will remain for some time, significant uncertainty about the final waste inventory that will require geological disposal. Paragraph 3.22 of the MRWS White Paper recognises that mechanisms will have to be agreed for updating the disposal inventory in discussion with local communities as the programme proceeds. We expect this to be an important area for early engagement between a CSP and DECC, where we would provide technical information and advice as appropriate.

2 Scope

The next sections of the report describe:

- the radioactive wastes and materials that may require geological disposal;
- geological settings that are potentially suitable to host a geological disposal facility;
- the development of a range of geological disposal concepts that would be appropriate for the disposal of the different types of radioactive wastes and materials in the various types of rock considered suitable;
- the use of a reference case as a basis for planning assumptions and as a benchmark for provision of information;
- the phases of work comprising our overall geological disposal programme;
- how we identify and aim to meet the relevant regulatory requirements;
- the main organisations that we will work with to deliver geological disposal and the nature of our relationships with those organisations;
- how we communicate and engage with the public and stakeholders, and how we aim to develop this part of our programme; and
- the costs of geological disposal.

Section 5 of the report describes how we are using a subset of the range of geological disposal concepts that we are investigating to provide the basis for assessments of the safety of a geological disposal facility during its construction and operation and in the long-term, after its closure. We use the same subset of concepts as the basis for assessments of the potential environmental, social and economic impacts of developing a facility and for assessments of the costs of its development, construction, operation and closure.

The current use of reference concepts as a planning basis for project costs, resource requirements and programming is explained in Section 6. The main assumptions behind the lifetime cost figures presented in NDA's Annual Report and Accounts (Ref. 4) are discussed to allow the figures to be put in context.

The report also explains (in Section 9) the links between these activities and the assessments of the disposability of higher activity wastes conducted by RWMD in support of the retrieval, conditioning and packaging of wastes by waste producers; this includes discussion of the implications of potential new nuclear build.

In Section 7 there is a more detailed explanation of the activities that we believe will be required over the next few years, covering site assessments and preparations for surface-based site investigations, with a high level description of subsequent activities. The report also outlines, in Section 7, our plans to develop into the organisation responsible for the delivery of the geological disposal facility, as required in the MRWS White Paper.

In parallel with this report we are working on more detailed plans to inform the decisions that have to be made by the UK Government and the NDA on funding the geological disposal programme.

3 Waste inventory

The MRWS White Paper defines the radioactive wastes to be managed in the long-term through geological disposal as those that:

- cannot be managed under the Policy for the Long-term Management of Solid Low Level Radioactive Waste (LLW) in the United Kingdom (Ref. 5) - the "LLW Policy"; and
- are not managed under the Scottish government's developing policy for higher activity waste, currently interim, near-surface, near-site storage.

This higher activity waste comprises principally high-level waste (HLW) and intermediate-level waste (ILW) and includes also the small fraction of LLW that cannot be managed under the LLW Policy. The MRWS White Paper gives definitions and descriptions of these categories of wastes. Fuller descriptions and an account of the processes that generate the wastes can be found in Reference 6.

Figure 3.1: Typical items of low-level waste

Figure 3.2: Steel drum of cement-encapsulated intermediate-level waste

Figure 3.3: Vitrified high-level waste

In addition to these wastes, there are some radioactive materials that are not currently classified as waste, but may need to be managed through geological disposal if they came to be considered as waste in the future. These include spent fuel discharged from nuclear power reactors that is not currently destined to be reprocessed to extract uranium and plutonium; plutonium separated from spent fuel that has been reprocessed; and separated uranium that comes mainly from the manufacture of nuclear fuel and from the reprocessing of spent fuel.

Information on the sources, quantities and properties of UK radioactive waste holdings is published in the UK Radioactive Waste Inventory (UKRWI), which is currently updated every three years. The latest version (the "2007 UKRWI") for a waste holdings stock date of 1 April 2007 was published jointly by the Department of the Environment, Food and Rural Affairs (Defra) and NDA in June 2008 (Ref. 7). For the first time this version contains information on radioactive materials not currently classified as waste, but some of which could come to be considered as waste in the future.

The Baseline Inventory of higher activity wastes for geological disposal comprises the total amounts of the relevant radioactive wastes and other materials that could, possibly come to be regarded as waste in the future. It was developed using information from the 2007 UKRWI and published in the MRWS White Paper, as shown in Table 3.1 below.

Table 3.1: The MRWS White Paper Baseline Inventory

Materials	Notes	Packaged volume		Radioactivity (At 1 April 2040)	
		Cubic Metres	%	Terabequerels	%
HLW	1, 2, 3, 5	1,400	0.3%	36,000,000	41.3%
ILW	1, 2, 5	364,000	76.3%	2,200,000	2.5%
LLW (not for LLWR)	1, 2, 5	17,000	3.6%	<100	0.0%
Spent nuclear fuel	1, 4, 5	11,200	2.3%	45,000,000	51.6%
Plutonium	1, 4, 5	3,300	0.7%	4,000,000	4.6%
Uranium	1, 4, 5	80,000	16.8%	3,000	0.0%
Total		**476,900**	**100**	**87,200,000**	**100**

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Notes:

1. Quantities of radioactive materials and wastes are consistent with the 2007 UK Radioactive Waste Inventory.

2. Packaging assumptions for HLW, ILW and LLW not suitable for disposal at the existing low-level waste repository (LLWR) are taken from the 2007 UKRWI. Note that they may change in the future.

3. The HLW packaged volume may increase when the facility for disposing the canisters, in which the vitrified HLW is currently stored, has been implemented.

4. Packaging assumptions for plutonium, uranium and spent nuclear fuel are taken from the 2005 CoRWM Baseline Inventory (Ref. 8). Note that they may change in the future.

5. Radioactive data for wastes and materials was derived using the 2007 UK Radioactive Waste Inventory. 2040 is the assumed start date for the geological disposal facility.

6. It should be noted that at present the Baseline Inventory is based on UK Inventory figures, and as such, currently contains waste expected to be managed under the Scottish government's policy of interim near-surface, near-site storage as announced on 25 June 2007 (Ref. 9)

The UK Government's policy (paragraph 3.8 in the MRWS White Paper) is that, pending a decision whether the radioactive materials included in the Baseline Inventory should be declared as waste, we will factor their possible inclusion into the design and development of the geological disposal facility. Therefore we use for planning purposes the Baseline Inventory as the basis for developing a disposal system specification and, in turn, geological disposal facility engineering designs that meet this specification. These facility designs in turn provide the basis for assessments of the associated safety and environmental, social and economic impacts and for assessments of costs.

We recognise that the higher-activity wastes to be managed in the long term through geological disposal will exclude any that are managed under the Scottish government's policy for higher-activity waste. However, as noted in the MRWS White Paper, these wastes are included in the Baseline Inventory and we are using that as the basis for our disposal system specification, design and assessment work.

There are further sources of uncertainty in the eventual inventory requiring geological disposal which are also covered by our work programme. These include uncertainties in the volumes and radionuclide contents of the currently identified wastes and materials in the Baseline Inventory and uncertainties in scenarios for the future operation of the nuclear plants that produce these wastes and materials. We must also consider the possible inclusion of spent fuel, plutonium and uranium owned by the Ministry of Defence that are not currently within the Baseline Inventory.

We can create a range of scenarios for the inventory of wastes that may require geological disposal in order to evaluate the implications of these uncertainties for the geological disposal programme. In particular we have developed an "Upper Inventory" to give an indication of the quantities that might need disposal. We want to be able to demonstrate that a geological disposal facility can be developed to deal with this inventory safely and securely in addition to being confident that the same will be true for a lesser inventory. The Upper Inventory also provides visibility to local communities that are considering participation in the site selection process of what might be involved in hosting a geological disposal facility.

3.1 Waste from new nuclear power stations

The Baseline Inventory does not include radioactive waste arising from proposed new nuclear build in the UK. The volume of such waste produced would depend on factors such as the reactor type, number of new reactors and their operational life. The UK Government considers that it would be technically possible, and desirable, to dispose of any waste arising from new nuclear build in a geological disposal facility alongside legacy waste and has committed to exploring this through the MRWS process.

We do not know the amounts of higher activity wastes that new build may produce. In order to deal with this uncertainty we include a contribution of wastes from new build in the Upper Inventory. This is so that we can assess the implications of wastes from this source on geological disposal. In particular we want to be able to understand the relationship between the amounts and nature of such wastes and the implications for the size and design of a geological disposal facility and for the level of safety and environmental protection provided by the facility.

Through the Generic Design Assessment process the nuclear regulators will assess the safety, security and environmental impact of power station designs, including the quantities and types of waste (gaseous, liquid and solid) that are likely to arise, their suitability for storage and their disposability. We have contributed to this process by

assessing the disposability of higher activity wastes (where higher activity wastes include spent nuclear fuel in the event that it came to be declared as a waste) that may arise from new nuclear build against geological disposal facility design and safety considerations. We have completed assessments for the wastes from two designs of reactors proposed by so-called “requesting parties”:

- the EPR (European Pressurised Water Reactor) proposed for the UK by EdF and AREVA, who are jointly acting as a requesting party (Ref. 10);

- the AP-1000 (Advanced Pressurised Water Reactor) proposed by Westinghouse Electric Company LLC (Ref. 11).

We have concluded that compared with legacy waste and existing spent fuel, no new issues arise that challenge the fundamental disposability of the wastes and spent fuel expected to arise from operation of both designs of reactor. Fuel from new reactor designs will be subject to higher “burn-up” than in existing UK reactors. This refers to the extraction of more energy from the same amount of fuel, with the result that the spent fuel is hotter and more radioactive. Our disposability assessments show that spent fuel with such characteristics can be accommodated without adverse effects on the safety of a suitably designed geological disposal facility.

The costs of geological disposal are discussed in Section 11, but it is important to note that we also work out the cost impact of accommodating new build wastes and provide UK Government with the information it requires to ensure that new build will pay its full share.

4 Geology

The range of geological settings that could be suitable for hosting a geological disposal facility for higher-activity radioactive wastes in the UK is wide and diverse. UK Government policy is that the siting process for a geological disposal facility will be based upon voluntarism and partnership. This means that any geological settings available for the disposal facility will depend on the locations of sites identified through discussions with local communities involved in the process.

Until such time as more specific information becomes available, the approach that we will take is to define a limited number of generic geological settings, encompassing typical, potentially suitable UK geologies. We are adopting this approach to provide a manageable number of engineering design case studies and associated assessments of safety and environmental, social and economic impacts and assessments of the costs to develop a facility. In particular we want to be able to show the viability of disposal of the UK's higher activity wastes in a range of geological settings; we are developing a Generic Disposal System Safety Case and Generic Strategic Environmental Assessment that will present our assessments, which are discussed further in Section 7.

The geological settings that we have defined are based on consideration of the host rock formation (where the disposal areas will be developed) and the cover rocks (the geological formations that occur between the disposal areas and the ground surface). At this stage in our programme we are using only coarse descriptions to distinguish different geological settings. As information becomes available on candidate sites, at the appropriate stages in the site selection process we will take into account more specific information on the geological and hydrogeological characteristics that will be necessary for the design and safety case for the geological disposal facility. We have chosen the mechanical strength of the rock as the main distinguishing characteristic at this stage as, along with the wastes requiring disposal, this has the most influence on the conceptual design of the facility. This enables us to describe realistic concepts as examples of how geological disposal could be implemented in each of these generic settings. The cover rocks are very important in restricting the movement of radionuclides in groundwater out of the disposal facility, potentially towards the surface environment, so cover rocks are included in these coarse descriptions.

The use of generic geological settings does not imply that any specific sites are being considered. The host rock descriptions correspond to three distinct general rock types that are considered potentially suitable to host a disposal facility for higher activity wastes, based on studies carried out in the UK and internationally, and which occur in the UK. They are described as follows:

- Higher strength rocks - these would typically comprise crystalline igneous, metamorphic rocks or geologically older sedimentary rocks, where any fluid movement is predominantly through divisions in the rock, often referred to as discontinuities. Granite is a good example of a rock that would fall in this category.
- Lower strength sedimentary rocks - these would typically comprise geologically younger sedimentary rocks where any fluid movement is predominantly through the rock mass itself. Many types of clay are good examples of this category of rocks.

- Evaporites - these would typically comprise anhydrite (anhydrous calcium sulphate), halite (rock salt) or other evaporites that result from the evaporation of water from water bodies containing dissolved salts.

As a relatively simple explanation of the terms used in these descriptions, most bodies of rock are not physically uniform (or continuous), but contain features such as pores or fractures which resulted from the processes that first formed the rocks and, thereafter, from the response of the rocks to various geological events. We call features such as fractures, discontinuities.

In the absence of discontinuities, higher strength rocks typically have a very low permeability to water flow. However, fractures may be present which, depending on their properties, will allow water to flow more readily, and so the main water movement is expected to be through these discontinuities rather than through the more uniform rock, or “rock matrix”.

In lower strength sedimentary rocks, discontinuities are typically in the form of pores which are relatively small in length and in aperture, and are evenly distributed through the rock matrix. In this case the discontinuities do not represent a separate, easier path for water flow and flow occurs through the uniform arrangement of particles of rock and the pores between them.

Evaporites often contain water that was present at the time of their formation, but this is trapped between the evaporite rock crystals. Evaporite rocks have been stable over geological timescales and, in the absence of major geological changes, are effectively isolated from flowing groundwater that would cause them to dissolve. Therefore groundwater flow is not expected to occur through evaporites. Any flows of other fluids, such as gas or any pressurised, trapped water from the time of the rock’s formation, would require fissures to open up within the evaporite, which could then create groundwater flow pathways.

The covering rocks included in the generic geological settings are:

- Host rocks to surface - this means that the geological formation that comprises the host rock extends from the level of waste emplacement to the ground surface.
- Sedimentary cover rocks - this means that there is a sequence of sedimentary rocks overlying the host rock formation that have characteristics different from those of the host rock formation.

The combinations of host and cover rocks that are considered are summarised in Table 4.1.

Table 4.1: Host and cover rocks

		Host Rocks		
		Higher strength rocks	Lower strength Sedimentary rocks	Evaporites
Cover rocks	Host rocks to surface	Possible	Possible	Not possible
	Sedimentary cover rocks	Possible	Possible	Possible

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The setting of evaporite host rocks extending to the surface does not exist in the UK. The rainfall that we receive is sufficient to ensure that rocks near the surface will be saturated with groundwater. Evaporites would dissolve under these circumstances. In the UK, for evaporites to persist and therefore be considered a potentially suitable host rock for geological disposal of radioactive wastes they must be separated from the circulating groundwater system close to the surface, typically by a cover rock having low permeability to groundwater flow.

5 Geological disposal concepts

Selecting the most appropriate method for implementing geological disposal will require us to carry out assessments and make decisions at different levels of detail. At the current stage of the programme our work is focused on analysing and developing potentially suitable geological disposal concepts. At later stages we will develop design solutions to implement the concept or concepts that are then being considered.

As described later in this report, once specific candidate sites have been identified, we will gather information on each site. This will enable us to identify and assess the possible range of geological disposal concepts, taking account of the waste inventory for disposal, which could be implemented at the site. In this way we aim to support a well-informed selection of the concept or concepts that will be carried forward in the work programme for the site. As the geological disposal programme progresses we will move from high-level decisions on the concepts to be considered, to concept-specific and design decisions on the range of materials to be considered and, eventually, to decisions on the designs and materials to be used. Therefore we can only make meaningful selections of concepts and design components when we have sufficient site-specific information.

A range of generic geological disposal concepts, being studied and developed in the UK and internationally, could provide safe and secure geological disposal of higher activity wastes for each of the potentially suitable UK geological settings identified in Section 4. Typically a different range of disposal concepts needs to be considered in relation to each different geological setting.

Previously a subset of internationally available geological disposal concepts was used to demonstrate the general viability of geological disposal of radioactive wastes in the UK (Ref. 12). In addition some specific disposal concepts have been worked up in more detail to support the development of waste package specifications and the assessment of the disposability of waste packages that would be produced as a result of proposals put forward by waste owners (Ref. 13).

Work that we carried out in 2008 identified a range of possible concepts for geological disposal of ILW/LLW (Ref. 14), and of HLW and spent fuel (Ref. 15), effectively providing us with a catalogue of concepts for consideration. The work drew on previous work in the UK, and disposal programmes in other countries, to identify disposal concepts for generic geological settings (host rock formations and associated geological and hydrogeological conditions).

At the current stage of the programme we are examining a wide range of potentially suitable disposal concepts so that a well-informed assessment of options can be carried out at appropriate decision points in the implementation programme. Drawing from this work we have set out illustrative concepts for each of the three generic geological settings, including the associated variants on overlying rocks.

We are using these illustrative concepts to:

- further develop our understanding of the functional and technical requirements of the disposal system;
- further develop our understanding of the design requirements;
- support the scoping and assessment of the safety, environmental, social and economic impacts of a geological disposal facility;

- support development and prioritisation of our R&D programme;
- underpin our analysis of the potential cost of geological disposal; and
- support assessment of the disposability of waste packages proposed by waste owners.

We have set out the illustrative concepts solely for these purposes. We do not intend that one of these illustrative concepts is necessarily the one that we would use in the relevant geological setting. At this stage, no geological disposal concept has been ruled out.

We selected the illustrative geological disposal concepts following consideration of the concepts identified in the studies of disposal concepts for ILW/LLW (Ref. 14) and for HLW and spent fuel (Ref. 15). We selected concepts that are well-developed and supported by extensive research and development, allow for ease of retrieval, and have been subject to detailed safety assessment, regulatory scrutiny and international review (Ref. 16). Currently we assume that the disposal concepts for ILW/LLW will be potentially suitable for the geological disposal of uranium residues in the Baseline Inventory and that the disposal concepts for HLW and spent fuel will be potentially suitable for the geological disposal of the separated plutonium and highly enriched uranium in the Baseline Inventory.

The illustrative concepts are listed in Table 5.1 and the attached notes present the key reasons why these examples were selected. The key features of each of these examples are shown in Figures 5.1 – 5.5.

Table 5.1: Illustrative disposal concept examples

Host rock	Illustrative Geological Disposal Concept Examples	
	ILW/LLW	HLW/SF
Higher strength rocks[a]	UK ILW/LLW Concept *(NDA, UK)*	KBS-3V Concept *(SKB, Sweden)*
Lower strength sedimentary rock[b]	Opalinus Clay Concept *(Nagra, Switzerland)*	Opalinus Clay Concept *(Nagra, Switzerland)*
Evaporites[c]	WIPP Bedded Salt Concept *(US-DOE, USA)*	Gorleben Salt Dome Concept *(DBE-Technology, Germany)*

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Notes:

(a) Higher strength rocks – the UK ILW/LLW concept and KBS-3V concept for spent fuel were selected due to the availability of information on these concepts for the UK context.

(b) Lower strength sedimentary rocks – the Opalinus Clay concept for disposal of long-lived ILW, HLW and spent fuel was selected because a recent OECD Nuclear Energy Agency review regarded the Nagra (Switzerland) assessment of the concept as state of the art with respect to the level of knowledge available. However, it should be noted that there is similarly extensive information available for a concept that has been developed for implementation in Callovo Oxfordian Clay by Andra (France), and which has also been accorded strong endorsement from international peer review. Although we will use the Opalinus Clay concept as the basis of the illustrative example, we will also draw on information from the Andra programme. In addition, we will draw on information from the Belgian super container concept, based on disposal of HLW and spent fuel in Boom Clay.

(c) Evaporites – the concept for the disposal of transuranic wastes (TRU) (long-lived ILW) in a bedded salt host rock at the Waste Isolation Pilot Plant (WIPP) in New Mexico, USA was selected because of the wealth of information available from this licensed, operating facility. The concept for disposal of HLW and spent fuel in a salt dome host rock developed by DBE Technology (Germany) was selected due to the level of concept information available.

5.1 Multi-barrier containment

All of these illustrative concepts are based on the principle of multiple barrier containment of the radioactivity in the wastes. This involves developing a combination of engineered barriers that will complement the natural barrier provided by the geology at the site. These barriers are designed to have properties that will ensure that the radioactivity in the wastes is sufficiently contained so that it will not be released back to the surface in unacceptable amounts that may cause harm to people and the environment. There are common features to the multiple barrier systems in these illustrative concepts, which can be described as follows:

The waste form: This is the form into which the waste is conditioned to make it suitable for disposal. This form might be chosen so that it is very resistant to the leaching of radionuclides by groundwater, as in the example of converting HLW into a glass waste form.

The waste container: The conditioned waste is placed in a container (sometimes called a canister), creating what is referred to as the waste package. The container must be chosen so that the waste can be safely transported and handled leading up to its disposal. The material and design of the container can be chosen to then provide reliable physical containment under disposal conditions for extended periods of time. This can be achieved in a variety of ways, for example, in the case of metallic containers, by using a metal such as copper that is highly corrosion-resistant under certain chemical conditions or by using sufficient thickness of a metal such as carbon steel so that it will take a long time to be corroded through.

The buffer or backfill: The buffer or backfill in this context refers to material that is placed immediately around emplaced waste containers in a disposal facility. The material and design can be chosen so that the buffer or backfill provides one or more beneficial functions. For example it can be used to control the chemistry of any groundwater that may eventually contact the wastes so that radionuclides are not very soluble in the water, as in the case of cement-based buffers or backfills.

Mass backfill: In addition to buffer or backfill to be placed immediately around the waste containers, other types of “mass backfill” will be required to fill excavated access tunnels, shafts or drifts. Again the material and design can be chosen so that the backfill provides one or more beneficial functions, for example sufficient mechanical strength to ensure other components of the barrier system are retained.

Sealing systems: Complementing the mass backfill, sealing systems will be required to control the movement of fluids along previously excavated access tunnels, shafts or drifts and through any part of the rock walls in these excavations that are more permeable to groundwater flow, for example as a result of the underground engineering work. Typically very low permeability materials are considered when developing designs of sealing systems.

Geology: The geological barrier can provide one or more helpful functions in ensuring the safety of disposal. These include:

- limiting the flow of groundwater into the waste disposal areas (through low permeability of the rock) so that there is limited potential for the leaching of radionuclides from the wastes;
- providing a long, slow flow path for groundwater to travel from the emplaced wastes to the surface environment so that radioactivity will have decayed away sufficiently that it cannot reach the surface in harmful quantities;
- providing rock surfaces that will remove radionuclides from solution in groundwater by naturally-occurring beneficial chemical processes;
- providing dead-end fractures or pores where groundwater containing radionuclides will effectively be stagnant;
- preventing the direct release to the surface environment of any gas generated from the wastes; and
- protecting the emplaced wastes from extreme changes that may take place at the Earth's surface, as a result either of natural causes, as in the example of glaciations, or of human actions.

In the case of the geological barrier, we will only know which safety functions we can rely upon when we have conducted investigations at a candidate site.

Figure 5.1 shows the multiple barrier containment system of the UK Geological Disposal Concept for ILW/LLW, employing cementitious materials as waste encapsulants and vault backfill.

Figure 5.1: UK geological disposal concept for intermediate level waste / low level waste

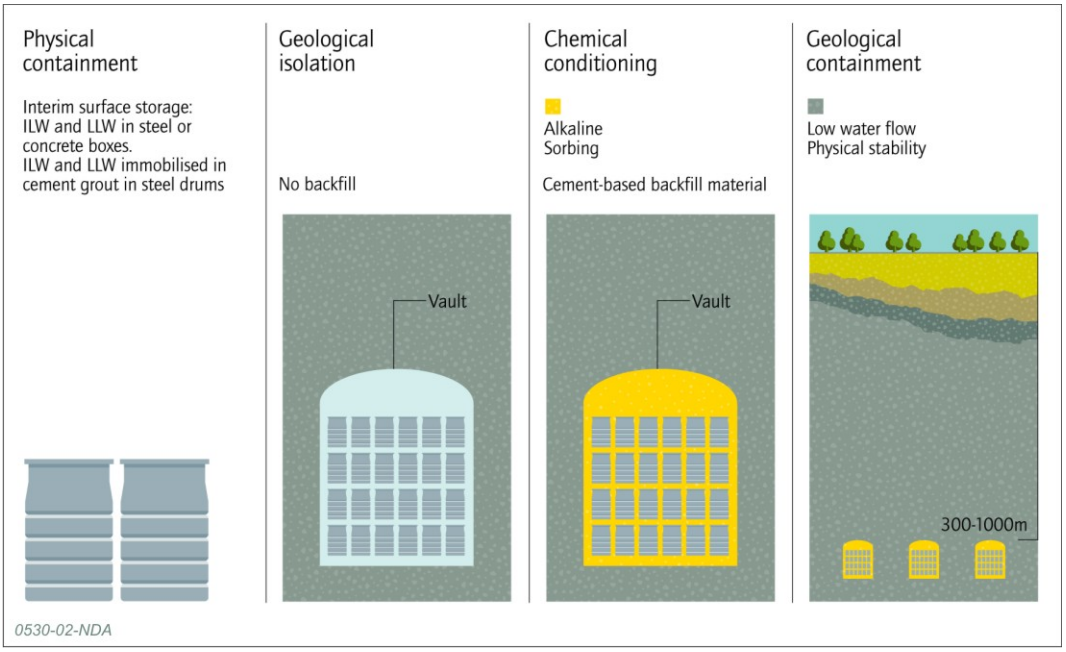


Figure 5.2 shows the key features of the KBS-3V disposal concept developed by SKB (Sweden) and Posiva Oy (Finland) for spent fuel, adapted to the disposal of vitrified HLW and spent fuel in the UK context, employing a cast iron supported copper disposal container and bentonite clay buffer.

Figure 5.2: KBS-3V disposal concept

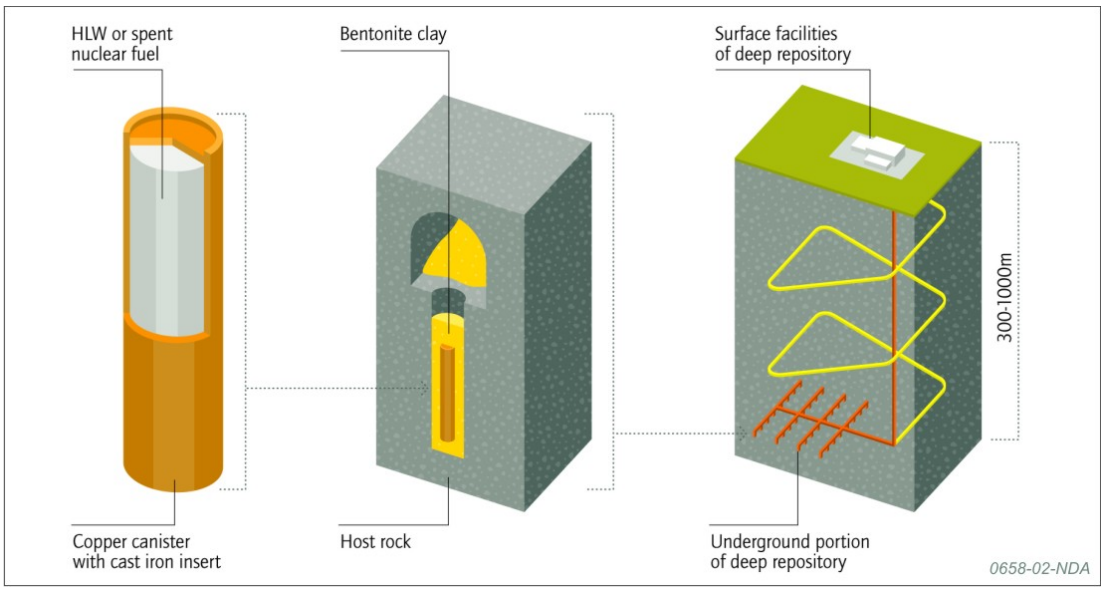


Figure 5.3 shows key features of the Nagra (Switzerland) concept for the co-located disposal concepts in Opalinus Clay host rock for vitrified HLW and spent fuel and for ILW. The HLW/SF disposal concept involves the emplacement of steel waste containers surrounded by bentonite clay buffer in horizontal tunnels. The ILW disposal concept involves the use of cementitious waste encapsulants and vault backfill ("mortar"), and shotcrete lining as support for the vaults.

Figure 5.3: Opalinus clay co-located disposal concepts

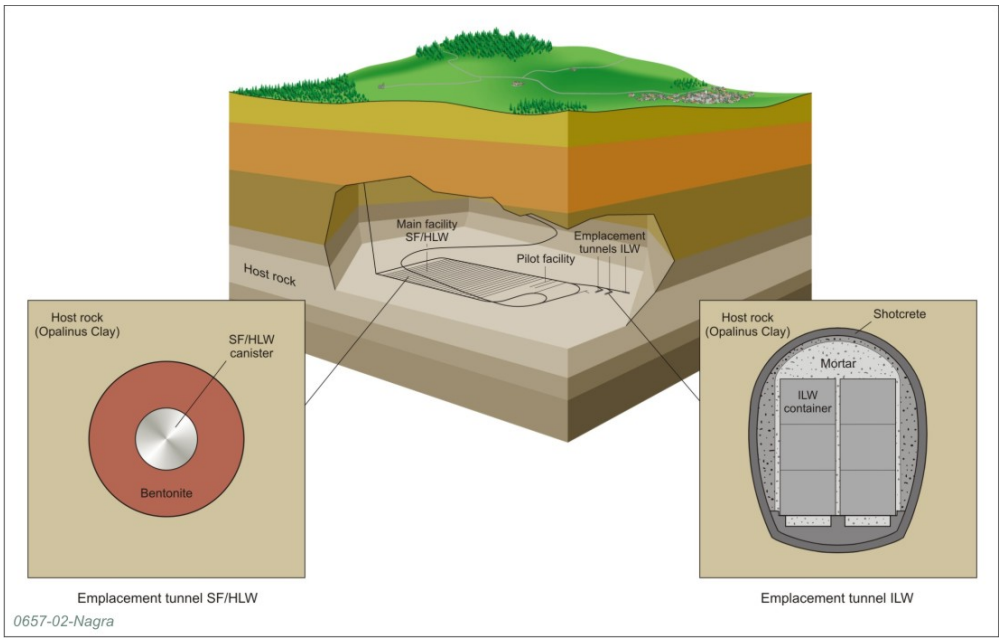


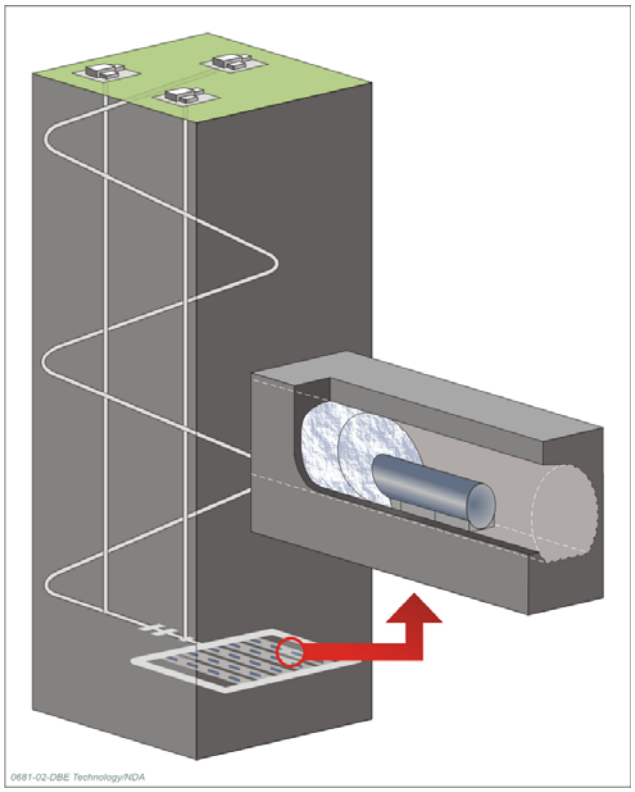
Figure 5.4 shows the disposal of Transuranic wastes (long-lived ILW) in the bedded salt host rock of the US-DoE Waste Isolation Pilot Plant (WIPP), New Mexico, USA, which typically does not require waste encapsulant material and uses bags of magnesium oxide

as a chemical buffer. The safety concept is based in part on enclosure of the waste and buffer in the naturally-converging salt.

Figure 5.4: US-DoE Waste Isolation Pilot Plant (WIPP)

Figure 5.5 shows the schematic illustration of one of two alternative concepts for the disposal of vitrified HLW and spent fuel in a salt dome, developed by DBE Technology (Germany). In view of the limited depth of evaporite formations in the UK, the concept based on emplacement in horizontal tunnels is used as an illustrative example. In this concept, the spaces around the emplaced steel waste containers are backfilled with crushed salt and the safety concept is based in part on the enclosure of the waste in the naturally-converging salt.

Figure 5.5: Salt dome disposal concept for vitrified HLW and spent fuel



In our work to evaluate these illustrative concepts we have adapted them to the UK context. In particular we have developed conceptual designs that are scaled for the UK Baseline Inventory and key concept issues have been interpreted for UK-specific factors. As part of our evaluation work we undertake post-closure safety assessments; in these assessments we take into consideration the impact of ranges of different flow characteristics in the host rock and the variability in possible overlying geological formations.

In addition to scaling the illustrative conceptual designs for the Baseline Inventory, we are also developing and evaluating conceptual designs that could accommodate the possible additional wastes and materials identified in Section 3. In this way, the range of possible combinations of waste inventory and geological setting will be covered by our work programme.

6 Reference case programme

A number of uncertainties are inevitably present at this early stage of the planning process, some of which have been outlined in preceding sections, involving the nature and quantities of the wastes for disposal, the geological setting and, related to this, facility design. Other important areas of uncertainty involve the time required for deliberations to enable key decisions to be made, for example decisions by local communities at key stages of the site selection process or decisions by regulatory bodies variously on land-use planning, health and safety, or environmental protection matters.

In order to be able to plan and to provide certain sorts of information in light of this level of uncertainty we have developed a reference case programme. This programme provides both a basis for our planning and a framework for formal and transparent control of significant changes to the programme as it evolves. We also use the reference case programme to support the information on implementation of geological disposal that we provide to UK Government and other interested parties.

The reference case programme has been developed in respect of implementing a geological disposal facility for the Baseline Inventory. It is based on locating the facility in a higher strength host rock since we have access to reliable and detailed information on what would be entailed in developing the facility in such rock from the former United Kingdom Nirex Limited programme. It assumes a depth of disposal of 650 metres below ground level since that allows us to use the information on timings and costs that was previously generated by Nirex for developing a facility at this depth. By making assumptions such as this we have developed a reference conceptual design of a geological disposal facility, which provides the basis for our estimations of timings and costs of the various activities that we would carry out to implement a facility. To complete the information we need to develop a reference case programme, we also make assumptions, based on analysis of precedents in the UK and internationally, about the durations of less technological aspects such as the various decision-making processes. All this information is recorded in more detail in our developing provisional implementation plans.

We use the reference case programme and its underpinning information and assumptions for planning and benchmarking purposes. In developing the reference case programme we are not seeking to present what we think will happen or what we want to happen. Therefore the technical work programme will not be focussed solely on the science and technology associated with the reference case programme. More generally, we will seek to maintain awareness of all the relevant uncertainties and the way in which they will change or be eliminated as successive decisions are made in the national programme.

6.1 Reference conceptual design

The reference case programme currently used for planning purposes is based on the assumption of a single geological disposal facility to accommodate all the wastes and materials in the Baseline Inventory. In such a “co-located” disposal facility there would be two distinct excavated disposal areas, separated by an appropriate distance, one for ILW, LLW and uranium residues, and the other for HLW, spent fuel, plutonium and highly-enriched uranium. The disposal operations would share surface facilities, access tunnels, construction support and security provision. This is in line with the statement made in paragraph 4.25 of the MRWS White Paper that *“in principle the UK Government sees no case for having separate facilities if one facility can be developed to provide suitable safe*

containment for the Baseline Inventory." Since we take into account the need to prevent deleterious interactions between the different types of wastes and engineered barriers in such a facility, we believe that this represents a demanding scenario and therefore a good benchmark for what needs to be considered at the current stage of the implementation programme.

We maintain an exchange of information with the national programmes in countries such as France and Switzerland where plans for co-located disposal of similar wastes are well advanced. However, it is recognised that, as stated in the MRWS White Paper, *"the final decision would be made in the light of the latest technical and scientific information, international best practice and site-specific environmental, social, economic and safety and security assessments"*, so the possibility that more than one facility would be required is recognised.

The reference conceptual design uses the illustrative disposal concept examples for higher strength rocks described in Section 5, comprising:

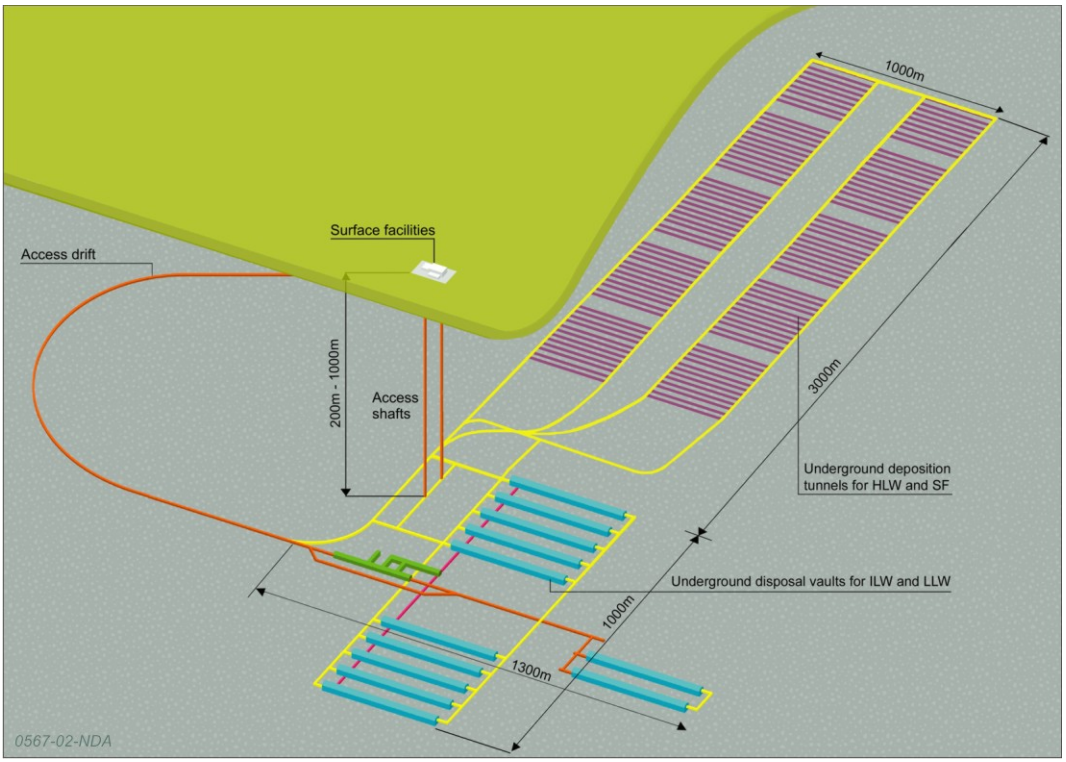
- the concept previously developed in the UK for ILW/LLW disposal; and
- the "KBS-3V" disposal concept developed in Sweden and Finland for the disposal of spent fuel.

These concepts were selected because of the level of knowledge and experience arising from the evaluations of conceptual designs developed for the UK waste inventory. For much of the period from about 1980 to 2001 the focus of the UK programme was on ILW and LLW, leading to the development of the UK geological disposal concept for these wastes. In this period there was effectively a watching brief being maintained on the concepts being developed in other countries for the geological disposal of HLW and/or spent fuel. The MRWS programme, initiated in 2001, covered all higher activity radioactive waste and hence it was necessary to assimilate the work on HLW and spent fuel to test the viability of their geological disposal in the UK. The KBS-3V concept was chosen as the benchmark for this test since it was, and still is, being carried forward in two countries, Sweden and Finland, where it has been subject to independent regulatory scrutiny and extensive international peer review.

Therefore there is confidence in using these concepts as a basis for planning. However, as noted in Section 5, work is in hand to develop conceptual designs and evaluations for concept examples appropriate to other host rock types so that confidence in these will be increased.

Figure 6.1 shows a stylised layout of a co-located disposal facility based on these two concepts, with all disposals at approximately the same depth and with physical separation between the underground area containing disposal vaults for ILW, LLW and uranium and that containing disposal tunnels and deposition holes for HLW, spent fuel, plutonium and highly enriched uranium. However, it is recognised that the disposal areas could be at different depths.

Figure 6.1: Schematic representation of a generic co-located geological disposal facility



The way wastes are prepared for disposal, including their packaging, is important in determining the numbers and characteristics of the disposal packages and, from that information, the volume that the wastes will occupy when placed in a disposal facility. The reference conceptual design adopts the packaging arrangements identified for ILW and LLW in the 2007 UKRWI, in line with the definition of the Baseline Inventory in the MRWS White Paper. The packaging assumptions for spent fuel, plutonium and uranium are those identified in the MRWS White Paper definition of the Baseline Inventory. In the reference case for vitrified HLW, the waste in its stainless steel storage container is assumed to be placed inside a cast-iron supported copper container, as appropriate to the KBS-3V disposal concept.

6.2 Interim surface storage and timing for disposal

The timing of the disposal programme is of course very important for planning, not only for us but also for the organisations having responsibility for the wastes held in interim storage and for communities affected by the management arrangements for the wastes. The durations of each of the stages leading up to the start of disposal operations identified in the MRWS White Paper can be estimated using information on the processes that are to be followed, combined with experience on technical aspects such as geological investigations drawn from the previous UK programme and from equivalent programmes in other countries. Waste holders are currently assuming that a geological disposal facility will be available to receive ILW and LLW in 2040 and HLW and spent fuel in 2075. It is recognised that the basis for the MRWS site selection process is voluntarism and partnership and consequently the process is driven in large part by discussions with local communities. Furthermore all those involved to take stock before deciding whether or not to move to the next stage at a particular site. Therefore this date, like all other

aspects of the reference case programme, must not be seen as fixed, but rather a reasonable basis for planning based on current assumptions.

The timing of the receipt of wastes at the disposal facility is based on information in the plans of the waste holders, for example the Lifetime Plans of Site Licence Companies responsible for decommissioning and clean-up at sites within the NDA estate where wastes are stored or will be produced in the future. There is considerable scope for refining the plans and close cooperation with the waste holders is envisaged in this area of planning.

6.3 Disposability assessments and costing studies

As part of the regulatory arrangements for the management of higher activity wastes, we provide assessments of the disposability of proposed waste packages, as described in Section 9.3.2. We use our reference conceptual design in the development of waste package specifications and disposability assessments However, we also look to ensure robustness of our specifications and assessments to the implications of an alternative concept being adopted. This involves ensuring that all waste packages compliant with the requirements of the reference conceptual design would be similarly compliant with alternatives. Examples of the assessments conducted in relation to this include:

- ensuring that the dimensions and weights of packages would be consistent with the range of excavation dimensions and waste-handling equipment associated with alternative disposal concepts and different geological settings;

- ensuring that the radiation or heat emitted from waste packages would not compromise the safe operation of the facility or long-term safety functions of the engineered and natural barriers associated with alternative concepts; and

- ensuring that the long-term safety of disposal of the wastes is not dependent on some special feature of the reference conceptual design that would not be present in alternative concepts.

We also ensure that we understand the differences in costs that would be associated with implementing a different concept from that in the reference case and these differences are included in the “parametric cost model” that we have developed and which is described in Section 11.

6.4 Generic transport system

Once a geological disposal facility is constructed and regulatory authorisation has been given to accept wastes for disposal, waste will need to be transported safely and securely to the facility from the sites where it is being stored. We have developed a generic transport system design that would meet these requirements.

International standards and guidance for the safe transport of radioactive materials have been developed on the basis of world-wide experience and best practice. This experience is distilled into the International Atomic Energy Agency (IAEA) Transport Regulations (Ref. 17), which apply to road, rail, sea and air transport of radioactive materials. We have developed a concept for a national transport system to transport safely, securely and efficiently, in compliance with the IAEA Transport Regulations, all the UK's higher activity wastes from the sites where they are held to a geological disposal facility site. This concept includes the specification of a range of transport packages[i] and vehicle types, as well as transport operation logistics. Key aspects are:

- development of designs and specifications for standard waste containers and specifications for their allowable contents;
- conceptual designs for a range of reusable shielded transport containers for the transport of unshielded waste packages requiring shielding to protect the public and/or workers from external radiation;
- development of realistic transport routes and logistics for a national transport system including all nuclear licensed sites holding higher activity wastes and any one notional destination; and
- development of designs for rail wagons, road vehicles and associated transport equipment.

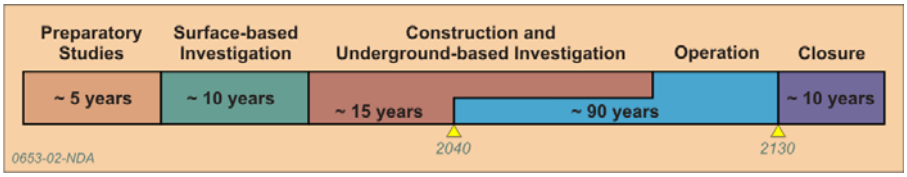
[i] The term transport package is used to describe the form in which a waste package is transported. It will sometimes be necessary for a waste package to be placed within a transport container, in which case the waste package and transport container comprise the transport package.

7 Phases of work in the Geological Disposal Programme

The lifecycle of the Geological Disposal Programme can be described for planning purposes as five phases, as shown in the stylised programme in Figure 7.1.

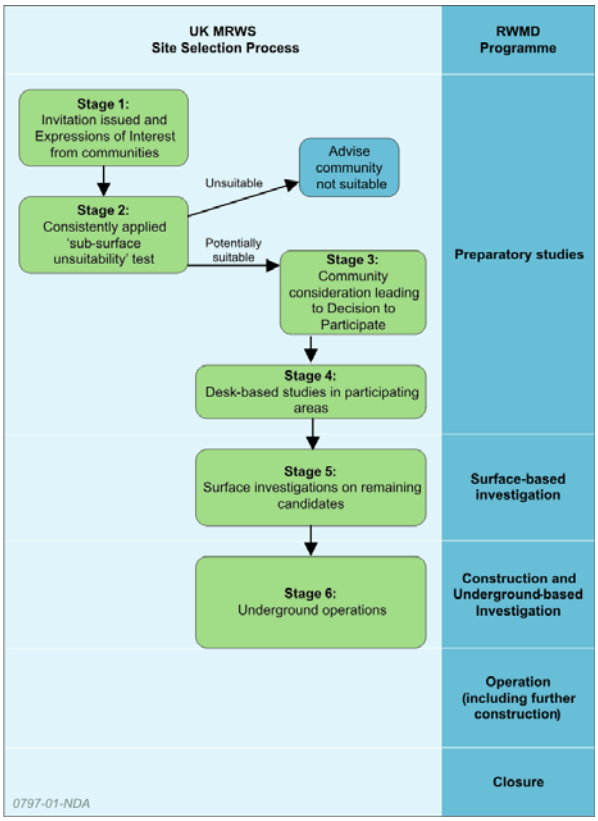
The overlapping Construction and Underground-Based Investigation and Operation Phases will almost certainly represent a high proportion of the overall programme timeline, but the figure is purely illustrative and the relative proportions of time shown for each phase do not reflect our planning assumptions. Our planning assumptions about the duration of each phase, leading to first emplacement of ILW in 2040 and first emplacement of HLW in 2075 (as discussed in Section 6), are shown in the figure.

Figure 7.1 Geological Disposal Programme timeline indicating phases



As noted in the introduction, the MRWS site selection process defined by the Government in the MRWS White Paper is based on a staged decision-making process, comprising six stages in total, which will allow local decision making bodies to decide whether to proceed to the next stage and the UK Government to determine whether it is satisfied that the programme should be allowed to progress through from one stage to the next. Figure 7.2 shows how the phases that we are using in planning the implementation of geological disposal relate to the stages of the MRWS site selection process.

Figure 7.2 Relationship between programme phases and stages of the MRWS site selection process.



In the following sub-sections we describe our work programme as we currently envisage it during each of these phases.

7.1 Preparatory Studies Phase

The Preparatory Studies Phase comprises our work during the first four stages of the MRWS site selection process. These first four stages are repeated here for reference:

- Stage 1: Expression of interest, corresponding to the period up to the point where a community decides to open up without commitment discussions with the Government;
- Stage 2: Initial screening out of unsuitable areas using sub-surface screening criteria described in the MRWS White Paper, applied by the British Geological Survey;
- Stage 3: Community consideration leading to Decision to Participate following which it is expected that a formal Community Siting Partnership will be set up as described in the MRWS White Paper; and
- Stage 4: Desk-based studies in participating areas.

Participating communities whose areas have not been screened out by the application of sub-surface criteria (Stage 2), and who wish to continue their involvement by making a decision to participate (Stage 3), will be carried forward to Stage 4, desk-based studies.

If large areas are considered as potentially suitable, local partners could, at the start of Stage 4, undertake a preliminary review of their areas to identify potential candidate sites. We are currently considering how we might support the local partners in this event, for example by gathering data or providing relevant information, if they would find that helpful.

Stage 4 of the site selection process will involve us in undertaking assessments focusing on the specific site or sites once these are identified. These assessments will involve gathering all available, relevant information about the candidate communities and sites and evaluating that information using the criteria and process to be defined by the UK Government for the site selection process. In response to a request from the UK Government, we have developed criteria and proposals for the approach to be used in Stage 4 of the site selection process (Ref. 18) which we will further consult on and develop in the light of stakeholders' views. The final criteria are likely to require information to be collected on a wide range of characteristics including geology, natural environment, landscape, specially designated natural and architectural features, transport infrastructure and socio-economic conditions. This illustrative listing is not intended to be exhaustive and we will work with local communities to ensure that local issues are addressed in the assessments.

Assessments will be scrutinised by the independent regulators (who are identified in Section 8) and by the Government's advisory committee, CoRWM. Following completion of these assessments and associated reviews, and of any additional work that organisations required us to undertake to inform their respective deliberations:

- the Community Siting Partnership would make recommendations to local Decision Making Bodies about whether to proceed to the next stage of the site assessment process;

- the Decision Making Bodies would decide whether to proceed to the next stage of the site assessment process; and
- the UK Government would then decide on one or more candidate sites to take forward to surface-based investigations in the subsequent Stage 5 of the site assessment process.

7.1.1 Work programme in the Preparatory Studies Phase

Our work programme for the Preparatory Studies Phase currently includes:

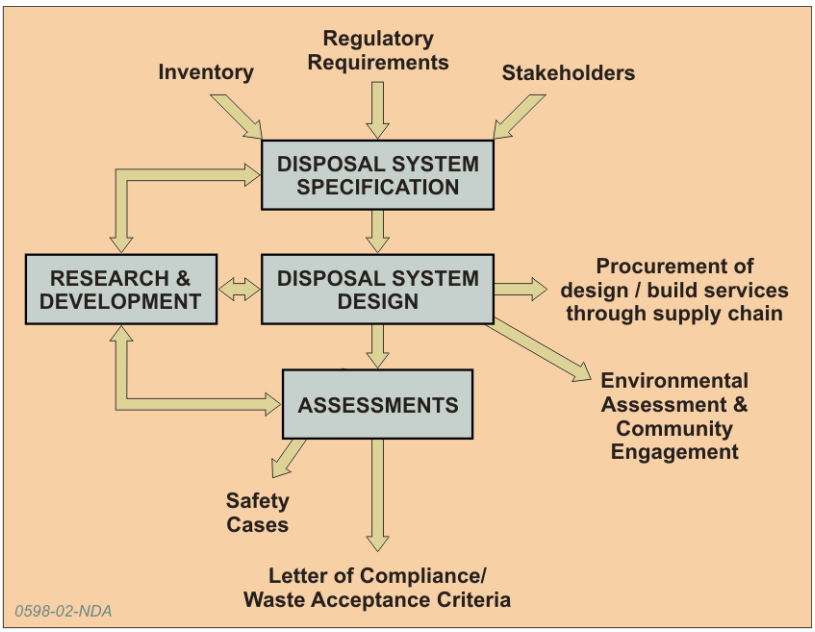
- Supporting the UK Government's and communities' activities within the MRWS programme.
- Development and optimisation of geological disposal facility and transport system designs: work will move on to the development and assessment of site-specific geological disposal concepts and designs when candidate sites have been identified.
- Development of a peer-reviewed generic Disposal System Safety Case (DSSC) by September 2010 and subsequent development and maintenance of the safety case.
- Making ready to support Stage 4 of the MRWS site selection process by September 2010 [ii] including support, if required, to the identification of potential, candidate sites within larger areas and desk-based studies of candidate sites.
- Development of the MRWS site assessment process: progress will be dependent on engagement with regional and national stakeholders and local communities and the suitability of the potential areas. We will work in partnership with the local communities to ensure their issues and concerns are addressed.
- The commissioning of supporting research and development (R&D) to resolve generic issues: this has involved developing an intensified R&D programme to address uncertainties in the DSSC (including issues associated with new build wastes) and engineering design of a geological disposal facility.
- Determining the implications for the MRWS programme should the additional wastes and materials (such as those from new nuclear power stations and used fuels from the Ministry of Defence) be include within the Baseline Inventory.
- Development of RWMD into a "prospective Site Licence Company (SLC)", and further organisational developments thereafter.

[ii] This date was the earliest we could envisage following publication of the MRWS White Paper and we made preparations accordingly; it does not imply that we are expecting a local community to make a Decision to Participate by then.

- Continued application of the “Letter of Compliance (LoC) assessment process”: through which we will continue to provide the nuclear industry with advice on the packaging of radioactive waste and materials.
- Public and stakeholder engagement.
- Environmental assessment (including a generic Strategic Environmental Assessment (SEA) and Sustainability Appraisal).
- Development of plans for surface-based investigation of candidate sites in Stage 5 of the MRWS site selection process.
- Continued engagement with the regulators. More details are given in sections 8 and 9.3.2 on the work that we are doing to support this engagement process.
- Working with other parts of the NDA assisting with related strategic priorities.

The work programme delivers the information needed for the process of iterative development of a geological disposal system, which is illustrated in Figure 7.3. This shows how identified requirements and constraints are used to develop a disposal system specification. A disposal system design is then developed to meet the specification. This design is then subject to assessments of its safety and environmental impacts. Information from R&D is required to support all these main activities and the outputs from the assessments of safety and environmental impacts are used to identify where further R&D is required.

Figure 7.3 Iterative development of a geological disposal system



In order to ensure coherent, comprehensive and cost-effective delivery of this work programme to the required quality and timescale, we have currently identified eleven main projects through which it will be managed. These project activities are supported by internal assurance and business support functions. Research and development required

to support these projects is included within their scope. A brief description of these projects and any significant outputs from them to date can be found below:

- **Disposal System Safety Case Project**

This project is to develop approaches to the assessment of safety for a geological disposal facility in each of the different geological settings defined in Section 4. This is to provide a basis for the assessment of the prospective safety of geological disposal at candidate sites, as will be required in support of Stage 4 of the MRWS site selection process. It will set out for the regulators how a safety case for a geological disposal facility will be developed in subsequent stages of the site selection process as information becomes available from the investigation of candidate sites. The safety assessments within the Disposal System Safety Case (DSSC) will provide the benchmark for the provision of disposability assessments of waste packaging proposals under the Letter of Compliance (LoC) process and of wastes that may be produced from new nuclear build (as described in Section 9.3.2).

Under this project we are developing a Generic DSSC that sets out the methods and types of data that will be used to assess the safety of transport of wastes to the geological disposal facility, the safety of construction and operation of the geological disposal facility, and the environmental safety of the geological disposal facility both before and after it has been backfilled, sealed and closed. In particular it shows how information related to safety will be produced for use in desk-based siting studies in the future Stage 4 of the MRWS site selection process and thus to support Government decisions on taking candidate sites forward for characterisation.

A combination of numerical assessments and qualitative arguments will be used to demonstrate, at the generic stage, how the safety of geological disposal of the inventory of higher activity wastes can be achieved and evaluated.

Currently we are finalising a suite of documents comprising the Generic DSSC, ready for their external peer review which will start in April 2010.

- **Environmental Assessment and Management Project**

The purpose of this project is to understand the potential impacts of implementing geological disposal to ensure the regulatory requirements of the Environmental Assessment Directives (Ref. 19) are met. It will also ensure appropriate management of the potential impacts.

The MRWS White Paper (paragraph 5.41) put requirements on us to develop a strategy for undertaking sustainability appraisals and environmental assessment. As part of this project, after consultations, we have developed a strategy for sustainability appraisal and environmental assessment that outlines the aims and objectives of the assessments, when and how they would be undertaken in relation to the MRWS site selection process and how stakeholders will be involved (Ref. 20).

Under this project, we will complete a Generic Strategic Environmental Assessment (SEA) to assess the potential environmental, social and economic impacts of implementing geological disposal. This will include consideration of alternative waste management options that we will continue to keep under review and assess as appropriate, in line with the relevant policy statement in the MRWS White Paper (paragraph 4.32). The Generic SEA will also outline how these potential impacts could be assessed in Stage 4 of the MRWS site selection process.

- **Disposal System Specification Project**

The purpose of this project is to ensure that the requirements to be met by the geological disposal system are up-to-date, well understood and justified. We are currently finalising a Disposal System Technical Specification that will set out all constraints and requirements for the design of a geological disposal system.

- **Disposal System Design Project**

This project is to develop the design and costed engineering solutions for geological disposal systems and associated waste transport system, to provide safe and secure geological disposal. The outputs of the project provide the basis for safety assessments and enable assessment of the potential environmental, social and economic impacts of implementing disposal.

In this project we will continue to develop a range of geological disposal concepts that are potentially suited for the range of geological settings identified in Section 4. This will ensure that we will have the information required to undertake site assessments in support of Stage 4 of the MRWS site selection process and will provide a solid basis and understanding from which site-specific designs can be developed in due course. These disposal concepts will be developed through iterations with safety and environmental assessments and build upon ongoing research and development. This work will allow us to conduct evaluations of alternatives at the appropriate point in site assessment studies.

We are finalising an outline geological disposal facility design document as a key input to the Generic DSSC and are using this to obtain regulatory views on our approach to disposal system design at this stage.

- **Optioneering Project**

This project is to develop processes to support the selection of the most appropriate design of geological disposal facility taking into account factors such as the wastes, the geology and community requirements (for example retrievability).

We will continue to develop the approach that we will use to select optimal geological disposal concepts and facility designs at the appropriate points in the programme, and perform studies to provide the information required to support such decisions.

- **Letter of Compliance / Waste Package Specification and Guidance Project**

In this project, we conduct the Letter of Compliance (LoC) assessment process in order to provide disposability assessments for wastes expected to be disposed of to a geological disposal facility and provide any “Requesting Parties”, proponents of the construction of new nuclear power stations, with disposability assessments for wastes that are proposed to be produced from their operation.

As part of this project we also develop waste package specifications to define the requirements for a disposable waste package and guidance on its application to support waste holders to produce proposals for waste retrieval, conditioning and packaging.

- **Site Assessment Methodology Project**

The purpose of this project is to ensure we are in a position to undertake desk-based studies and apply the UK Government site assessment methodology during Stage 4 of

the MRWS site selection process. The work we are undertaking currently under this project is described earlier in this section of the report and many of the other projects described will provide the necessary inputs of information.

- **Preparation for Surface Based Investigations Project**

This project is to undertake sufficient preparatory work such that, when required, the surface-based site investigations during Stage 5 of the MRWS site selection process will provide the information we need in order to develop a geological disposal facility and the information to meet the needs of others such as regulators and stakeholders. It is also to ensure that the investigations can be implemented in a timely, cost-effective and efficient manner.

We have identified the information that we believe we will require and the means of obtaining that information (Ref. 21). We have also carried out an important preparatory activity in developing a specification for the data management system for the surface-based investigations (Ref. 22).

- **Public and Stakeholder Engagement and Communication Project**

The aim of this project is to develop and implement our approach to public and stakeholder engagement and communications to enable a wide range of stakeholders to be involved in and influence the implementation of geological disposal in order that there is public confidence in the proposed way forward.

The MRWS White Paper (paragraph 4.40) put requirements on us to develop a public and stakeholder engagement strategy. As part of this project, after consultations, we have developed a public and stakeholder engagement and communications strategy that outlines the aims and objectives of the strategy and how we propose to engage and communicate with stakeholders about our work programme on geological disposal (Ref. 23). This strategy has been agreed by the UK Government.

- **Organisational Development Project**

Through this Project, we became a Prospective Site Licence Company (SLC) in December 2009. This means that we are putting in place the organisational arrangements and management systems that will be necessary for us to be capable of holding an environmental permit and a nuclear site licence when the programme reaches the stage when we are carrying out operations at a preferred site. Through this project we are fulfilling commitments on organisational change that we have made to regulators and Government.

A recent review by the regulators – the Environment Agency, the Nuclear Directorate of the Health and Safety Executive and the Department for Transport - considered the structure and staffing of the NDA's Radioactive Waste Management Directorate (Ref. 24).

We agreed with the regulators that the transition to Prospective SLC would be marked by:

- arrangements being in place for us to voluntarily submit to regulatory scrutiny and advice; and
- regulatory agreement that we have made progress toward meeting agreed principles concerning the governance, structure and operation of our organisation as a Prospective SLC as measured by specific progress criteria.

The regulators believe that we have made significant progress in working towards the status of 'Prospective SLC' and further development is now needed to demonstrate that the principles (including the criteria) have been fully achieved. This will require us to start operating as a Prospective SLC under voluntary regulatory scrutiny to address the issues raised in their review, and this has been done.

- **Programme Delivery Capability Project**

We have initiated the Programme Delivery Capability Project to develop our organisation into one that is capable of delivering the geological disposal programme to the expectations of our stakeholders in a timely and cost effective manner. This requires a combination of ongoing business activity, such as production of our monthly report, and project activity, which includes implementation of new systems and procedures that will equip us with the capability to manage such a significant programme as part of the wider NDA portfolio.

Under this project we produce business plans as required for budget management and the detailed plans required to support the UK Government and NDA spending decisions mentioned in Section 2.

The implementation of the surface-based investigations will represent a major step-change in the spend profile within our organisation. Many of the investigation activities that will be required will be highly specialised and involve procurement of a wide range of highly specialised contractors, many of whom are only able to undertake a relatively narrow range of activities. A commercial strategy is being developed to cover this work. A suppliers' workshop was held in January 2009 to seek the views of potential suppliers on the issues that the strategy needs to address, a strategy is being drafted for further informal consultation during 2010.

Through this Project we have also secured the agreement of our Management Board to our proposals for project support and control arrangements for the Prospective SLC.

- **Research & Development**

The UK Government's MRWS White Paper noted that the NDA has statutory responsibility under the Energy Act 2004 (Ref. 25) for carrying out research to support the activities for which it is responsible. Research and development required to support these projects described above is included within their scope.

Much of the work in the projects described above is underpinned by the outputs from research and development (R&D) work that has been conducted in the past and is continuing in the UK and internationally. We published our R&D strategy in 2009 (Ref. 26) following an extensive consultation exercise that was initiated by the publication of a proposed strategy at the same time as the UK Government's MRWS White Paper.

We describe our R&D programme as needs-driven. This means that we carry out R&D to meet information needs that are identified through the iterative process of developing the disposal system specification and design, and in assessing the performance of a particular geological disposal concept, as illustrated in Figure 7.3. Information needs may take a number of forms. In some cases it may be a data requirement, for example a need for information relating to a specific material property to support a functional requirement. In other cases the information need may be an improved understanding of a physical or chemical process that is important for ensuring safety, or an improved capability to model a particular process.

We are finalising a report on our proposed future R&D programme for publication in April 2010. This will present an analysis of the gap between our current knowledge on a given aspect of geological disposal science or technology and that which we need to acquire. We aim to address and reduce these gaps in our knowledge, so that we can be confident in the arguments put forward to underpin the design and safety of the geological disposal facility.

7.2 Surface Based Investigation Phase

The Surface-Based Investigation Phase will commence after the identification by Government of one or more candidate sites at which surface-based investigations will then be carried out. This corresponds to Stage 5 of the MRWS site selection process (surface-based investigations on remaining candidates).

We appreciate that the MRWS site selection process is largely driven by discussions with local communities. We will review planning assumptions as we gain a better understanding of the likely rate of progress in the preceding stages of the MRWS site selection process through dialogue with local communities engaged in the process and with the UK Government. Following identification of candidate sites we will submit applications for the necessary planning and regulatory permissions at the appropriate times to enable the permissions to be granted prior to commencing investigations.

Surface based investigations include acquiring and interpreting information on the geological and hydrogeological conditions at each candidate site. The information obtained is to be used in developing a basis for the UK Government to identify a preferred site, and will be an input into the development of the safety case, the Environmental Impact Assessment and the engineering design of the geological disposal facility. Where necessary, planning permission will be sought to undertake the investigations.

The overall objective of the surface based investigations would be to provide sufficient information to establish whether each candidate site is suitable for the development of a geological disposal facility for the identified wastes. In order to deliver this objective, there will need to be sufficient information to:

- develop geoscientific understanding of the characteristics of the sites and to permit engineering designs of the geological disposal facility to be prepared;
- develop a safety case to a level of detail sufficient to allow a preferred site to be identified to satisfy the regulators, community and other stakeholders;
- enable the production of an Environmental Impact Assessment (EIA);
- achieve a level of confidence in the characteristics of the preferred site such that it is appropriate to proceed with seeking the regulatory and planning permissions necessary for construction of a geological disposal facility at that site (noting that we would expect to carry out underground-based investigations in parallel with construction at the preferred site but if enough information were not obtained from the surface-based investigations we would need to consider a separate planning application for underground-based investigations); and
- enable a more detailed assessment of the costs of development at each site.

Surface based investigations include initial non-intrusive geological and geophysical surveys, then at a later date, drilling of boreholes to varying depths to investigate the geology in more detail. Purely for planning purposes, an assumption is made that

surface-based investigations will be undertaken during a period of about ten years. During the investigations, a baseline monitoring programme will be established to provide information for a long-term monitoring programme that will run throughout the remaining duration of the project.

Figure 7.4 shows geological mapping of an outcrop of rock during the surface based investigations undertaken in the siting process for the Swedish geological disposal facility for spent fuel. Figure 7.5 shows a seismic survey as an example of non-intrusive geophysical surveying and Figure 7.6 shows the drilling of an investigation borehole.

Figure 7.4: Geological mapping of an outcrop of granitic rock during site investigations at Oskarshamn, Sweden

Figure 7.5: Seismic survey

Figure 7.6: Exploratory borehole as part of the surface-based investigations

Assessment work that we expect to carry out in the Surface Based Investigation Phase includes the development of site-specific Disposal System Safety Cases and Environmental Impact Assessments (covering environmental, social and economic impacts). We will work in partnership with the Community Siting Partnerships to ensure that local issues are addressed in the selection and will evaluate the sites against the criteria agreed as part of the UK Government's site assessment process. The UK Government proposes that once these more detailed assessments have been completed they will be reviewed, as described previously in relation to Stage 4 of the site selection process, and:

- the Community Siting Partnership would make recommendations to its local Decision Making Bodies about whether to proceed to the next stage of the site selection process;
- the Decision Making Bodies would decide whether they wish to proceed to the next stage of the site selection process; and
- the UK Government would make an informed decision on a preferred site for implementation.

Regional and national stakeholder engagement will continue throughout this phase. It is expected that key discussion areas will include the investigations and assessments being undertaken at the sites and the development of the geological disposal facility design. The communities will also be discussing the package of measures to meet local needs that they would like to see implemented alongside the facility.

Figure 7.7 shows the possible surface site layout for Sweden's geological disposal facility at Forsmark which SKB announced in 2009 as the site for the geological disposal facility for Sweden's spent nuclear fuel. In our programme this announcement would correspond

to the end of Stage 5 of the MRWS site selection process when the UK Government selects its preferred site for the geological disposal facility.

Figure 7.7: Possible surface site layout for a geological disposal facility for spent nuclear fuel at Forsmark, Sweden (SKB)

7.3 Construction and Underground Based Investigation Phase

The Construction and Underground Based Investigation Phase is expected to commence when a preferred site for the geological disposal facility has been identified by the Government. This relates to Stage 6 of the MRWS site selection process (underground operations). Appreciating that the MRWS site selection process is largely driven by discussions with local communities and purely for planning purposes, an assumption is made that the Government could be in a position to take this step around 2025. This recognises our current estimate that about ten years will be required to conduct the actual surface-based investigations in the preceding phase of our work programme.

Following the identification of the preferred site the applications for planning and regulatory permissions will be submitted. During this process, the procurement/contractual arrangements for construction will be finalised.

We plan to undertake underground investigations in parallel with construction at the preferred site. The aim of this work will be to confirm whether the site is suitable to host a geological disposal facility that complies with safety and environmental regulatory requirements. This process will be subject to regulatory scrutiny and, at hold-points agreed with regulators, we will need to submit documents meeting specified requirements for regulatory consideration. If the site meets the regulatory requirements, the regulators would be expected to permit construction of a geological disposal facility to proceed. Planning permission will be required for underground investigative work and construction of the geological disposal facility. It is envisaged that a single planning application could be made, covering underground investigations and the construction of the disposal facility, rather than applying initially for solely the underground investigations. If we cannot obtain sufficient information from the surface-based investigations carried out in Stage 5

of the MRWS site selection process to support such an approach, then it would be necessary to consider separate planning applications for underground investigations and facility construction.

The granting of planning and regulatory permissions will then initiate the start of physical construction activities.

Initially, sufficient infrastructure, comprising surface facilities, shafts and underground tunnels will be constructed to allow us to undertake underground investigations and begin long-term demonstrations and testing. The investigations, demonstrations and testing will enable further development of the models and assessments of system performance that support the safety case. The information gained will be incorporated into the refinement of the geological disposal facility design and safety and financial cases, and used in updating regulatory submissions.

Figure 7.8: Surface facilities constructed at WIPP, Carlsbad (New Mexico) USA.

If the regulators give permission for construction of the geological disposal facility to proceed, further tunnels and disposal areas will be excavated. During this construction stage, engineered facilities will be commissioned in preparation for the various operations, including receipt, inspection and emplacement of waste underground. The following description of the engineering work that we will undertake is based on our analysis of the reference conceptual design outlined in Section 6. The details of the engineering of the eventual geological disposal facility will of course depend on factors such as the geological conditions, the inventory for disposal and the rate and timing of waste disposals.

Based on the work that we have conducted to date, receipt facilities at the geological disposal facility are currently expected to include a waste handling and transfer building and a transport-container maintenance and storage building. Buffer/backfill handling facilities will be constructed.

Access underground is assumed to be via an inclined tunnel (a “drift”), with three shafts constructed for ventilation and spoil removal. The final design will be based on the information collated during the Surface Based Investigation Phase and the underground investigations undertaken at the start of the Construction and Underground Based Investigation Phase. The selection and design of the most appropriate form of access depends on several factors, including package throughput, the depth of the vaults, the geological characteristics and the views of stakeholder groups and the public.

Figure 7.9: Tunnels in the underground research laboratory at Bure, France

Following the receipt of relevant approvals, the underground facilities will be developed in stages to enable waste emplacement operations to commence.

Key underground facilities that would be constructed include underground waste receipt facilities, disposal vaults (for ILW, long-lived LLW and uranium residues), deposition tunnels (for HLW, spent fuel, plutonium and highly-enriched uranium), and buffer/backfill handling facilities. In line with the MRWS White Paper, we currently assume that the underground facilities would be constructed and equipped in such a way that the option of waste retrievability is not excluded. We expect to discuss waste retrievability and its implications for engineering design with the local community and the regulators well in advance of finalising the design. The finalised design would then reflect the decisions made in the light of those discussions.

Later in the Construction and Underground Based Investigation Phase, additional disposal vaults and deposition tunnels will be constructed, equipped and commissioned as required. Construction and waste emplacement activities will be managed to ensure physical segregation of the two activities.

We will undertake a programme of inactive and active commissioning of surface waste receipt and handling facilities, underground waste receipt and transfer systems, and waste emplacement systems.

We will also undertake a programme of monitoring throughout the construction activities. This will be intended to validate construction design, for example by confirming the stabilisation of the rock by engineered support or the control of groundwater inflows into excavated tunnels. The monitoring programme will also be intended to ensure there are no adverse environmental impacts from construction, for example the discharge from the facility of untreated groundwater containing levels of impurities such as natural salts that are unacceptable.

Stakeholder consultation at the local, regional and national level will continue throughout the Construction and Underground Based Investigation Phase. We will continue to work in partnership with the local community through arrangements that best meet their needs.

7.4 Operation Phase

The Operation Phase will start when we have obtained all the relevant permissions and authorisations to receive and emplace waste at the geological disposal facility. Purely for planning purposes, and appreciating that the MRWS site selection process is largely driven by discussions with local communities, an assumption is made that ILW emplacement could commence around 2040.

Operations will include waste receipt, inspection and emplacement underground.

During the Operation Phase, additional disposal vaults and deposition tunnels will be constructed, equipped and commissioned as required. Construction and waste emplacement activities will be managed to ensure physical segregation of the two activities.

On-site transport operations associated with the geological disposal facility include the transportation of radioactive waste, construction materials, excavation spoil and personnel. Careful attention to the design of the transport system, selection of the most appropriate transport modes, transport routes and sympathetic infrastructure development will all serve to minimise any potential environmental impact and, at the same time, result in a transport system which can be operated in a safe and efficient manner.

Under currently established arrangements, prior to any waste packages being despatched to the geological disposal facility a rigorous system of checking and monitoring of each package will be carried out by the despatching organisation (the waste owner or the organisation acting on behalf of the waste owner). This will ensure in particular that the specific identification of individual waste packages in terms of the nature and quantity of waste is confirmed and the package will have to be shown to comply with the waste acceptance criteria that we will establish for receiving waste at the disposal facility.

Upon arrival, vehicle documentation of trains or road vehicles carrying transport packages will first be checked and processed before packages are allowed onto the geological disposal facility site.

Waste packages will be transferred within a Waste Handling and Transfer Building for subsequent transportation underground via an inclined drift. Following receipt of packages onto the disposal facility site, we will carry out inspections, for example physical examination of the waste container and radiological measurements of surface contamination and the package contents. This would ensure that any damage sustained

in transit is detected before emplacement of waste in the facility and act as a cross-check on the inspection carried out at the point of despatch.

The means of emplacing the waste underground will depend upon the design of the geological disposal facility and of the waste packages.

The duration of the Operation Phase will be determined by a number of technical and economic factors, in particular the time it takes to emplace waste in the geological disposal facility in an acceptable manner and in accordance with an acceptable environmental safety case, as well as factors such as the decommissioning strategies for nuclear power stations. The length of time for this phase will be revisited in the future as more information becomes available. Appropriate controls on the environmental conditions and associated monitoring arrangements will be maintained in the disposal areas and underground facilities to ensure safety and security.

We will continue to work in partnership with the community at the site to ensure their issues and concerns are addressed.

Environmental and operational monitoring will continue throughout.

7.5 Closure Phase

The decision on when to close the facility after all of the waste has been placed underground for final disposal will take into consideration the views of the local community. An assessment of the potential impacts of carrying out closure operations will be undertaken to optimise the process, taking account of the outcomes of discussions with the regulators and local community. We expect the exact condition of the surface site at the end of closure operations will be agreed through consultation with the UK Government, regulators and the local community. A key aim of the Closure Phase will be to achieve that state.

Leading up to closure of the underground facilities, disposal vaults and deposition tunnels will have been backfilled, the underground openings sealed and the access ways backfilled and closed. The specifications, designs and methods of emplacement of seals and backfill will be determined by analyses of their required functions in providing safety and security.

Surface facilities will be decommissioned, stripped of engineering equipment and demolished. The surface environment will be remediated and landscaped to the end state agreed with the UK Government, regulators and the local community.

For planning purposes a notional period of 10 years has been included during which time backfilling, sealing and closure will be implemented.

Monitoring of the closure operation and the environment will continue throughout the closure phase.

Records from the geological disposal facility will be placed in a national archive for use as required by future generations. Any physical marking of the site that might be required by the UK Government, regulators or in an agreement with the local community will be undertaken.

Following closure, the facility will be the responsibility of the authority charged with institutional control. A period of post-closure monitoring could be undertaken by that authority.

8 Regulatory requirements

In consultation with UK Government Departments and regulatory bodies we are developing a Permissions Schedule that is consistent with the policy set out in the MRWS White Paper. It aligns regulatory requirements with the stages of the site selection process set out in the MRWS White Paper.

Permissions Schedules have been developed and used successfully by UK implementers and regulators in progressing other regulated nuclear projects. We have agreed the use of the term with the regulators since it is well-understood by decision-makers in this field. The Geological Disposal Programme is at an early stage of planning so the Permissions Schedule is currently viewed by us as reflecting a process that we will follow to seek the required permissions rather than a timetable for submissions and assessments.

The principal regulatory bodies identified in the MRWS White Paper are as follows:

- Health and Safety Executive (HSE) which through its Nuclear Installations Inspectorate (NII) regulates the nuclear, radiological and industrial safety of nuclear installations.
- Environment agencies, the Environment Agency in England and Wales, which authorises and regulates radioactive and non-radioactive discharges and disposals to air, water and land.
- Office for Civil Nuclear Security which is a division within the HSE Nuclear Directorate responsible for regulating security arrangements in the civil nuclear industry.
- Department for Transport which, with other organisations, regulates the safety of radioactive material transport by road, rail and sea in Great Britain.

These arrangements are subject to change, since it is planned that the HSE Nuclear Directorate will operate as a Statutory Corporation as the Office for Nuclear Regulation, incorporating the current responsibilities of the Department for Transport (Ref. 27).

Local authorities will perform a dual role in the MRWS programme. In the context of the Permissions Schedule they act in the role of land-use planning regulator (where their precise role will depend on whether the application for development consent for a geological disposal facility will be taken by an Infrastructure Planning Commission, as discussed in the MRWS White Paper). However, they will also act as the decision-making bodies on behalf of local communities participating in the site selection process. Although not part of the regulatory process, the willingness of the local community to proceed with the site assessment process is of course essential to progress the implementation of geological disposal. Up until the end of Stage 5 of the MRWS site selection process a community has a right of withdrawal. Local Authorities have the responsibility as decision-making bodies, for exercising the right of withdrawal or deciding to proceed, based on advice and recommendations from the Community Siting Partnership.

Therefore, interactions with potential host communities, in particular through Community Siting Partnerships, are important and are taken into account in the Permissions Schedule, as far as possible at the current stage in the MRWS programme. As potential host communities become engaged with the site selection process we expect that they may well develop requirements for further documents to provide the information that they will need to carry out their own assessments.

8.1 The Permissions Schedule

The Permissions Schedule for Geological Disposal sets out :

- the regulatory submissions to be made by us;
- the assessments to be made by regulatory organisations; and
- the permissions we will need to obtain throughout the stages in the site selection process set out in the UK Government's Managing Radioactive Wastes Safely (MRWS) White Paper.

The Permissions Schedule covers the regulatory disciplines of:

- environmental protection (including any radioactive discharges and trans-boundary pollution);
- nuclear safety (including provisions for third party claims and liability);
- land-use / spatial planning (including supporting environmental assessment work);
- transport safety;
- nuclear security; and
- non-proliferation (nuclear safeguards).

There is no timescale set out in the MRWS White Paper for completion of the stages of the site selection process, and the Permissions Schedule 'timeline' therefore cannot link to any specific dates. Our regulatory submissions and the regulators' assessments have been co-ordinated in the Permissions Schedule and 'kept in step' to allow progress to be made simultaneously across all the regulatory disciplines. This means that the full suite of regulatory views will be available at the relevant point in each stage in the MRWS site selection process to inform decision-making.

The Schedule shows which submissions, assessments and permissions will be needed across all the regulatory disciplines in the respective stages of the MRWS site selection process and it also shows, for each regulatory discipline, the series of submissions, assessments and permissions.

The links to the MRWS site selection process are as follows:

- During Stages 1 to 3 (Expression of Interest; Initial screening out of unsuitable areas; and Community consideration leading to Decision to Participate) no site selection decisions will have been taken. The Permissions Schedule sets out the 'generic' (non-site-specific) assessment work to be undertaken by us, and the regulatory scrutiny of this work needed to inform communities and to underpin the work to be undertaken in subsequent stages.
- In Stage 4 (Desk-Based Studies) we will carry out a strategic environmental assessment (SEA) to assess the potential environmental, social and economic impacts of implementing geological disposal. Also, for each candidate community and candidate site, we will make evaluations against criteria that are being developed through consultation with stakeholders and the public before seeking their agreement by UK Government (Ref. 18). These evaluations will feed into the UK Government's site selection process. The local community has the Right of Withdrawal at this stage and decision-making bodies acting on behalf of the community would have to decide to proceed for a candidate site to remain within the process. Subject to a decision not to exercise the Right of Withdrawal, regulatory assessments of this desk-based work will inform the UK

Government's decision on which candidate sites to take forward to surface-based investigations.

- In Stage 5 (surface-based investigations on remaining candidates) we will begin surface-based investigations and, after making the appropriate applications and receiving the necessary planning permissions and environmental permits, start drilling boreholes. We will use the results gained from the surface-based investigations to construct preliminary safety evaluations and environmental impact assessments to support future activities. Again, the local community has the Right of Withdrawal at this stage. Subject to the Right of Withdrawal not being exercised, regulatory assessments of this work will inform the UK Government's decision on the preferred site to take forward into Stage 6 of the MRWS site selection process.
- In Stage 6 (underground operations) the Permissions Schedule sets out the applications for planning permission(s), a nuclear site licence, a revised environmental permit and other permissions that we will need to carry out underground operations (underground investigations, construction and waste emplacement) at the preferred site. The licence and permits will impose a series of regulatory hold-points prior to the commencement of significant elements of the work such as construction of the shaft and waste emplacement. Depending on the level of the information obtained from surface-based investigations, it may be necessary to consider separate planning applications for underground-based investigations and facility construction.

8.2 Future documents

We have produced a list of the key publications that we are planning currently. This list will be updated annually. The current list includes the suite of documents being produced to describe, and assess the potential impacts of, the generic geological disposal system. The Generic Disposal System Safety Case and the Generic Strategic Environmental Assessment, described in Section 7.1, will draw together all these strands of work to provide the regulators, local communities and other stakeholders with assessments of the likely impacts of implementing geological disposal.

9 Working with other organisations

In order to successfully implement our work, we have to work closely with a number of other organisations. Amongst the most important of these interrelationships are the ones with the UK Government, with local decision making bodies, with Community Siting Partnerships and with current and prospective waste producers as described below. There are also important interactions with other organisations such as the regulatory bodies, which have been described earlier in this report.

9.1 The UK Government

The UK Government has given us the mandate for implementing the policy of geological disposal for higher activity wastes. It approves the NDA's annual plan and sets NDA's budget through the Department of Energy and Climate Change (DECC) settlement in the Government's three-year spending review cycle.

It owns the site selection process and will take the key decisions required to move the process through successive stages up to the selection of a preferred site (at the end of Stage 5 of the MRWS site selection process). In particular, the site assessment methodology must be agreed by the UK Government before being applied in Stage 4 of the MRWS site selection process, the desk-based studies stage. Following application of the methodology and the review and consideration of the outcomes by the relevant parties and local decisions about continued participation, the UK Government will decide on the sites to be taken forward into Stage 5, the surface based investigations stage. At the end of this stage, again following review and consideration by relevant parties, the UK Government will make an informed decision on a preferred site to take forward into Stage 6, the underground operations stage. Throughout this process, we will provide the UK Government with the financial and technical information it requires to maintain progress and to support decision-making.

9.2 Community Siting Partnerships and decision making bodies

The expectation in the MRWS White Paper is that following a local decision to participate in the site selection process, a formal Community Siting Partnership will be set up and will work with us and other relevant interested parties for the remaining stages of the process. We will seek to work with partnerships in a way that maximises their ability to comment on our plans and activities. In particular we will consult with local communities on the development of the site assessment methodology before it is submitted for agreement with the UK Government. Once the methodology is agreed we will work with the partnerships to ensure that local issues are addressed in the assessments and that the partnerships are involved in the review and evaluation of the assessments before they are finalised for consideration by decision-making bodies. Once the assessments have been finalised in both Stages 4 and 5 of the process, the Community Siting Partnerships play a key role in recommending to the decision-making bodies whether to proceed.

At the end of Stages 4 and 5 of the MRWS site selection process the Decision Making Bodies make a decision about moving forward to the next stage of the process. We will work closely with them to ensure our assessments address their requirements.

9.3 Site Licence Companies (SLCs)

Under arrangements established by the NDA to discharge its responsibilities for decommissioning and clean-up at nuclear sites, Site Licence Companies (SLCs) manage

the required operations at the respective sites within the NDA estate. Each SLC within the NDA estate is required to publish a Lifetime Plan, which is periodically updated. These describe the key elements of the programme of work, and their timing and the associated costs, which will be required to remove waste from the site and ultimately bring the site to an agreed state in terms of removal of redundant buildings and engineering plant and suitability for future use. We also work with other SLCs that are not part of the NDA estate and which hold higher activity waste requiring geological disposal. From the time of our establishment as RWMD, we have put significant effort into identifying the interdependencies of the geological disposal programme and the programmes of the SLCs (in the case of those within the NDA estate, as defined in their respective published Lifetime Plans). The main interdependencies are outlined below.

9.3.1 Emplacement rates, inventory and packaged volumes

An important interdependency relates to the operational period of the geological disposal facility when the waste will be dispatched to the facility for emplacement underground. This determines the time when all waste can be removed from the site at which it is stored and thereafter when the site can be put to a future use; these factors have an important bearing on the costs of decommissioning and clean up and are important to regulators, stakeholders and the local communities. The ILW throughput used in planning the geological disposal facility is aligned to the aggregate of the volumes of this waste type that are shown (for example in Lifetime Plans) as being produced by each of the Site Licence Companies.

Further work is required to fully align the planning of geological disposal and the relevant SLC Lifetime Plans relating to HLW and spent fuel in the Baseline Inventory. The work is needed in three broad areas; the rate of disposal, the assumed inventory for disposal, and the amount of material loaded into a disposal package. These three aspects of the management of these materials are inter-related and impact on each other and on the cost.

9.3.2 Letter of Compliance / Waste Package Specification and Guidance

Revised regulatory arrangements have been in place for the management of higher activity wastes on nuclear licensed sites since January 2004 (Ref. 28). The arrangements aim to ensure that proper consideration is given to the long-term management of wastes at the earliest stage possible (i.e. before they are created in the case of wastes from proposed new nuclear power stations). To service these arrangements, the Environment Agency of England and Wales (EA), and the Scottish Environment Protection Agency (SEPA), have established nuclear waste assessment teams to facilitate the provision of advice to the Nuclear Installations Inspectorate (NII).

The regulators (NII, EA, SEPA) have developed joint guidance to industry on the operation of the arrangements (Ref. 29). The joint guidance requires nuclear site licensees to produce ‘Radioactive Waste Management Cases’ for their higher activity wastes. Radioactive Waste Management Cases should set out the plans for retrieving, conditioning, storage and ultimate disposal of the wastes, and provide reasoned argument why the conditioned waste is believed to be disposable.

The Letter of Compliance (LoC) process is recognised as a key input to Radioactive Waste Management Cases and the regulators expect nuclear site licensees to seek advice on disposability of waste from us through the LoC process. The LoC process is operated by us in our capacity as implementer of geological disposal in the UK as a

service to the nuclear industry. The primary output from the LoC process is the Assessment Report which sets out for the waste producer the case for disposability. The Assessment Report will be accompanied by a Letter of Compliance, as appropriate, when compliance with our understanding of the requirements for geological disposal is demonstrated. It is the responsibility of the waste producer to understand the advice that we provide and to use it to demonstrate appropriate management of the wastes to the regulators through the Radioactive Waste Management Case.

In order for the regulators to have confidence in the LoC process and the underlying assessments, we and our technical assessment process are subject to scrutiny by the environment agencies' nuclear waste assessment teams. A series of scrutiny projects have been undertaken and reports of the findings have been produced and published (for example Ref. 30).

9.4 Contribution to new nuclear-build Generic Design Assessment (GDA)

Government policy for new nuclear-build in the UK requires "requesting parties" to submit proposed reactor designs to the regulators' Generic Design Assessment process. We have been identified by regulators as the appropriate body to advise requesting parties on disposability issues associated with higher-activity wastes. In order to support this process we have used the well established principles from the LoC process to develop a tailored process for provision of advice to requesting parties. This process is described in a protocol (Ref. 31) agreed with regulators and requesting parties in 2008. This process is managed within our Letter of Compliance / Waste Package Specification and Guidance Project.

9.5 Contribution to Integrated Waste Strategy

The NDA has developed a National Integrated Waste Strategy (Ref. 32). The principles of this strategy include the application of the waste hierarchy and deciding how to manage wastes on the basis of business cases that take account of the full lifecycle of alternative waste management options. Where appropriate we participate in projects that are undertaken in support of this strategy. For example, we are involved in the NDA project to consider alternative waste management options for the large quantity of graphite waste that will result from reactor decommissioning and that is currently included in the Baseline Inventory. We are also participating in the European Commission – sponsored CARBOWASTE Project that is investigating important technical aspects of this issue.

9.6 International relations

We have developed relationships with counterpart organisations in other countries in order to provide access to international good practice. Many of these organisations face challenges similar to our own and it makes sense to share experiences, learn lessons and create synergistic relationships to enhance value for money. Where appropriate, this is achieved through establishing bilateral agreements or other formal or informal mechanisms.

Bilateral agreements somewhat ease the process of co-operating with other organisations by facilitating liaison and indicate the mutual respect each has for the other's capabilities and standard of work. They provide a number of benefits, and importantly allow for international benchmarking, training opportunities and access to information which may otherwise not be available. They could also provide a basis for entering into commercial arrangements where appropriate.

Through the NDA we will continue to maintain bilateral relationships with the organisations listed in Annex 1 and establish new ones where justified. All new bilateral agreements will be subject to an appropriate business case to ensure it will deliver genuine value. The value delivered by an agreement will be evaluated before the agreement is renewed. The NDA prioritises its interactions with the respective organisations based on its business objectives and needs.

We undertake high level involvement with the United Nations International Atomic Energy Agency (IAEA), Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (NEA), the European Commission (EC), other organisations, and national governments, where our input (where appropriate in liaison with the Government Department for Energy and Climate Change) can help influence technical, legislative and policy development, and promote good relations. In particular we take part in the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), (Ref. 33) and the European Union's Club of Waste Management Agencies[iii] in order to maintain high level networking with counterpart organisations and to explore further opportunities for accessing international good practice.

In order to gain further experience and maximise financial leverage, we take part in internationally co-ordinated joint research and development, working groups or other collaborative mechanisms, such as through the EC's R&D Framework Programme (including the Technology Platform for Implementing Geological Disposal (Ref. 34)), IAEA and NEA.

9.6.1 Benchmarking

We have undertaken a benchmarking exercise with other comparable programmes to validate our programme. This work has included the programme of the Swedish waste management organisation, SKB, on its geological disposal concept for spent fuel (as the reference case programme is based in part on implementing the KBS - 3V design), and also the French and Belgian geological disposal programmes. SKB has also been commissioned to undertake an independent review of the current programme to inform the programme's future development and improvement.

[iii] The Club of Agencies' members are the waste management organisations of the EU and Switzerland, and the EC's Directorate General of Energy and Transport and the Directorate General for Research

10 Engaging and communicating with the public and stakeholders

We are committed to working in partnership with the communities who participate in the site selection process. Experience, both in the UK and overseas, has shown that where the public and other stakeholders have been involved in the decision making process, better decisions have been made which also stand a better chance of being implemented. Building stakeholder confidence is vital to making progress with implementing geological disposal (Ref. 35). Those countries with inclusive and innovative engagement and communication programmes (e.g. Belgium, Finland and Sweden) have been able to work in partnership with the potential host communities and make significant progress towards implementation. Research shows that active engagement of stakeholders, especially in the early stages of a project, increases the chances of success and can create significant savings in the long term (Ref. 36). Early involvement allows stakeholders' issues to be addressed, preventing problems later and avoiding legal challenge. These are the reasons why we have developed an active Public and Stakeholder Engagement (PSE) and Communications Strategy (Ref. 23).

The aim of the PSE and Communications Strategy is to outline our approach to enable a wide range of stakeholders to be involved in and influence the implementation of geological disposal to improve decision making and build public confidence in the proposed way forward.

We recognise that engagement will be taking place on a number of different levels throughout the siting, development, construction, operation and closure of the facility. We plan to engage appropriate stakeholders throughout the development of our work programme on geological disposal. This is likely to involve the following:

- Engaging appropriate stakeholders in previewing the work programme that is to be undertaken including the scope and terms of reference for the work where appropriate.
- Undertaking specific joint fact finding projects where appropriate and reviewing the work at key stages prior to finalisation.
- Discussing preliminary results and their implications with stakeholders.
- Engaging stakeholders in reviewing the results of work.

We will work with appropriate stakeholders to agree which approach will be suitable for individual topics. We recognise that a wide range of stakeholders are interested in geological disposal and that a range of engagement and communications mechanisms will be needed to involve them in our programme. We will discuss the approach to engagement and communication with stakeholders. We will provide clear and timely feedback to stakeholders on actions taken and, if inputs are not acted upon, to explain why in a timely manner. We will also review our engagement and communications work to ensure that we learn lessons and continually improve.

We will develop a range of communications material and will develop documents with different levels of detail to enable people to engage with issues at the level they feel comfortable. All documents will contain an accessible executive summary so that people can easily understand what the document is about.

We will develop a needs driven approach to PSE and communications i.e. one where there is the greatest need for some form of engagement. In no particular order this needs driven approach will be based on:

- involving stakeholders to define the processes which allow their needs and issues to be considered and, where appropriate, addressed;
- statutory requirements;
- the stage of the geological disposal programme and the key issues that need to be addressed at that time; and
- good practice in the UK and internationally.

Our engagement work will include, in no particular order:

- Consultations required as a consequence of statutory, regulatory or similar requirements, for example, as part of strategic and environmental impact assessment and the permissioning schedule.
- Engagement as part of the NDA's wider community engagement activities, including Site and National Stakeholder Groups. This will include engagement around specific topics that are relevant to the different stages of development of the geological disposal facility.
- Meeting the specific requirements of local communities that are involved in the site selection process. This will include engaging with local decision making bodies, host communities and wider local interests and the partnerships they establish.

Engagement and communication with a wide range of stakeholders will also include those bodies that have a formal role in regulating or overseeing our activities. This engagement with statutory bodies will be visible and transparent to all stakeholders.

11 Cost

In order to plan the financing of the geological disposal programme and to inform UK Government's staged decision making process we evaluate the potential cost of the geological disposal programme. This cost is affected by many factors, but the most significant are the inventory of waste, the timing of waste arisings, the timing and duration of each phase of implementation, the geology at the site of the geological disposal facility and the design of the geological disposal facility itself.

At the current stage of planning there are inevitable uncertainties about all of these factors. Therefore we have developed not only a reference case, comprising a reasonable set of assumptions around a reference disposal concept as the planning basis for the implementation programme, as described in previous sections, but also a tool to identify the cost impact of other scenarios. The tool is termed the Parametric Cost Model where the factors identified above are the equivalent of parameters in the cost model.

For a given design and geological setting, the costs of a geological disposal facility can be broken down into:

- Fixed costs, such as the site selection and investigation programme and the construction of the surface facilities, access shafts and access drift. These are considered to be predominantly fixed costs as they are largely unrelated to the volume of waste being emplaced; and
- Variable costs, such as the construction and operation of underground deposition tunnels for HLW and spent fuel and the underground disposal vaults for ILW. These are considered to be variable costs as they vary with the volume of waste being emplaced.

The cost of implementing geological disposal will increase if the inventory increases and reduce if the inventory reduces. The relationship between inventory and cost is approximately linear for the 'variable' cost component of the geological disposal facility. In the cost model, if the total number of disposal packages (which is directly related to inventory) increases then the duration of the emplacement programme is extended. Should the timings of the arisings change from that currently assumed, then the costs could be impacted. In practice, if the change in timings results in a longer period to emplace waste in the facility there would be appropriate action taken, for example the phasing of emplacement operations, to limit any increases in costs.

The type of rock in which the disposal areas are excavated and in which the access shafts and drifts are constructed can influence the construction method and the temporary and permanent support that is required to maintain the integrity of these underground structures. Other characteristics of the geological environment, such as stress in the rocks, will also be important. In very simple terms, rock-types that are less mechanically strong will require greater engineered support and hence will be more costly to develop. The increase in rock stress with increasing depth means that greater engineered support is also likely to be required as the depth of excavations increases.

The design of the geological disposal facility is strongly influenced by its geological setting and the inventory of wastes requiring disposal. However, a range of disposal concepts are suitable for each of the different geological settings and the choice of concept and hence of the engineering solutions (methods and materials) and method of operation of the geological disposal facility will also influence costs.

The cost for the reference case is used as the current basis for planning, and this will be refined as more information becomes available for concepts that are suitable for candidate sites that have been identified by Community Siting Partnerships. The modelling tool provides us with the knowledge of the impact that different scenarios in which date of availability, rate of emplacement, inventory, etc are varied so that UK Government can understand the impact that variances could have on the cost.

In addition to providing the required information on the geological disposal of legacy wastes, the Parametric Cost Model is also used to provide UK Government with a substantiated basis for assessing the costs of geological disposal of wastes that may be produced from new nuclear power stations.

The estimated cost for the NDA's share of the geological disposal programme for the HLW, ILW, LLW and spent nuclear fuel in the Baseline Inventory is published in the NDA Annual Report and Accounts (ARAC) (Ref. 4). In line with the requirement placed on the NDA, the reported figures are "discounted costs" where account is taken of an annual discount rate, an assumed rate of decrease in the value of money in the future. The discounted cost of £3.7 billion reported in the 2008/09 ARAC is equivalent to an undiscounted lifetime cost of about £12 billion. We provide information on when costs will be incurred over the project lifetime, and this is used to calculate the discounted cost.

This estimated cost of geological disposal includes research, design, construction, operation and closure of a disposal facility for the HLW, ILW, LLW and spent fuel in the Baseline Inventory. The estimated undiscounted cost up to the time at which first waste is emplaced (which we currently assume for planning purposes will occur in about 2040) is about £4 billion. The cost excludes some significant activities, in particular the costs of waste encapsulation and of transport of wastes to the geological disposal facility which are the responsibility of the waste owner.

Costs of any post-closure monitoring of the facility during institutional control are not estimated since these will be the responsibility of the authority charged with that control.

The estimated cost does not include disposing of the separated uranium and plutonium in the Baseline Inventory, in line with the way these materials are treated in other areas of the ARAC. Nonetheless, we have assessed the costs of geological disposal of these materials and put these costs at circa £2 billion without discounting, assuming that they will be disposed of in the same facility as the other wastes and in the way described in Section 6 concerning the reference case.

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14 Annex 1 – List of Bilateral Agreements

Organisations with which the NDA has bilateral agreements and their dates of signing and duration:

Andra, the French "national agency for the disposal of radioactive waste" regarding very low level and low level waste disposal, geological disposal, national inventory development and graphite disposition. (May 2008, 5 years.)

Electricité de France (EDF), through its decommissioning arm CIDEN for decommissioning strategies, graphite waste disposition, and contaminated land management. (January 2006, 3 years; extended January 2009.)

DBE Technology, the German repository construction and operation organisation regarding geological disposal. (October 2009, 5 years.)

Japan Atomic Energy Agency (JAEA), regarding low level waste management, waste treatment, decommissioning and geological disposal. (July 2008, 5 years.)

Japan Nuclear Fuel Limited (JNFL), regarding low level waste disposal, waste treatment facilities, decommissioning and public acceptance activities. (Open ended.)

The Nuclear Waste Management Organisation of Japan (NUMO), in respect of geological disposal. (June 2004, 5 years; extended June 2009.)

The Radioactive Waste Management Funding and Research Centre of Japan (RWMC), in respect of low, intermediate and high-level waste management, including geological disposal. (September 2004, 5 years.)

Nagra, the Swiss "national co-operative for the disposal of radioactive waste" for intermediate and high level waste, and spent fuel disposal. (February 2006, 5 years.)

ONDRAF/NIRAS, the Belgian "agency for radioactive waste and enriched fissile materials" regarding decommissioning activities, low and intermediate level waste disposal, and geological disposal. (October 2005, 5 years.)

SKB, the "Swedish Nuclear Fuel and Waste Management Company" for low and intermediate level waste disposal and geological disposal of spent fuel. (February 2002, 5 years; extended February 2007.)

The United States Department of Energy (USDOE), through its Office of Environmental Management (EM) in respect of decommissioning and clean-up activities and the Office of Civilian Radioactive Waste Management regarding geological disposal. (March 2007, 5 years.)

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