Radioactive Waste Management

NDA Report no. DSSC/101/01

Geological Disposal

Overview of the generic Disposal System Safety Case

December 2016

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Preface

Radioactive Waste Management Limited (RWM) has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity radioactive wastes in the UK. As a pioneer of nuclear technology, the UK has accumulated a legacy of higher activity wastes and material from electricity generation, defence activities and other industrial, medical and research activities. Most of this radioactive waste has already arisen and is being stored on an interim basis at nuclear sites across the UK. More will arise in the future from the continued operation and decommissioning of existing facilities and the operation and subsequent decommissioning of future nuclear power stations.

Geological disposal is the UK Government's policy for higher activity radioactive wastes. The principle of geological disposal is to isolate these wastes deep underground inside a suitable rock formation, to ensure that no harmful quantities of radioactivity will reach the surface environment. To achieve this, the wastes will be placed in an engineered underground facility – a geological disposal facility (GDF). The facility design will be based on a multi-barrier concept where natural and man-made barriers work together to isolate and contain the radioactive wastes.

To identify potentially suitable sites where a GDF could be located, the Government has developed a consent-based approach, based on working with interested communities that are willing to participate in the siting process. The siting process is on-going and no site has yet been identified for the GDF.

Prior to site identification, RWM is undertaking preparatory studies which consider a number of generic geological host environments and a range of illustrative disposal concepts. As part of this work, RWM maintains a generic Disposal System Safety Case (DSSC). The generic DSSC is an integrated suite of documents which together give confidence that geological disposal can be implemented safely in the UK.

Executive Summary

Background

The generic Disposal System Safety Case (DSSC) is a suite of documents that assesses the safety and environmental implications of the geological disposal of radioactive waste. This Overview report sets out the context for the generic DSSC and provides an overview of the suite of documents and the interfaces between them, with pointers to where further information can be found, as well as a summary of the key safety conclusions and the arguments that support them. It is intended primarily for a regulatory audience.

RWM has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the UK's higher activity wastes, as set out in the UK Government's White Paper on a framework for the long term management of higher activity waste.

The White Paper defines an inventory of materials that may need to be managed through geological disposal: High Level Waste (HLW), Intermediate Level Waste (ILW), some Low Level Waste (LLW) unsuitable for near-surface disposal, spent fuel, depleted natural and low-enriched uranium, highly-enriched uranium and separated plutonium.

A geological disposal facility (GDF) will be a highly engineered facility, located deep underground, where the waste will be isolated within a multi-barrier system of engineered and natural barriers, preventing the release of harmful quantities of radioactivity to the surface environment.

To identify potentially suitable sites where the GDF could be located, the Government is developing a consent-based approach based on working with communities. Development of the siting process is ongoing and no site has yet been identified for the GDF.

Therefore, the disposal system development process is currently generic, in that it is not specific to any site. It is also iterative. It starts with the identification of requirements and realistic assumptions, from which a Disposal System Specification (DSS) is developed. Designs, based on illustrative disposal concepts for a range of geological environments, are developed to address these requirements, which are then assessed for safety and environmental impacts. Outputs from the safety and environmental assessments identify where further research and development may be needed, and provide feedback into the specification and the designs.

The generic Disposal System Safety Case

The generic DSSC suite of documents is central to the iterative development of the GDF. The DSSC documents include the specification, design, safety cases, assessments and the underpinning knowledge base. The purpose of the generic DSSC is to:

- demonstrate that RWM is confident that the UK's radioactive waste can be safely disposed of in the UK
- invite and support discussions with regulators and other stakeholders, such as waste producers and the NDA
- maintain a basis on which RWM can provide advice to waste producers on packaging for disposal, and for assessing the disposability of waste packages
- support the siting process by providing information to communities interested in hosting the GDF
- inform RWM's Science and Technology Plan by identifying research and development needs

- provide a basis for the early assessment of the suitability of potential sites, informing the development of illustrative disposal concepts and designs as part of the iterative development process
- provide a source of information to support the future development of site-specific designs and safety cases.

The generic DSSC considers radiological safety in the following phases of the disposal system lifecycle:

- transport of the waste to the GDF - presented in the generic Transport Safety Case (TSC)
- construction and operation of the GDF - presented in the generic Operational Safety Case (OSC)
- the long term period after closure - presented in the generic Environmental Safety Case (ESC)

In addition to radiological safety considerations, the generic DSSC also considers conventional safety in the operational phase, in order to inform the design development of the GDF; and generic non-radiological environmental and sustainability assessments to support illustrative design development and inform the early stages of the siting process for the GDF. The latter comprise a non-radiological environmental assessment, a socio-economic assessment and a health impact assessment. In the future, a site-specific Environment Impact Assessment will support development consent applications for borehole drilling and GDF construction.

RWM produced an initial generic DSSC in 2010. Since 2010, there have been a number of drivers for a comprehensive update of the generic DSSC, most notably the availability of an updated inventory for disposal. The entire suite of documents has now been updated. The update process was managed under RWM's Quality Management System.

Purpose and scope of this Overview

This Overview is primarily intended for regulators, RWM staff and other interested organisations and individuals. Its purposes are to:

- introduce the generic DSSC, explain its purpose and scope, summarise its history and outline its envisaged development during the generic and site-specific stages of GDF implementation
- map out the structure of the generic DSSC document suite, signposting where specific information can be found
- explain how the individual documents interface with one another in order to provide the key arguments and evidence for the overall safety case
- summarise the key messages of the constituent safety cases
- describe the processes that have been followed in producing the generic DSSC, to ensure quality in document production and in the management and use of data

This document differs from the 2010 generic DSSC Overview. The 2010 Overview was a public-facing document that presented the key technical concepts and safety case messages to interested stakeholders. Unlike the 2010 Overview, this document does not give details of technical background. Such details are now provided in a separate Technical Background document that, in order to avoid repetition across the document suite, collates all common technical information.

Key findings

The generic DSSC concludes that the GDF can be implemented safely in a range of geological environments.

The GDF can be designed, constructed and operated safely and in compliance with statutory dose limits and RWM's radiological protection criteria. Waste can be safely transported to the GDF with operator doses from routine operations below the legal limit, even under bounding conditions, and below the Basic Safety Objective for the inventory as assessed. The generic DSSC demonstrates how environmental safety can be assured, not only at the time of disposal, but also in the long-term after wastes have been emplaced and the disposal facility has been closed.

The assessment of the entire inventory for disposal as presented in the White Paper and on which the 2013 Derived Inventory is compiled has confirmed that a single GDF will be bounding and that the safety arguments of the 2010 generic DSSC remain valid.

The level of confidence has increased, principally through:

- quantified assessment of three illustrative geological environments
- consideration of alternative inventory scenarios
- the alignment of the generic OSC with the requirements of Preliminary Safety Report
- improvements in the knowledge base

A number of areas have been identified where further research and/or feedback to system specification and design is required. These are being planned for and integrated into RWM's Science and Technology Plan and/or future actions within the iterative design development process.

Next steps

As RWM's work programme moves forward, the generic DSSC will be maintained and developed, in order to provide feedback to the iterative development process and so that RWM may continue to interact with regulators, give disposability advice on waste packaging proposals and engage with stakeholders.

As potential sites are identified, site-specific safety cases will be developed to inform site assessment, optimisation studies and regulatory submissions. The generic safety cases will continue to be maintained for as long as they are needed to support disposability advice and for generic studies. Eventually, when there is sufficient confidence in the site-specific safety cases for all waste types, the generic safety cases will no longer be necessary and all ongoing safety work will be site-specific.

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1 Introduction

1.1 Purpose and scope of this Overview

This document provides an overview of the generic Disposal System Safety Case (DSSC): the suite of documents that considers the safety and environmental implications of the geological disposal of radioactive waste. The Overview provides context and a summary of the conclusions and key safety arguments. It provides a way into the suite of documents, the interfaces between them and pointers to where information can be found. It is intended primarily for a regulatory audience.

The initial generic DSSC was published in 2010. Since then, there have been a number of drivers for updating the safety case as an entire suite of documents, most notably the 2014 White Paper, which contains an updated inventory for disposal [1]. This comprehensive update has now been carried out, and this document updates the 2010 generic DSSC Overview [2].

The 2010 Overview was a public-facing document that presented the key technical concepts and safety case messages to interested stakeholders. This Overview is primarily intended for the licensing regulators (the Office for Nuclear Regulation (ONR), the Environment Agency (EA) and Natural Resources Wales (NRW)), RWM staff, and other interested regulators, organisations and individuals. These may include the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment Agency (NIEA).

In addition to presenting the key conclusions of the generic DSSC, this Overview also focuses on the role, scope and structure of the generic DSSC, its history, future development and the processes followed in its production.

This Overview has a number of purposes, namely it:

- introduces the generic DSSC, explains its purpose and scope, summarises its history and outlines its envisaged development during the generic and site-specific stages of a geological disposal facility (GDF) implementation
- maps out the structure of the generic DSSC, signposting where specific information can be found
- explains how the individual documents interface with one another in order to provide the key arguments and evidence for the overall safety case
- summarises the key messages of the constituent safety cases
- describes the processes that have been followed in producing the generic DSSC to ensure quality in document production and in the management and use of data

Unlike the 2010 Overview, this document does not give details or technical background. These details are now provided in a separate Technical Background document [3] that, in order to avoid repetition across the document suite, collates all common technical information.

1.2 Background

RWM has been established as the organisation responsible for implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity wastes.

The GDF will be a highly engineered facility, located deep underground, where the waste will be safely isolated within a multi-barrier system of engineered and natural barriers to prevent the release of harmful quantities of radioactivity and non-radioactive contaminants to the

surface environment. It is expected to have an operational lifetime of 150 years and the volume of packaged waste it will contain is expected to be in the region of 650,000 m^3.

To identify potentially suitable sites where the GDF could be located, the Government is developing a consent-based approach based on working with interested communities that are willing to participate in the siting process [1]. Development of the siting process is ongoing and no site has yet been identified for the GDF.

Technical information on the geological disposal system and associated transport system as it is currently envisaged, such as the inventory for disposal, illustrative disposal concepts for possible host rocks, the engineered and natural barriers and waste packages, is provided in the Technical Background [3].

The development process for a disposal system is iterative. It starts with the identification of requirements for the disposal system, from which a Disposal System Specification is developed. Designs, based on illustrative disposal concepts, are developed to meet the requirements in this specification and the designs are then assessed for safety and environmental impact. The generic DSSC is a demonstration that the requirements for the disposal system can be met. An ongoing programme of research and development informs these activities. Conclusions from the safety and environmental assessments identify where further research and development may be needed, and/or provide feedback into the specification and/or the facility designs.

The generic DSSC plays a major role in this iterative development process, being the suite of documents that considers the safety and environmental implications of the geological disposal of radioactive waste. The generic DSSC captures information at a point in time and will be kept up to date via a rigorous change management process.

Further information on the above key context topics is provided in Section 2.

1.3 Document structure

The remainder of this Overview is structured as follows:

- The remaining parts of Section 1 describe the purpose of the generic DSSC in the context of RWM's Corporate Strategy [4], its scope and how it is expected to be used
- Section 2 expands on the background information in Section 1.2, providing further information on the context for the generic DSSC
- Section 3 explains, using a series of 'map' figures, the hierarchy of documents that make up the generic DSSC, and how they relate to each other in order to provide arguments and evidence for safety
- Section 4 gives an overview of the drivers for change since the 2010 generic DSSC and how the document suite has been changed and improved in response
- Section 5 describes the quality management system that has been applied in producing the generic DSSC and how RWM expects to develop into a company with the governance and competences required to hold environmental permits and a nuclear site licence for a disposal facility
- Section 6 outlines the key conclusions and arguments from the operational, transport and environmental safety cases and of the environmental assessments, drawing together the key messages
- Section 7 outlines how the DSSC will develop in future, through its generic and site-specific stages
- Section 8 concludes by summarising findings and the next steps

1.4 The generic DSSC

This section describes the purpose and scope of the generic DSSC, sets the generic DSSC in the context of RWM Strategy and explains how the generic DSSC will be used.

1.4.1 Purpose and scope of the generic DSSC

The main purpose of the generic DSSC is to give confidence that the GDF can be implemented safely in the UK. It does this by describing and assessing the safety and environmental implications associated with all aspects of geological disposal of higher activity wastes. In addition, environmental and sustainability assessments consider the non-radiological socio-economic and health impacts of the GDF.

The generic DSSC explains and assesses the following safety implications of geological disposal of radioactive waste:

- Radiological safety of transporting the waste to the GDF. This is presented in the generic Transport Safety Case (TSC) [5]. The generic TSC does not consider the conventional safety of transport operations activities such as road traffic or rail movements, but the Generic Health Impact Assessment does cover transport and health.
- Radiological and conventional safety of constructing and operating the GDF. This includes radiological environmental safety in relation to releases of radioactivity during construction and operation. These are presented in the generic Operational Safety Case (OSC) [6].
- Environmental safety of the GDF after closure is presented in the generic Environmental Safety Case (ESC) [7]. The ESC considers both radioactive materials and other toxic or hazardous substances present in the inventory

Alongside its generic radiological safety case work, RWM carries out generic non-radiological environmental and sustainability assessments in order to support illustrative design development and to inform the early stages of the siting process for the GDF. These documents comprise a non-radiological environmental assessment [8], a socio-economic assessment [9] and a health impact assessment [10]. In the future, a site-specific Environment Impact Assessment will support development consent applications for borehole drilling and GDF construction.

They are included in the generic DSSC suite to contribute to information available to stakeholders and to the iterative development of the disposal system, but they do not add to the safety arguments made in the generic TSC, generic OSC and generic ESC.

Security and safeguarding risks will be considered separately, taking account of the requirements of the Nuclear Industries Security Regulations [11] and associated regulations for security and of the EURATOM treaty [12] for safeguards. The current status of work on security and safeguards is described in the GTSD [13, Section 8] and in [14].

1.4.2 Relationship to RWM's Corporate Strategy

The RWM Corporate Strategy [4] includes a number of points that are particularly relevant to the generic DSSC. It states that RWM will:

- *'Continue to engage with the regulators to ensure it has the necessary capability, organisation, resources and arrangements in place to apply for and hold environmental permits and a site licence, ahead of the time RWM needs to apply for them.*

- *Develop and maintain our geological disposal concepts to underpin waste packaging advice and provide a basis for the siting and development of a GDF. We will undertake scientific and engineering work to support development of geological disposal concepts. This needs to reflect changes to the radioactive waste inventory and the understanding gained through our research programme.'*

These points are reflected in RWM's approach to demonstrating, through its safety cases, that a geological disposal system can be implemented safely, and for developing the DSSC in response to the progressive refinement and understanding of the system as the knowledge base increases. This approach is set out in the Safety Case Production and Management report [15].

The generic safety cases will continue to be maintained, with site-specific safety cases being developed as separate and parallel workstreams, rather than evolving the generic safety cases into site-specific ones. This strategy ensures that that disposal options are not prematurely foreclosed and that RWM has accepted benchmark safety cases whilst developing the site-specific safety cases.

The DSSC is termed 'generic' at this stage because a site has not yet been identified. The generic DSSC is therefore based on illustrative concepts showing how geological disposal might be implemented in a range of host rocks typical of those found in the UK, based on realistic assumptions. These illustrative disposal concepts have been developed through adaptation of relevant concepts used by waste management organisations around the world.

Thus the generic DSSC plays an important part in the delivery of RWM's Corporate Strategy. It provides confidence that at this stage of development, RWM understands the important factors influencing the safety of geological disposal, understands the uncertainties in the safety case and has a needs-driven and competent research programme in place to address them. The generic DSSC is a demonstration that RWM is confident that the waste can be disposed of safely in a range of environments.

1.4.3 Use of the generic DSSC

The generic DSSC will be used for the following purposes:

- to demonstrate that RWM is confident that the UK's radioactive waste can be safely disposed of in the UK
- to invite and support discussions with regulators and other stakeholders, such as waste producers and the NDA
- as a basis for advice given by RWM to waste producers in packaging waste, and as a basis for assessments of waste package disposability carried out as part of RWM's Disposability Assessment process [16]. The disposability assessment process aims to give confidence to waste packagers that their proposed packages will comply with the eventual needs for transport to, and disposal in, the GDF, and confidence to RWM that the disposal system considered within the DSSC will be appropriate to the wastes
- to provide information to communities interested in hosting a GDF
- to inform RWM's Science and Technology Plan by identifying research and development needs
- to inform the iterative development process

2 Context

This section expands on the background provided in Section 1.2, providing further information on the context for the generic DSSC. It covers Government policy, the siting process and the inventory for disposal as set out in the 2014 White Paper, the National Geological Screening (NGS) exercise and the roles of RWM and the regulators. Lastly, the iterative nature of the geological disposal system is explained.

2.1 Government policy and the siting process

In 2001, the UK Government and devolved administrations[1] initiated the Managing Radioactive Waste Safely programme [17], with the aim of finding a practical long-term solution for the management of the UK's higher activity wastes. The Committee on Radioactive Waste Management (CoRWM) was established and undertook extensive consultation with the public and expert groups. In July 2006, CoRWM recommended that the best available approach was geological disposal, preceded by safe and secure interim storage [18]. CoRWM's recommendations were accepted by the UK Government and the devolved administrations in a response published in 2006 [19].

CoRWM's recommendations are in line with an international consensus [20] that geological disposal provides the safest long-term management solution for higher activity wastes. In Europe, a 2011 Council Directive established a framework for the responsible and safe management of spent fuel and radioactive waste, recognising that deep geological disposal represents the safest and most sustainable option as the end point [21]. The USA, Canada, Finland, France, Sweden and Switzerland have also adopted geological disposal policies.

The definition of geological disposal given by CoRWM and subsequently used by Government is:

> *'geological disposal means burial underground (200 -1000m) 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 2008, the UK Government with the Welsh and Northern Ireland devolved administrations, published a White Paper [22] that set out how the Government intends to manage higher activity waste in the long-term through geological disposal, with interim storage and ongoing research and development to support its optimised implementation. It set out a consent-based siting process for identifying a GDF site that was based on local communities' willingness to participate in the process.

The siting process operated for five years. A number of communities engaged with the process and participated in its early stages. However, discussions between the interested parties did not progress beyond 'Stage 3' of the process and by February 2013 there were no longer any communities actively involved in this siting process.

A call for evidence and public consultation then followed, which highlighted the importance of providing clear, evidence-based information on both technical issues and the process of working with communities, in advance of formal discussions between communities and the

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[1] UK Government in this context means the Business, Energy and Industrial Strategy (BEIS). The devolved administrations are the Welsh Assembly Government and the Department of the Environment Northern Ireland. Scottish Government policy is that the long term management of higher activity radioactive waste should utilise near-surface facilities and that these should be located as near as possible to the site where the waste is produced. The Scottish Government therefore did not sponsor the 2008 or 2014 White Papers.

developer. Following this, in July 2014, the UK Government produced a revised White Paper [1] confirming the policy for the management of higher activity wastes and setting out the policy framework for the future implementation of geological disposal in the UK. It updates (and replaces in England and Northern Ireland[2]) the 2008 White Paper. The UK Government remains committed to a consent-based approach that is based on the willingness of local communities to participate in the process.

The management of radioactive waste is a devolved policy issue and therefore the devolved Government administrations have responsibility for this issue. The Scottish Government does not support deep geological disposal and in January 2011 published its own policy [23] proposing the use of near-surface facilities for the long-term management of higher activity wastes arising in Scotland.

The 2014 White Paper establishes a number of initial actions to be undertaken by the UK Government and RWM as the developer, including:

- the development and implementation of a National Geological Screening exercise to help answer questions about potential geological suitability for GDF development across the country (more details are given in Section 2.3)
- development of a policy framework for planning decisions in England
- development of a process for working with communities to identify potential sites for a GDF

The high level stages of the siting process, as presented in the 2014 White Paper, are shown in Figure 1.

[2] The policies and proposals contained in the 2014 White Paper do not apply in Wales. The Welsh Government subsequently adopted a policy for geological disposal [Welsh Government, Welsh Radioactive Policy on the Management and Disposal of Higher Activity Radioactive Waste, ISBN 978 1 4734 3615 2, 2015] delivered through a voluntary partnership with interested local communities.

Figure 1 High level stages of the siting process

The proposed approach to site identification could lead to the consideration of several sites with different geological environments. However, the White Paper expresses the Government's preference for one GDF, on the basis that there would, in general, be lower costs and environmental impacts.

The construction and operation of the GDF will be subject to regulatory approval by the ONR and the appropriate environmental regulator. An outline of the respective roles and functions of the regulators is provided in Section 2.5.

2.2 The inventory for disposal

The 2014 White Paper explains that Government Policy for disposal of higher activity waste applies to High Level Waste (HLW), Intermediate Level Waste (ILW), and some Low Level Waste (LLW) not suitable for near-surface disposal in current facilities. The UK has been generating higher activity wastes since the 1940s as a result of the generation of electricity in nuclear power stations, from the associated production and reprocessing of the nuclear fuel, from the use of radioactive materials in industry, medicine and research, and from defence-related nuclear programmes.

Some of this has already arisen as waste and is being stored on an interim basis at nuclear sites across the UK. More waste and material will arise as existing facilities reach the end of their lifetime and are decommissioned. In addition, waste will be generated from the operation and decommissioning of any new nuclear power stations and other nuclear facilities.

In addition there are some radioactive materials that are not currently classified as waste that would, if it were decided at some point that they had no further use, need to be managed as wastes through geological disposal. These include spent fuel (including spent fuel from new nuclear power stations), plutonium and uranium.

The wastes that are planned for disposal in the GDF are referred to as the 'inventory for disposal' and are discussed further in the Technical Background [3].

2.3 National Geological Screening

The policy framework set out in the 2014 White Paper includes a number of initial actions for the UK Government and RWM as the developer to deliver, in order to provide clear, evidence-based information covering England, Wales and Northern Ireland and to inform any local discussions. These initial actions, which are expected to take two years to complete, will be followed by a longer-term process of working with communities, informed by the initial actions.

The initial actions set out in the 2014 White Paper are:

- the National Geological Screening exercise
- development of land use planning processes
- preparations for working with the communities

The first of these, the National Geological Screening exercise, is the responsibility of RWM and commenced in 2014 in parallel and in conjunction with the development of the current generic DSSC. The remaining two initial actions are the remit of Government and are not discussed further in this Overview.

National Geological Screening will present an overview of existing information about the geology to a depth of about 1000 metres or so beneath England, Wales and Northern Ireland. It will focus on aspects of the geological environment that are relevant to long-term safety.

The National Geological Screening Guidance [24] explains that the requirements of a disposal system are to provide:

- isolation of radioactive waste
- containment of radioactive waste
- confidence in long-term safety
- low likelihood of future generations inadvertently intruding into the GDF

The guidance directs the reader to the generic DSSC for evidence that safety can be achieved in a range of geological environments.

The findings from the National Geological Screening exercise and the safety assessments presented in the generic DSSC for a range of host geological environments will together provide information to communities in the next stage of the siting process.

2.4 RWM's role and duties

The Nuclear Decommissioning Authority (NDA) is responsible for implementing Government policy on the long-term management of radioactive waste, as set out in the 2014 White Paper. To support it in discharging these responsibilities, the NDA established RWM, a wholly-owned subsidiary of the NDA, as a delivery body to work with the waste producers to develop waste management solutions and deliver geological disposal.

In implementing geological disposal, RWM has a number of duties under international, EU and UK legislation relating to health and safety, environment, transport and security, both in general, as an employer, and specifically in relation to radioactive substances. Relevant legislation and principles include:

- all relevant Euratom Treaty requirements as transposed into UK law, including Council Directive 96/29/Euratom laying down basic safety standards for the protection of the

health of workers and the general public against the dangers of ionising radiation [25] (the Basic Safety Standards Directive)

- the principles of radiological protection established by the International Commission on Radiological Protection (ICRP) as reflected in EU and UK legislation and standards
- relevant UK legislation, including:
  - the Health and Safety at Work etc Act 1974 (HSWA) [26]
  - the Nuclear Installations Act 1965 (as amended) (NIA65) [27][3]
  - the Construction (Design and Management) Regulations 2015 [28]
  - the Ionising Radiations Regulations (IRRs) (1999) [29]
  - the Environmental Permitting (England and Wales) Regulations 2010 [30]
  - the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 [31] and
  - the Nuclear Industries Security Regulations 2003 [32]

Further details of legislation relevant to the DSSC are provided in the Disposal system Specification.

RWM will implement management arrangements for the control of key activities and demonstrate to the nuclear regulators that it has the necessary capability, organisation, resources and arrangements to undertake these activities safely and securely. RWM will also need to demonstrate that it is confident that the inventory for disposal can be safely disposed of in the GDF and that the GDF will protect people and the environment at the time of disposal and in the future, following closure. The generic DSSC serves that purpose, as far as appropriate to the current generic stage.

2.5 The regulators' roles

The regulators provide advice and comment to Government, the NDA, RWM, local authorities and other stakeholders on geological disposal. The Office for Nuclear Regulation (ONR) and the Environment Agency (EA) are currently leading the review and scrutiny of RWM's work: both ONR and the EA have established agreements with RWM to do this. Other regulators, depending on the GDF location, may include Natural Resources Wales (NRW), the Northern Ireland Environment Agency (NIEA) and the Scottish Environment Protection Agency (SEPA). In particular, if the siting process progresses with communities in Wales or Northern Ireland, NRW or NIEA respectively would be involved. However, for brevity, "EA" is used in this report where "appropriate environmental regulator" would be more accurate.

The scrutiny will help RWM to progress implementation of the GDF and the associated safety cases, and will inform the preparation of any necessary applications for licences or permits. The work will also inform the regulators' decision-making throughout this process.

While ONR and the EA have no formal regulatory role in selecting a site for geological disposal, they will help the process by advising and commenting on safety, transport and

[3] The NIA65 applies to prescribed installations and activities, which are defined in a way that would not include a GDF. The Government has declared an expectation that any future GDF would be licensed [ONR, Licensing Nuclear Installations, 4th edition January 2015, see also 2014 White Paper para 3.38] and RWM therefore assumes that the NIA65 will be amended to include the GDF in its scope.

environmental matters, which will become important once their regulatory roles begin in earnest, when RWM applies for the relevant licences and permits.

RWM expects that any future GDF will be a nuclear installation under the NIA65. As such it will be ONR's role, if it is satisfied with the safety of what is proposed, to grant a licence for the site, with conditions as appropriate, and then to enforce the requirements of that licence. ONR will also be responsible for regulating security arrangements.

ONR also has responsibility for providing advice on the transport of radioactive material, and for granting approval, if it is satisfied, for the transport of the packages of higher hazard radioactive materials.

The EA will, if satisfied, grant environmental permits to carry out site investigation and to construct the GDF. The EA will require RWM to demonstrate that the location and design of the GDF ensures environmental safety[4] of the facility during the period of authorisation[5] and subsequently. The location and design will need to satisfy the requirements of the EA as specified in the Guidance on Requirements for Authorisation [33].

Further details of regulatory roles are provided in the Safety Case Production and Management report [15]. In this context, the DSSC will inform and support the regulatory submissions and dialogue with the regulators.

2.6 Iterative development of a geological disposal system

Development of a disposal system is iterative, as shown in Figure 2.

The process starts with the identification of requirements from which a Disposal System Specification is developed. The requirements include external considerations such as regulatory and stakeholder requirements, as well as the nature, characteristics and quantities of the radioactive wastes requiring disposal.

A range of illustrative disposal concepts is selected for the implementation of geological disposal in a range of geological environments, typical of those found in the UK. From these, illustrative designs are produced to address the requirements. The designs are assessed for safety and environmental impacts and the outputs from these assessments inform subsequent development of the requirements and illustrative disposal concepts, and identify knowledge gaps where further research and development is required.

Note that 'Safety Cases' and other 'Outputs' in Figure 2 refer only to the finished documentation; the *process* of developing such documents is considered as part of the 'Assessment' box and feeds back into the iterative cycle. Assessment includes disposability assessments, site assessment and site suitability criteria.

Throughout this iterative process, RWM maintains an up to date knowledge base underpinned by needs-driven research and development. Developing this knowledge base is a fundamental component of RWM's business model; it is the key means of meeting the needs of the disposal system design development.

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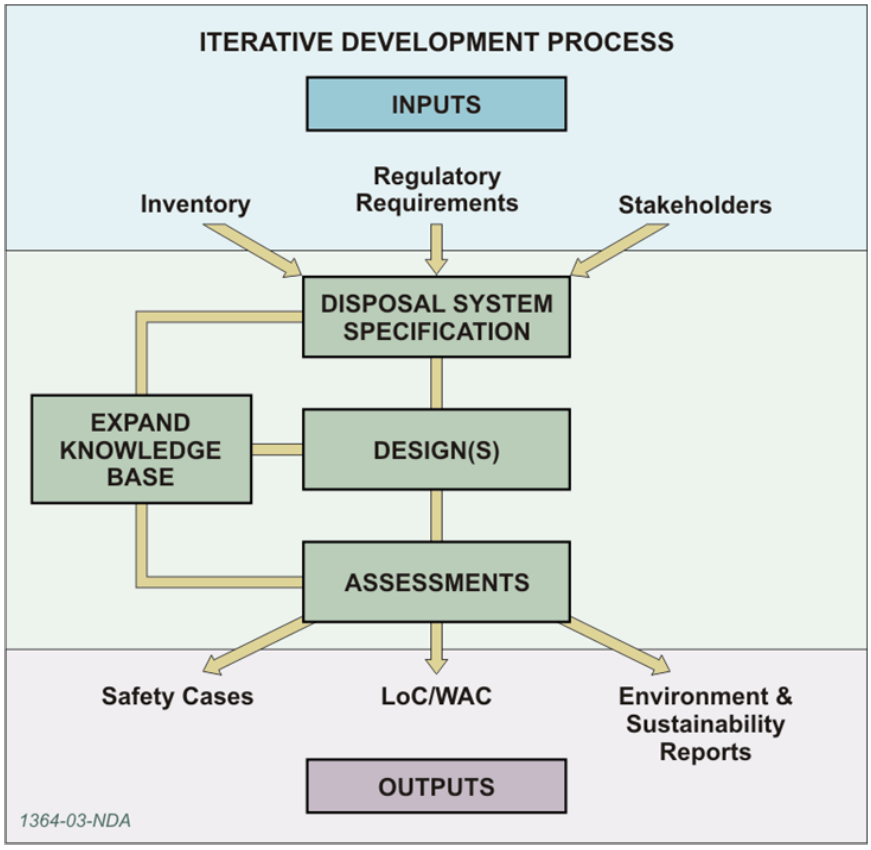
4 The safety of people and the environment both at the time of disposal and in the future.

5 The period of authorisation of a disposal facility includes the period of time while disposals are taking place and any period afterwards while the site is under active institutional control.

Figure 2 Iterative Disposal System Development



The Science and Technology Programme [34] sets out a programme for developing the data, knowledge and understanding required for the technical aspects of RWM's activities in Disposal System Specification, development, safety assessments and siting and stakeholder engagement, describing the evolution of the programme as the siting process progresses. A number of key deliverables (termed 'Major Products') necessary to deliver RWM's mission are described.

Implementation of the programme is described in the Science and Technology Plan [35], which presents an analysis of the nature and timing of RWM's future generic research and development activities and sets out a substantial research programme. Specific packages of technical work required to deliver the Major Products are described in task sheets. In addition to projects managed by RWM, it includes international projects and programmes in which RWM participates in order to gain access to information and best international practice in waste management and disposal. Although primarily an internal document used to plan research priorities, it is intended that its publication will provide opportunities for dialogue with and involvement of interested parties in the development of the knowledge base. The S&T Plan also demonstrates how RWM will fulfil the stated aim of its business plan:

> *'to continue to work with suppliers to effectively deliver the needs-driven technical programme (including research and development, design and assessments) to meet White Paper commitments, reduce uncertainties in advance of site-specific work and support work on new build wastes using their expertise and knowledge to deliver solutions to issues'*

The S&T Plan looks across a horizon of a decade, during which time it is expected that most of the planned generic research will be completed. Until the siting process results in the identification of one or more specific GDF sites, the Plan's scope is limited to activities appropriate to this generic stage. The identification of a specific geological environment,

together with the proposed disposal concept, will provide opportunities for optimisation of the S&T plan.

Previous versions of the Science and Technology Programme and the S&T Plan were produced in 2014 and together formed the Technical Programme [34]. The need to replace and restructure the Technical Programme came from significant developments in the implementation programme, including the establishment of RWM as a wholly-owned subsidiary of the NDA on 1 April 2014 and the publication of the 2014 White Paper.

Documents reporting on findings of each part of the iterative process are brought together in the generic DSSC. The suite of documents, which is described further in Section 3, includes the safety and environmental assessments together with the specification, design and research status reports that represent the underpinning knowledge base.

The 2010 generic DSSC brought together more than 25 years of work by RWM, its precursor organisations and other waste management organisations in examining the scientific basis for geological disposal, including periodic scientific updates and safety studies. The generic DSSC has been updated, in this 2016 issue, via a rigorous change control process, so that it may continue to inform iterative development, as well as providing an up to date basis for disposability assessments of proposed waste packages. This generic DSSC will continue to be subject to review and update, either in whole or in part, as the specification and designs develop and as the status of research advances. Where necessary, individual generic DSSC documents will be revised or replaced, with new documents added as appropriate.

Factors that drive the iterative process include the following:

- Regulatory expectations for periodic review and update of the safety cases which, for the DSSC, will continue throughout the GDF design, construction and operational periods. The maintenance of the DSSC, like any safety case, must include review against current standards and take account of new knowledge and experience gained nationally and internationally.
- Completion of further work identified during a previous iteration. Many of the 2010 generic DSSC documents identified knowledge gaps, and made recommendations on where future research and development should be targeted. Accordingly, a number of work packages were identified, incorporated into the Science and Technology Plan, and implemented to improve the knowledge base. Results from these work packages have been, and continue to be, incorporated in the development of the illustrative disposal concepts and the generic illustrative designs.
- Feedback from stakeholders. The regulators [36] and CoRWM [37] reviewed and commented on the 2010 generic DSSC, and in response RWM updated its work programme to take account of that advice. Findings from these work packages have been incorporated into the generic DSSC as is appropriate at this stage.
- Issues are from time to time raised by stakeholders and RWM operates an issues management process [38] to ensure these are captured and acted upon as appropriate. The process includes the identification of any work that needs to be incorporated into the Science and Technology Plan and any matters that may need to be fed back into the Disposal System Specification or safety assessments.
- Optimisation is a fundamental duty under the Health and Safety at Work etc Act 1974 [26] and is therefore a key element of the iterative development process. This is discussed in more detail in Section 2.7.

Following the publication of the 2013 UK Radioactive Waste Inventory [39] and the July 2014 White Paper, RWM considered it an appropriate time to update the generic DSSC. More information on the drivers behind this specific update and how they have been taken into account is provided in Section 4.1.

RWM's remit to implement geological disposal brings with it a need to work closely and pro-actively with key stakeholders to share knowledge, report progress, provide advice and promote good practice. For example, RWM advises waste producers on the disposability of their higher activity wastes, informs Government on topics such as estimated costs of disposal, works with the NDA in implementing the NDA Strategy and will engage with potential host communities to inform decision making.

2.7 Optimisation

Optimisation - the requirement to reduce risks so far as is reasonably practicable (SFAIRP) (or as low as is reasonably practicable - ALARP), is a fundamental legal duty and is therefore a key element of the specification, design, development, and safety assessment of a geological disposal system. Optimisation for radiological protection is also a principle in the EA's Guidance on Requirements for Authorisation. Optimisation needs to consider the entire lifecycle of the system: the regulators have specifically indicated that they expect to see evidence of the balance between operational and post-closure safety being taken into account in the decision-making process.

RWM discussed optimisation with the regulators in advance of the publication of the 2010 generic DSSC and following its review. The regulators published their review of the generic DSSC in December 2011 and in June 2012 RWM published its initial response [40]. Following this, the regulators raised a Regulatory Observation (GDF-RO-002) that:

> *'From our dialogue with RWMD it is clear that RWMD is incorrectly interpreting the regulatory requirement to optimise for radiological protection...'*

The regulators identified three specific actions to be addressed in response to this regulatory observation:

- to establish a common and clear understanding of regulatory expectations regarding optimisation as applied to geological disposal
- RWM to lay out in broad terms its process for optimisation in a radiological protection sense over the lifetime of the GDF programme
- RWM to present any optioneering or optimisation work in progress or planned that may be relevant to the operational and/or post-closure safety of the GDF

RWM subsequently provided to the regulators an approach to address each action. The key points are:

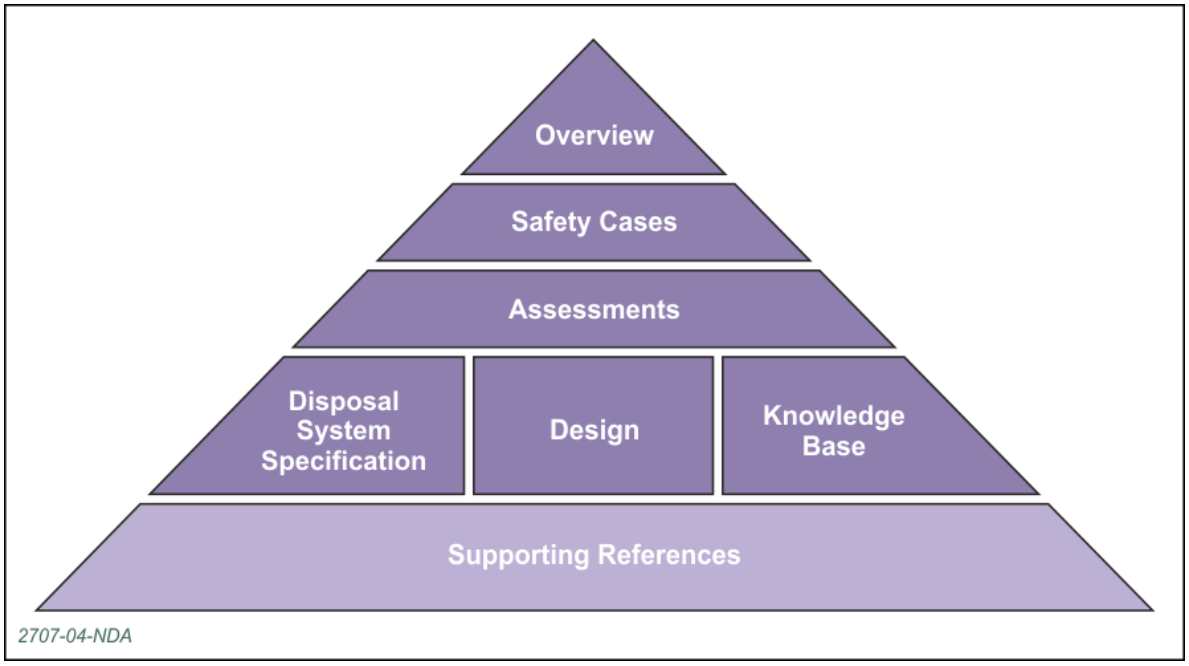
- optimisation is an intrinsic part of RWM's approach to site-selection, concept-selection and design development
- the approach to optimisation at the current stage is focussed on non-foreclosure of options, that is, ensuring that waste packaged now will be suitable for transport and disposal without unduly ruling out options for future implementation of geological disposal

More detailed optimisation work, such as Best Available Techniques studies for environmental matters, and consideration of the reasonable practicability of additional risk reduction measures for health and safety, will be carried out when a suitable site and initial design have been identified.

3 Signposting to Other Generic DSSC Documents

The suite of documents that make up the generic DSSC, and its high-level structure, are shown in Figure 3. At the top of the hierarchy is the Overview (this document), which presents the main reasons why RWM is confident that the waste can be disposed of safely, and provides a summary of, and guide to, the document suite. The second tier comprises the safety cases themselves, which cover the transport of radioactive waste to the GDF (the generic TSC), the operation of the facility (the generic OSC) and its long-term safety following closure (the generic ESC). The assessments support these safety cases with more in-depth data and illustrative evaluations and also address other environmental and sustainability considerations. In the fourth tier, the Disposal System Specification, design and knowledge base provide the basis for these assessments. The whole suite is underpinned by an extensive set of supporting references.

Figure 3 Structure of the generic DSSC



The documents that together comprise the generic DSSC suite are listed in Appendix A.

Figure 4 expands on Figure 3, showing the documents within each tier. (The abbreviated document names used in Figure 4, and the subsequent three Figures, are explained in Appendix A.) Figure 4 also shows the relationships between the document tiers and groups and indicates the overarching safety management system controls for the production of documents at all levels. The feedback loops between the assessments and the specification, design and knowledge base are shown as green arrows.

Figure 5, Figure 6 and Figure 7 provide greater detail for each of the three main safety cases: the generic TSC, generic OSC and generic ESC respectively, mapping the relationships between the individual documents relevant to each. These Figures follow the same structure of Figure 3, but each tier is expanded to show the documents from which the safety cases and assessments are developed and those documents that they support.

Figure 4 **Relationships between generic DSSC document tiers**

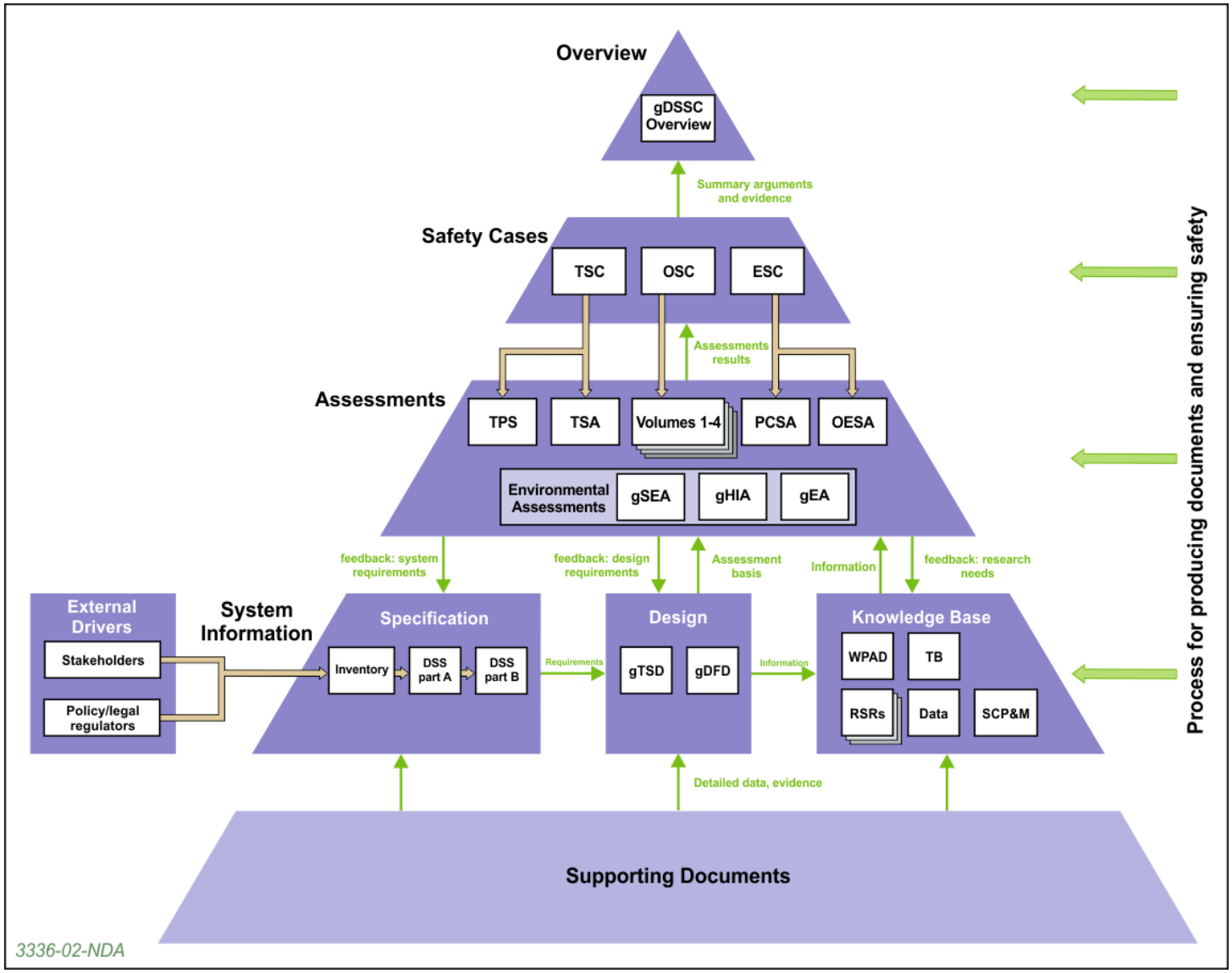


Figure 5 Map of relationships between TSC documents

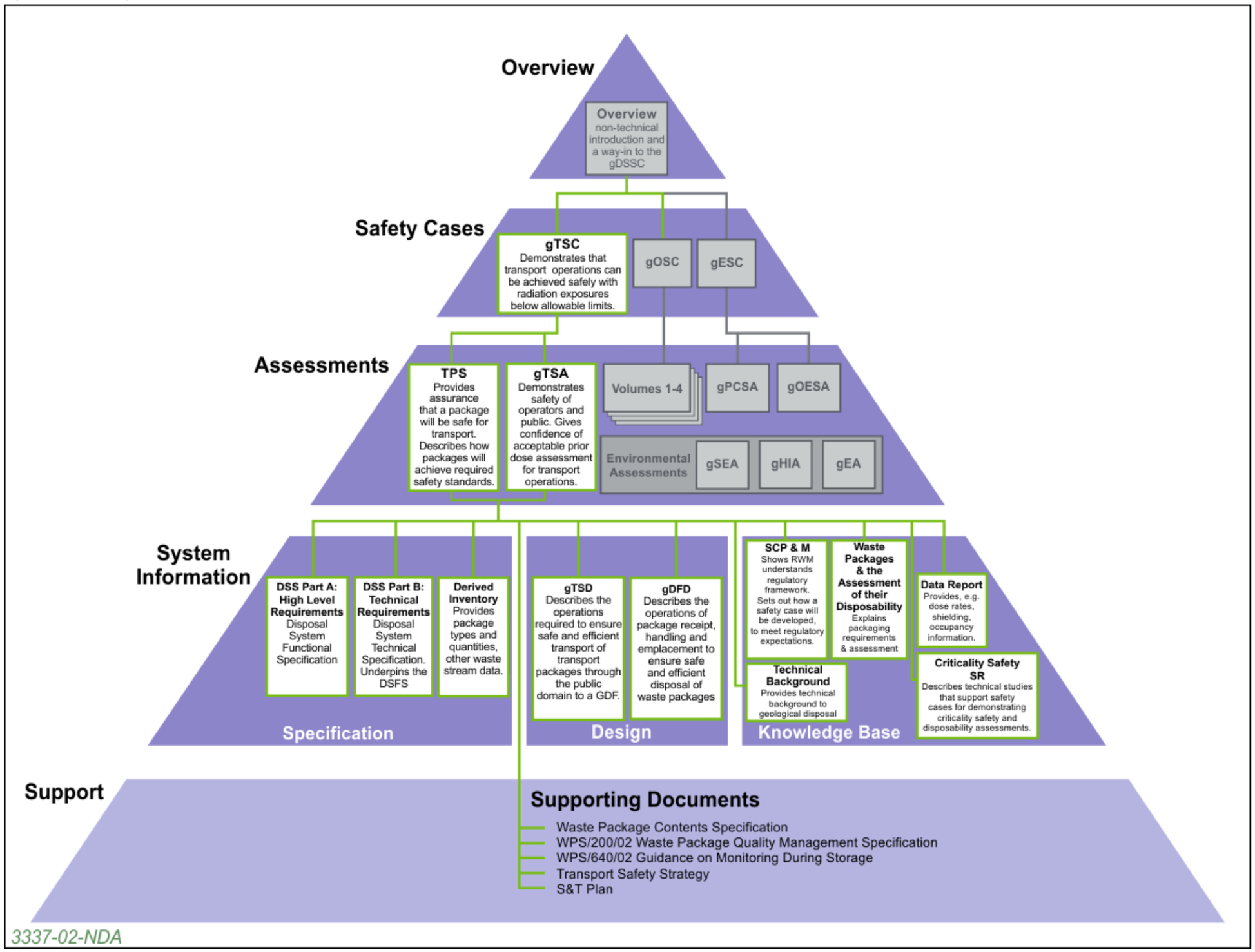


Figure 6 **Map of relationships between OSC documents**

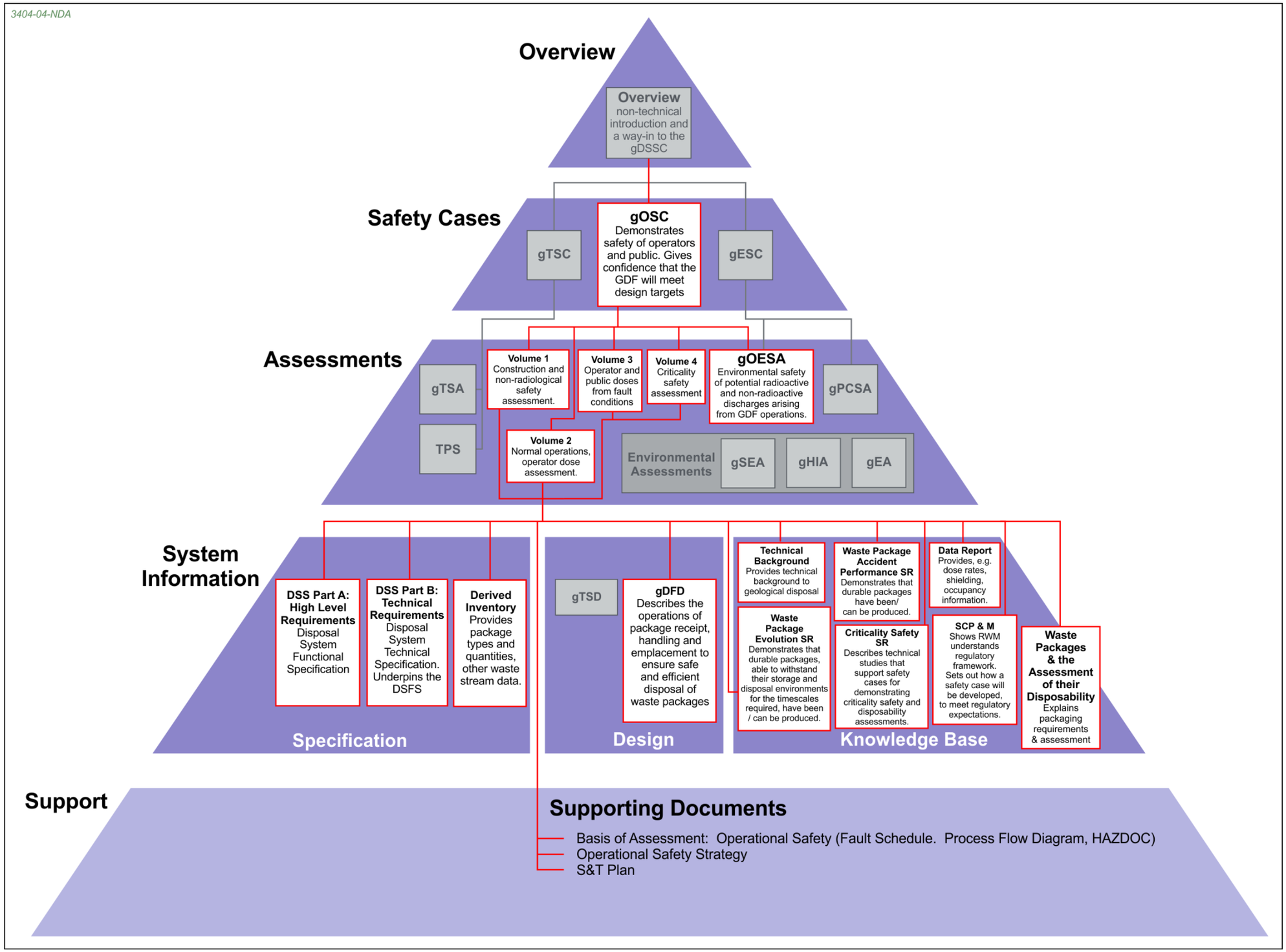
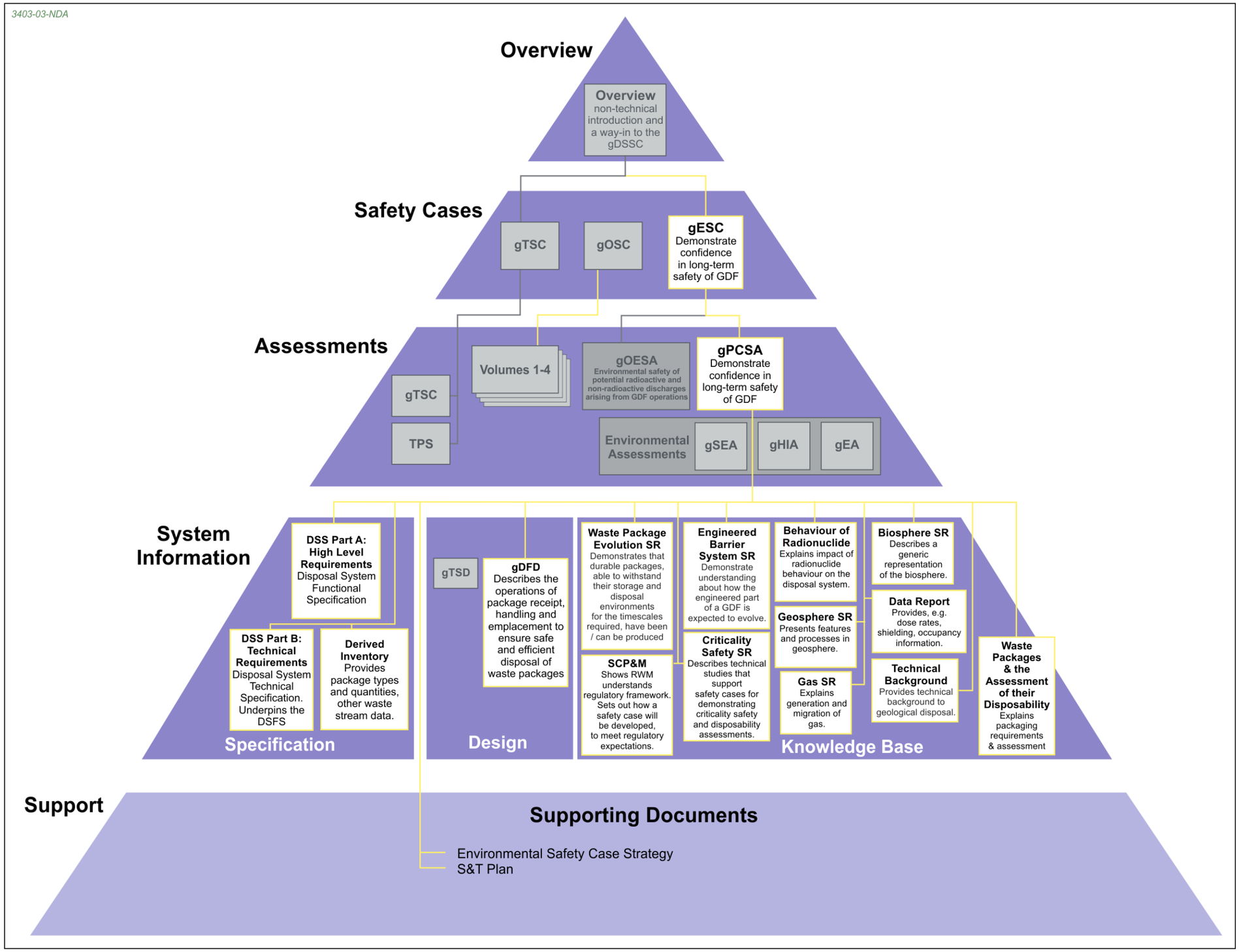


Figure 7 **Map of relationships between ESC documents**



4 Developments since the Previous Generic DSSC

4.1 Drivers for updating the 2010 generic DSSC

The first generic DSSC, produced in 2010, demonstrated confidence that RWM will be able to make a full safety case for the GDF at an appropriately selected site at the appropriate time. It noted that there are uncertainties, some of which will remain until a site is identified, and others that RWM is able to investigate now through its Science and Technology Programme. Since its publication, certain developments, such as the updated inventory for disposal and improvements in the knowledge base, have had the potential to impact on the key safety arguments. Hence it is necessary to check that the arguments remain valid and up to date.

Until now, the generic DSSC has been kept up to date by publication of additional, interim documents, such as a report on the implications of changes to the waste inventory [41]. Eventually, however, the combination of a number of drivers warranted an update of the whole suite of documents that make up the generic DSSC. The main drivers were:

- the publication of the 2013 UK Radioactive Waste Inventory (UKRWI) and subsequent 2013 Derived Inventory [42] and alignment with the 2014 White Paper

  The 2013 Derived Inventory was developed from the 2013 UKRWI by identifying which wastes would be suitable for disposal in the GDF. The 2013 Derived Inventory also includes additional information needed for design and safety assessment work, such as information about the likely packaging for each waste stream.

  The 2010 generic DSSC was based on the 2007 Derived Inventory [43]. An addendum [41] was later published to explain the implications of the 2010 Derived Inventory, which were not sufficient to warrant a complete update of the generic DSSC. However, the 2013 Derived Inventory is sufficiently different from the 2007 Derived Inventory to warrant a complete update.

- the need to support the revised siting process. The updated generic DSSC will provide information to interested communities following completion of the initial actions of the siting process, provide a basis for the early assessment of the suitability of potential sites and provide a source of information to support the development of site-specific designs and safety cases

- the significant improvements in the knowledge base, including improved understanding of the behaviour of waste degradation products, improved post-closure criticality assessment and the development of the approach to gas assessment

- the adoption of design enhancements identified through iterative improvements.

- the need to respond to feedback from regulators and CoRWM on the 2010 generic DSSC

4.2 Changes and improvements in the 2016 update

The current generic DSSC is the result of the first simultaneous update of the entire suite of documents since 2010. Changes specific to each document, including information regarding how each document addresses comments such as peer review, are noted within the individual documents. The key changes to the generic DSSC suite as a whole are as follows:

1. Changes relating to the inventory:

   a. **Changes to the inventory itself**

      As noted in Section 2.2, the inventory for disposal has been updated to align with the 2014 White Paper and, as noted in Section 4.1, the most recent update to the UK Radioactive Waste Inventory. The most significant changes are: the inclusion of wastes and spent fuel associated with a 16GW(e) nuclear new build programme; reuse of 95% of existing plutonium stocks as mixed oxide spent fuel; the exclusion of waste managed under the Scottish Government's policy for higher activity wastes[6] and the inclusion of material associated with UK defence activities. It also allows for new waste containers in the packaging assumptions, these being Disposal Containers for spent fuel and vitrified HLW, Ductile Cast Iron Containers and the concrete drums proposed by EDF Energy. Changes in the inventory have led to an increased GDF footprint and extended operating time, and consequently assumptions regarding emplacement times have been updated.

   b. **A revised approach to consideration of the inventory for disposal**

      The ways in which different types of wastes are considered have been changed for the purposes of developing disposal concepts, in order to align better with waste-related requirements on system design. The waste categories (HLW, ILW etc) remain but the main breakdown is now into:

      High heat generating wastes (HHGW): spent fuel from existing and future power stations and HLW from spent fuel reprocessing. High fissile activity wastes, that is, plutonium (Pu) and highly enriched uranium (HEU), are also included in this group. These have similar disposal requirements, even though they do not generate significant amounts of heat.

      Low heat generating wastes (LHGW): ILW arising from the operation and decommissioning of reactors and other nuclear facilities, together with a small amount of LLW unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU).

      The breakdown thus reflects the key differences in time of arising, waste packaging and assumed emplacement in the GDF. For example, new build spent fuel is distinguished from legacy spent fuels which will be emplaced earlier. This approach differs from that of the 2010 generic DSSC, where the inventory for disposal was discussed simply in terms of ILW, HLW and spent fuel.

   c. **Treatment of uncertainty in the inventory**

      Understanding of uncertainty in the inventory for disposal has been improved through consideration of a wide range of inventory scenarios. These inventory scenarios have been developed to allow consideration of potential changes to the UK nuclear programme, for example, a decrease in Magnox fuel reprocessing or an increase in the anticipated operational lifetime of legacy reactors. This differs from the approach in the 2010 generic DSSC where inventory uncertainty was explored through the use of a single 'Upper Inventory' that made allowance for all the major uncertainties, including use of upper estimates, new build arisings and defence materials.

[6] The packaged volume of HAW associated with sites in Scotland is around 40,000 m^3. By comparison, the packaged volume associated with the 2013 Derived Inventory is nearly 764,000 m^3 (taking into account DNLEU packaging assumptions). If the wastes managed under the Scottish Government's policy were to be included in the inventory for disposal in the GDF, they would result in an increase in the packaged volume of just under 6%.

2. **A balanced approach to the presentation of safety in the geological environments**

   A more balanced assessment is now made, considering multiple geological environments each based on a host rock typical of UK geologies, namely a higher strength rock, a lower strength sedimentary rock and an evaporite rock. For each of these, illustrative disposal concepts for both LHGW and HHGW have been selected and used as the basis for the illustrative designs. This is an improvement on the 2010 generic DSSC approach which used an illustrative disposal concept for a higher strength host rock as a reference case, with quantitative or qualitative consideration of other host rocks.

3. **Improved safety case structures and methods**

   Greater emphasis is placed on demonstrating how safety is ensured through provision of safety functions by specific components in the disposal system, for example the requirement of the waste package to provide containment for post-closure safety and a means of safe handling for operational safety. The generic OSC has an improved structure, in readiness for a straightforward transition to a Pre-Construction Safety Report when required. Updated calculation models have been used and more robust safety case methods and procedures now defined in RWM's Quality Management System [44] have been followed. The scope of certain documents, in terms of what aspects of safety they cover, has been clarified.

4. **Updated Research Status Reports**

   Significant progress has been made in the underpinning knowledge base, and this is reported in the research status reports which set out the knowledge base on which the generic DSSC is based. The remaining significant uncertainties are subject to large, focused research projects undertaken by RWM. These large projects, together with other research and development planned to address knowledge gaps, are described in the Science and Technology Plan.

5. **A new approach in the Research Status Reports**

   In the 2010 generic DSSC, the Research Status Reports presented research findings in the context of safety and started to develop safety arguments. In the current generic DSSC they present the knowledge base but no longer develop safety arguments. Safety arguments are now made in the safety reports, drawing on the information presented in the Research Status Reports.

6. **Learning from experience**

   Experience gained from sister organisations and events that have occurred around the world has been incorporated into the safety cases. Examples include learning from the European Nuclear Safety Regulators Group stress tests carried out following the tsunami at Fukushima in 2011, safety studies undertaken by the US Department of Energy at the Waste Isolation Pilot Plant in New Mexico, other reviews by sister organisations and lessons learned from major construction projects.

7. **Improved and updated generic designs and design information**

   Including enhancement to the underground layouts of the vaults and tunnels, changes to the surface layout to improve security and adoption of new package types.

8. **Updates to take account of updated regulations and legislation**

   For example, changes to the fissile exception rules in the 2012 edition of the IAEA Transport Regulations. Another example is the consideration of the effect of non-radiological chemotoxic components of the inventory for disposal. The Environmental Permitting Regulations [30] place requirements on the conduct of activities in relation

to groundwater, and these are now reflected in the Disposal System Specification. The implications of these requirements are discussed qualitatively in the generic ESC.

The majority of the documents that make up the current generic DSSC are updates of the corresponding documents in the 2010 generic DSSC. However, there are a number of additional documents, as follows:

- **An Overview of the generic Disposal System Safety Case (this document)**

  This Overview is different from the 2010 generic DSSC Overview. As noted in Section 1, the 2010 generic DSSC Overview was a public-facing document that presented the key technical concepts and safety case messages to interested stakeholders. This Overview is primarily intended to present the key messages from the safety cases (summarised in Section 6 of this document) to the regulators and to provide a guide to the suite. It also gives information on the role, scope and structure of the generic DSSC, its history, future development and the processes followed in its production. Unlike the 2010 Overview, it does not give detail on the technical background to geological disposal, as this is provided in the Technical Background document (see below).

- **Technical Background to the generic Disposal System Safety Case [3]**

  This document collates all common technical background information into a single report, thus avoiding the repetition of this information in individual documents.

- **Use of Data in the generic Disposal System Safety Case [45]**

  This document provides a single reference to all data used in the generic DSSC, providing pointers to data sheets within RWM's data catalogue where specific data are held. It also describes how RWM's Data Management procedure ensures a robust system is in place for the correct, appropriate and consistent use of data.

- **Derived Inventory Scenarios Report [46]**

  This document describes the sensitivity of the 2013 Derived Inventory to a number of different scenarios.

- **Environmental and Sustainability Assessments of geological disposal implementation**

  These documents provide information on the non-radiological, non-safety, effects of the implementation of geological disposal on the environment, socio-economic factors and health. They are:

  - **The Generic Environmental Assessment [8]** provides information on the potential environmental effects of geological disposal implementation. It also informs the iterative development of the disposal system design, incorporating environmental mitigation and enhancement measures, as appropriate.
  - **The Generic Socio-economic Assessment [9]** assesses direct and indirect effects of geological disposal implementation on socio-economic factors and identifies opportunities for improvements.
  - **The Generic Health Impact Assessment [10]** provides information on potential health and well-being effects of geological disposal implementation.

The following document was included in the 2010 generic DSSC, but not in the current generic DSSC:

- **Summary of Generic Designs [47]**

  As the current generic DSSC is primarily intended for a regulatory audience, this high-level design summary is no longer necessary.

Lastly, the 2010 generic DSSC document titled the Near-field Evolution Status Report [48] has been renamed as the Engineered Barrier System Status Report [49].

5 Management Arrangements

This section describes RWM's Quality Management System and how it has been applied to this generic DSSC. It goes on to explain how RWM will evolve into an organisation capable of operating the GDF.

5.1 The Quality Management System

RWM holds certification to ISO 9001:2008 and ISO 14001:2004 from Lloyd's Register Quality Assurance, and the requirements of these certifications are met by RWM's Quality Management System [44].

The generic DSSC has been produced in accordance with the Quality Management System, which defines the organisation's quality objectives as follows:

- comply with all relevant legislation, regulations and other applicable requirements
- provide a listening, responsive and professional service to all stakeholders
- complete the agreed work programmes on time and within budget
- deliver results which are focused, wholly dependable, robust and fit for purpose
- achieve the best value from the Company's resources

In addition, RWM operates a safety and environmental management system which is documented in a suite of reports that are part of RWM's Quality Management System. Key reports include the following:

- Safety and Environmental Management Prospectus, which provides information on RWM's safety management system and how a positive safety and environmental culture is promoted.
- Organisational Baseline Document, which supports the Safety and Environmental Management Prospectus by defining what constitutes a suitable and sufficient organisation. It sets out all RWM's responsibilities for nuclear safety and environmental matters, including maintaining the DSSC, and indicates how these are covered by each of the posts within the organisation and the associated safety and environmental competence requirements.

Thus the generic DSSC has been developed to a high standard of quality and in accordance with the requirements of ISO 9001:2008 and ISO 14001:2004. The Competency Management System ensured that documents were produced only by individuals with the relevant competency level or under the control of individuals with Intelligent Customer status. Models were developed, calculations checked, and data selected and used appropriately in a controlled manner and documented accordingly.

Full details of RWM's safety strategy are given in the Safety Case Production and Management report [15].

5.2 Application of the Quality Management System to the generic DSSC

The Quality Management System is made up of a comprehensive range of procedures that cover all aspects of the work undertaken in producing this generic DSSC. These include procedures for producing and maintaining the transport, operational and environmental safety cases.

Important stages in the production of the generic DSSC as seen from a quality perspective are document production, change management, document review, control of calculations

and data management. The way in which quality has been assured in each of these areas is described below.

5.2.1 Document production

All reports in the generic DSSC suite have been produced in accordance with RWM's Document Management procedure. This procedure, which covers production and review, has been updated and improved since the production of the 2010 generic DSSC. The updated procedure addresses regulatory feedback and includes learning from the production of the 2010 generic DSSC.

An important improvement implemented in the production of the generic DSSC is the introduction of a mandatory Document Quality Plan for each document, which sets out for prior agreement the objectives, scope, a draft contents list and a detailed quality review plan that specifies reviewers, terms of reference and dates for each review stage of each document. Regulators reviewed summary versions of the Document Quality Plans, referred to as one-page Product Definition Documents, prior to the production of the documents and provided valuable feedback[7] which was taken into account in document production.

Also during the planning stage, RWM produced storyboards, that is, expanded contents lists, for new documents and provided these to the regulators for comment. Storyboards for this Overview, the Technical Background and the Data Report were provided to regulators and feedback[8] has been addressed.

An RWM member of staff expert in the relevant field led the production of each document in the generic DSSC. The competence of RWM staff is measured and assessed in accordance with RWM's Competence Management System, which sets out criteria for specific competencies in all technical areas relevant to RWM's work. Specialist contractors wrote the first drafts of some documents within the suite. Such contractors were selected though a competitive tendering exercise based on an evaluation weighted towards technical competence. Others documents are written by the RWM document lead. In all cases, the RWM document lead was the intelligent customer as defined by the Health and Safety Executive (HSE) [50] and the ONR [51].

5.2.2 Change management

Many of the generic DSSC documents are updated versions of equivalent documents issued as part of the 2010 generic DSSC. The changes were managed and controlled via the procedure for implementing periodic updates, as described in RWM's Change Management procedure. This involved the following activities:

1. During the planning phase for the generic DSSC update, document owners identified the key proposed changes to their respective documents and proposed a change categorisation, as required by RWM's Change Management procedure. These planned changes were presented to RWM's Nuclear Safety and Environment Committee (NSEC) for their advice and scrutiny prior to report production.

   NSEC was in support of all changes, with the exception of a change in the assumption that backfilling of the ILW vaults would no longer be carried out during the closure phase, but would instead be brought forward and carried out for each vault once filled; the Committee felt that there was insufficient justification at the time for this assumption. Hence this change has not been implemented.

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7 Environment Agency Ref: GDF/T&O/2015/07; ONR Ref: RWML70021N

8 Environment Agency Ref: GDF/T&O/2015/08

2. The implications of proposed changes to documents were evaluated and justified prior to the documents being written. All changes with a NSEC Category A or B, that is, higher safety or environmental significance[9], were reviewed by NSEC for advice.
3. During report production, document owners maintained a log of the more detailed changes, and as the reports neared completion, these were collated in order to understand fully the combined implications. This holistic view enabled additional changes introduced during document production or in response to document review to be evaluated and justified. It also enabled consideration of whether the cumulative effects of a large number of low categorisation changes could have more significant impacts. The NSEC provided advice on this process for managing change.
4. On completion of the final drafts, an audit was conducted to ensure that all proposed changes were enacted as proposed, and to confirm that due process was followed.

5.2.3 Document review

The quality review stages of the generic DSSC documents were in accordance with RWM's Document Production Procedure. For each document, a number of internal and external reviews have been carried out. Internal reviews started with verification checking and, in the case of contractor-produced reports, acceptance checking. These were followed by internal review to ensure the document met its objectives and communicated the key messages clearly, then internal approval for subsequent external review.

External review included peer review for every document. The safety case main and relevant underpinning reports also went through Independent Assessment (by an internal RWM team independent of the document production team) led by RWM's Health Safety Security, Environment and Quality department (HSSEQ) and received additional Endorsement by NSEC. The underpinning assessments were made available to HSSEQ and NSEC for reference. Finally, when these reviews were completed and their findings addressed, each document was approved internally for issue or publication.

Peer review

All documents in the generic DSSC have been reviewed by two independent peers who are technical experts in the document's topic area. RWM's response to each comment was recorded and discussed with the peer reviewers where necessary. The peer reviews conducted are listed in Appendix B , together with a summary of the main issues they raised and RWM's responses.

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[9] A Category A change has the potential to fundamentally affect the way RWM operates, and to compromise safety or environmental protection or the integrity of the packaging advice process. A Category B change is significant to RWM's structure, technical capability or operations, with the potential to significantly affect safety or environmental protection or the integrity of the packaging advice process.

Independent assessment

There is a regulatory expectation [52] that documents of high safety and/or environmental significance undergo Independent Assessment. In line with this regulatory expectation, within RWM, independent assessment is carried out or managed by the HSSEQ department using competent people independent of the functions involved in the production of the safety case. Independent assessment considers the technical content of the safety case, as well as the adequacy of previous steps in the safety case process. Independent assessment therefore takes place after in-function reviews and external peer review, and informs NSEC in considering additional Endorsement.

Additional endorsement

RWM's Document Production procedure includes an option for additional Endorsement prior to issue or publication. This would normally be required if the document supports the work of, or is of particular interest to, an external organisation. The need for the generic DSSC Safety Case Main Reports to undergo additional Endorsement was agreed at the planning stage and was undertaken by NSEC, in accordance with NSEC's role of providing advice and scrutiny, independent of projects or safety case development.

5.2.4 Control of calculations

All mathematical models and calculations used in the production of the generic DSSC have been developed and checked in accordance with RWM's procedure for Computer Modelling, Software Development and Calculation Checking.

Models developed by RWM have been developed and controlled in accordance with the procedure and the defined roles of Model Senior Responsible Owner and Model Technical Owner. The procedure covers life-cycle development of models, including the requirements for specifications, verification testing, configuration control, etc. Development of software and mathematical models carried out by contractors has also been done under the strict control of the procedure and the contactors' own Quality Management System. Ad-hoc calculations have also been verified in line with the procedure.

5.2.5 Data management

Data control has been implemented in the generic DSSC in accordance with RWM's Data Management procedure. RWM has a central catalogue of all data used in the organisation, from which data used in the generic DSSC have been drawn. As data are collated, they are logged into the Data Catalogue and recorded on Data Definition Forms, along with a reference, a statement on the quality of the data and pointers to individuals responsible for the data. In drawing upon data in the Data Catalogue for use in the generic DSSC, information on the data use is recorded on a Data Use Form and approved by the relevant internal authority. Information recorded on the Data Use Form includes the Data Definition Form from which the data were taken, the suitability of the data for the specific application and, in some cases, which parameter was selected from a range and why.

Specific roles and responsibilities have been defined for the control and management of data: a Data Owner has responsibility for specific data sets and a Data Manager supports and facilitates interactions between Data Owners and Data Users. RWM's Information and Knowledge Systems Manager and the Data Assurance Manager provide assurance that data are used appropriately. These roles apply across RWM, not just to the generic DSSC.

All data used in the generic DSSC, and the Data Management procedure are described in the Data Report [45], which is a new report in the generic DSSC.

5.3 Organisational development

This section explains RWM's vision and the steps being implemented to develop RWM into an organisation that has the capabilities and competencies to deliver the GDF.

RWM's vision, mission statement and values, as set out in the Corporate Strategy inform the Policy and all of RWM's activities. The vision is to ensure a safer future by managing radioactive waste effectively, to protect people and the environment. In order to achieve this, RWM's mission is to deliver the GDF and provide radioactive waste management solutions.

RWM's values describe the type of organisation that it strives to be and are used in developing the organisation and its people. The values, as listed in the Corporate Strategy are:

> *'**Professional**. We are experts in our field, acting with integrity and efficiency to deliver the best solutions.*
>
> ***Responsible**. We are committed to achieving the highest standards of safety and environmental protection.*
>
> ***Accessible.** We are open and communicate in a straightforward way that enhances understanding and encourages engagement.*
>
> ***Learning.** We continuously learn, share knowledge and build strong mutually beneficial relationships.'*

Ultimately, RWM will evolve into the organisation responsible for the construction, operation and eventual closure of the GDF. RWM will therefore have to demonstrate that it is capable of fulfilling the duties and achieving the standards required of an organisation that holds Environmental Permits and a Nuclear Site Licence.

Since December 2009, RWM has functioned as a 'Prospective Site Licence Company' (SLC). A Prospective SLC embodies the culture and demonstrates the competences of a company that is to hold an environmental permit and a nuclear site licence. The establishment of a Prospective SLC is the first step towards becoming a SLC / permit holder. As a Prospective SLC, RWM voluntarily submits itself to scrutiny by the regulators. Such scrutiny does not comprise formal regulation, but regulators are able to apply the appropriate rigour of the regulatory process and to examine RWM against all relevant aspects of legislation and regulatory guidance.

As noted in Section 2.1, RWM became a wholly-owned subsidiary of the NDA in 2014. This enabled the required separation of waste producer and disposal implementation functions to be achieved, allowing RWM to develop into an independent SLC operating the GDF.

RWM has a Policy for Management of Organisational Change for the GDF Delivery Organisation [53]. This policy covers any proposed change to RWM's organisational structure, resource or competence requirements. Any proposed change to the organisation is first assessed and categorised on the basis of its potential to affect safety and/or environmental compliance. Where the proposed change is significant, it is discussed by NSEC before the change is made. After a change has been introduced, there is a period of monitoring to ensure that the change had the desired effect and did not produce any unexpected adverse consequence.

In keeping with its vision, RWM is committed to fostering a learning culture. This is achieved through the following mechanisms:

- Operational experience: RWM works with several overseas waste management organisations to identify areas of common interest where mutual benefit can be gained through cross-fertilisation of ideas and sharing of experience.
- RWM is a member of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), which acts an international forum of national

waste management organisations. RWM is also a member of the 'Club of Agencies', which brings together the waste management organisations within Europe. RWM currently chairs the OECD-NEA Integration Group for the Safety Case (IGSC), the leading technical organisation for safety case experts from waste management organisations and regulatory bodies.

All aspects of organisational development are subject to regulatory scrutiny. There is an ongoing programme of regulatory inspections in which responses to any recommendations made by the regulators are agreed with them and the regulators monitor the satisfactory implementation of the agreed actions.

6 Summary of Key Conclusions and Arguments

The conclusions of the three main safety cases: for transport, operational and environmental safety are summarised in Sections 6.1 to 6.3 respectively. Overarching issues and key messages are outlined in Section 6.4.

The conclusions of the environmental and sustainability assessments of non-radiological effects are summarised in Section 6.5. As noted previously, these assessments do not contribute to the safety arguments, but are included in the generic DSSC as they contribute to the iterative development of the disposal system, and to the bank of information available to stakeholders.

6.1 Conclusions from the TSC

The generic TSC demonstrates why RWM has a high level of confidence that the inventory for disposal can be transported from its various locations to the site of the GDF in accordance with the requirements of the IAEA Transport Regulations, as implemented by UK regulations, and within RWM's own radiological criteria as currently defined.

The arguments and evidence for this confidence are derived from two main sources:

- the **Transport Package Safety report** (TPS) [54], which explains how packages will comply with the IAEA Transport Regulations, and how it is ensured that wastes prepared for transport now will be safely transportable in the future
- the generic **Transport Safety Assessment** (TSA) [55] which presents an illustrative assessment of radiological doses to operators under routine conditions of transport, from the system as a whole

Compliance with the IAEA Transport Regulations

The Transport Package Safety report describes the procedures, assessments and approvals that are, or will be, in place to ensure compliance with the IAEA Transport Regulations.

The key principles enshrined in the IAEA Transport Regulations are to ensure containment of the radioactive contents, control of external radiation levels, prevention of criticality and prevention of damage caused by heat. These principles are to be met by requiring that:

- safety is ensured mainly by the engineering design of the package, and limits on the contents, thus reducing the need to depend on operational controls such as route restrictions or speed limits
- packaging and performance requirements are proportionate to the nature and quantity of the contents (that is, to the magnitude of the hazard)
- appropriate responsibilities are assigned to all parties concerned with the transport operation, including the consignor, who has responsibility for preparing the packages for transport, and transport operators

The underlying principle is that radiological safety is primarily to be ensured by the package and contents limits, regardless of how they are transported. Safety is inherent in the package, rather than being dependent on site and route-specific factors or operational controls.

Thus, by complying with the IAEA Transport Regulations, the designs, procedures, assessments and approvals will limit the consequences of accidents, as well as keeping doses to workers and the public from routine operations (for each individual package), below the criteria set out in the Regulations.

Safe future transport of wastes being prepared currently

The Transport Package Safety report also describes how RWM interacts with waste producers through the Disposability Assessment process, using the generic TSC as a benchmark against which the suitability of waste packages for transport (and disposal) is assessed. This process gives confidence that wastes conditioned and/or packaged now will be safely transportable in the future. It also gives confidence to RWM that transport safety documentation is appropriate for the current stage and that the strategy for producing and maintaining transport safety documents in the future is appropriate. In particular, by describing requirements for waste package records, it gives confidence that the checks required during package manufacture and storage (which cannot be done retrospectively) can be carried out as necessary, such that the records required for transport will be in place and complete.

Radiological doses to operators under routine conditions

While the Transport Package Safety report considers the radiological safety of each individual package, the generic Transport Safety Assessment complements it by considering the overall transport operation.

The generic Transport Safety Assessment provides an illustrative evaluation of doses to transport operators from routine operations, and compares these doses with RWM's safety criteria. This serves two purposes. Firstly, it forms a basis for the prior radiological evaluation that is required as part of developing a Radiological Protection Plan, as required under the IAEA Transport Regulations. Secondly, the dose estimates provide a baseline against which the safety benefits of potential additional risk control measures can be compared, as part of the optimisation (ALARP) studies that will be needed to ensure compliance with the requirements of the IRRs and the HSWA.

This dose evaluation showed that for the illustrative transport system design, even under bounding conditions (for example, operations involving packages with the maximum dose rate and maximum annual exposure times), there is no operator group for which annual individual doses would exceed the legal limit. A best estimate dose assessment indicated that doses to operators can be kept below RWM's Basic Safety Objective (BSO).

Further work

While the TSC provides confidence that safe operation can be achieved, despite uncertainty in aspects of the system, it has identified areas in which data will particularly need to be obtained or refined, for example regarding the waste inventory, dose rates from certain packages and the details of operator job design and tasks.

By identifying the most significant contributors to dose (in terms of, for example, exposed groups, tasks and waste streams), the dose assessment has highlighted a number of areas where optimisation could be most effectively focused.

6.2 Conclusions from the OSC

The generic OSC is a safety focused feasibility study for the generic stage of the GDF programme. It makes no assumptions about the geological environment or the design detail. It considers the safety of operators and the public during construction and operation and presents the arguments and evidence to substantiate the following claims:

It focuses on ensuring that all reasonably practicable steps will have been taken to implement design provisions whose function is to prevent:

- or minimise the risk of injury due to conventional hazards
- or minimise routine exposures to radiation sources

- or mitigate the consequences of radiation accidents
- or mitigate the consequences of nuclear accidents (i.e. unplanned criticality)

The generic OSC presents the arguments in four strands, each covered by an underpinning volume:

- construction and non-radiological safety assessment
- normal operations radiological safety assessment
- accident radiological safety assessment
- criticality safety assessment

Generic arguments and evidence

Certain arguments and evidence are applicable across more than one, or all, of the four strands of argument. The nuclear and radiological safety aspects of the generic OSC have been developed in accordance with the RWM Nuclear Operational Safety Manual (NOSM). The contents and methods of the NOSM are similar to those in place at operating civil nuclear sites and meet industry best practice. This includes the application of systematic hazard identification studies using a functional process flow description (PFD) to ensure full coverage of the processes that take place from receipt of waste packages at the GDF to final emplacement. RWM's design and safety integrated process will ensure that the design is optimised, including meeting ALARP requirements for normal operations and accident conditions, and that it is appropriately balanced.

The generic OSC concludes that the GDF will be safe to construct and operate. The main findings that support this claim are:

- credible hazard management strategies can be developed to ensure that risks to workers and members of the public will be tolerable and ALARP
- the means of meeting these needs are not novel; they are based on technology available now that delivers tried and tested above ground solutions in a below ground environment
- the means of ensuring packages meet GDF requirements is already in place and operating through the Disposability Assessment process

In broad terms the processes and operations conducted at a GDF are functionally the same, or very similar, to those undertaken at numerous higher activity waste storage and handling facilities in operation in the UK. Safety cases and ALARP arguments for the operation of such existing facilities are mature, the engineered systems required to reduce risks are well understood. Future work will be focussed on implementing proven solutions within an engineered underground facility. Future designs will consider the specific requirements of operating a nuclear facility in the sub-surface environment, which may present certain unique challenges but are not expected to require novel technological solutions.

Construction and Non-Radiological Safety Assessment

An illustrative assessment of construction and non-radiological (conventional) safety has identified future design requirements for the management of conventional hazards. The safety claims specific to this assessment are that:

- the most significant conventional hazards associated with construction and operation activities have been identified by the systematic hazard identification process
- there is an understanding of the legislative health and safety requirements and current best practice associated with the construction and non-radiological hazards relevant to the GDF

- lessons learned from relevant incidents and recent major projects have been identified and assessed in order to ensure a continuous 'learning from experience' approach is implemented for the GDF programme

The assessment concludes that the following conventional fault groups are the most significant in terms of potential for harm during the construction phase:

- structural collapses underground including rockfalls
- fire and explosions (in particular in the underground environment)
- flooding (in particular in the underground environment)
- on-site movement accidents
- air quality underground

Hazard management strategies and development and implementation of detailed design requirements will ensure these hazards do not warrant further consideration as design basis accidents in the operational phase. Ongoing compliance with these requirements during the operational phase will be subject to ongoing regulatory review, ie Periodic Review of Safety.

The implication of different host rocks has also been assessed, including the differences between specific hazards associated with each host rock, together with the different techniques which may be applicable to the underground construction activities for each host rock type.

This assessment provides high confidence that RWM has an understanding of the construction and non-radiological hazards and arrangements that will need to be implemented, including design development, in order to satisfy the hazard management strategy. This process will ensure that potential hazards will be adequately addressed in the design and managed throughout the GDF construction and operational activities.

Normal Operations Safety Assessment

The normal operations safety assessment provides the arguments and evidence to support the claims that:

- RWM has developed a significant capability for assessing normal operational doses based on a PFD of the GDF
- the viability of the process based on man-effort requirements can be demonstrated and any 'pinch points' can be readily identified (a 'pinch point' is where the collective hours allocated to an exposed operator group to complete a task exceed the maximum hours available in a year)
- dose reduction factors required to reduce the doses predicted in this assessment to meet RWM criteria can be achieved through standard nuclear industry solutions. Solutions will be derived through optioneering and task-design
- there is very high confidence that it is feasible to design the GDF so that it can be operated safely, with any radiological exposures and doses to the workforce and members of the general public minimised and shown to be tolerable and ALARP

An illustrative assessment was undertaken that considered the radiological doses that could be received by operators and members of the public during normal operations. The focus of the normal operations safety assessment was on identifying activities that need to be optimised or supported with engineering design features to ensure safe operation.

Dose calculations for specific processes have been undertaken for bounding throughput years for the receipt and handling of high and low heat generating wastes. A set of

aggregated task durations and operator distances, with generic assumptions on the allocation of operator groups to tasks, has been used.

These assessments provide the basis to develop understanding and to inform future GDF design development. This will support all future optioneering, for which system requirements will be derived and robust engineering solutions developed.

The assessment concludes that there is very high confidence that it is feasible that the GDF can be designed and operated safely with radiological exposures and doses to the workforce and members of the public tolerable and ALARP.

Accident Safety Assessment

The accident safety assessment provides the arguments and evidence to support the claims that:

- it is feasible and credible that the identified set of representative design basis faults will be adequately protected in the developing design and that risk reduction measures can be identified
- there is an understanding of the uncertainties and variability issues which can impact on the results of the safety analysis
- there are no feasibility issues in terms of technical achievability and/or ALARP justification that will impact on RWM's ability to operate the GDF safely
- there is an understanding that there are complexities and differences between the safety requirements associated with a nuclear permissioning regime and relevant good practice that would be applied in non-radiological underground facilities such as mines
- there is an understanding of the nuclear safety challenges associated with operating a nuclear facility underground, including the transfer of waste packages from the surface to a deep underground environment
- there is confidence that it will be feasible to make the justification that risks to workers and members of the public from accident scenarios can and will be tolerable and ALARP

At this stage of the GDF programme, there is insufficient design definition to permit a complete safety assessment for all accident conditions. The appropriate approach is therefore to focus on the most significant faults to support this feasibility study. The most significant faults were identified through hazard identification studies and have been assessed either quantitatively or qualitatively, as appropriate. Fault groups have been identified as:

- loss of shielding
- loss of containment
- dropped loads and impacts
- fire
- external hazards
- internal hazards
- criticality

The quantitative assessment, ie the Design Basis Accident Assessment, included the calculation of the unmitigated radiological consequences to workers and members of the public and an initial conservative estimate of the fault initiating event frequency. The unmitigated dose was used as the basis of this assessment. This ensures effort was and will be concentrated on those faults that are considered both to be credible and will place

significant requirements on the design. This enabled the initial fault class (from A [highest class] to B, C or D [lowest class]) to be determined. Following this, the requirements on the design (in terms of conceptual safety functions, safety functional requirements and risk reduction targets) were determined.

For each design basis fault the risk reduction measures which could meet the requirements have been identified. These are based on the hierarchy:

- can the fault be eliminated by modification of the engineered design or the process itself?
- if the fault cannot be eliminated, what risk reduction measures could be incorporated into the developing design to:
    - provide a means of preventing the fault from challenging the safety function
    - provide a means of protecting against fault development by terminating the fault sequence prior to a radiological consequence being realised
    - provide a means of mitigating the radiological consequences of the realised fault

The risk reduction measures identified are considered feasible, for example, shield doors, interlocks, radiation monitoring equipment, remote handling and operations, ventilation systems, high reliability lifting equipment, etc. and do not invalidate the statement that there are no feasibility issues.

Qualitative assessment was undertaken for external and internal hazards. A baseline set of credible external hazards applicable to the GDF was identified and assessed. The conclusion is that no region of England or Wales is ruled out as a possible site based on the challenge posed by external hazards. For internal hazards, it was concluded that it will be feasible to manage identified hazards through suitable hazard management strategies and design principles.

A group of faults are related to the drop (or uncontrolled lowering) of a waste package down the shaft. The current illustrative concept only considers a shaft for transfer of waste packages underground in the evaporite host rock geological environment, however, for the purposes of a bounding assessment, a shaft has been assumed regardless of geological environment. The equivalent fault set for all waste types related to a drift has also been identified.

In the case of the drop of a waste package down the shaft, the hazard management strategy will need to explore all options to minimise the initiating event frequency to a level that is ALARP. This will be achieved by implementing a ‘de-risked’ engineering design of the load path, coupled with independent protective and mitigating safety measures which will ensure that significant radiological consequences cannot be realised. As these systems are not novel, are in use, or planned to be in use for the same application in other GDF projects, it is concluded that the use of a shaft does not present a feasibility issue for the UK GDF.

Criticality Safety Assessment

The specific claims for criticality safety are that:

- the GDF will be designed and operated safely with regard to criticality hazards; the key criticality safety issues associated with specific fault sequences have been identified and plans for resolution are in place
- it will not be possible for normal operations to give rise to a criticality incident provided there is compliance with the conditions in the relevant disposability assessment

- prior to seeking approval to operate, it will have been demonstrated that it will be possible to implement a robust design that classifies rockfalls and structural failures as beyond design basis faults

The nature of the waste material is inherently unfavourable to criticality and any failure of controls on waste packaging would not result in a critical configuration, either in individual packages or in combination. Normal operations at the GDF would not result in a change of configuration from sub-critical to critical.

The assessment also indicates that a criticality warning system is unlikely to be required on the basis of the arguments given above. This conclusion will be kept under review.

Further work

The assessment concludes that there are no feasibility issues that will fundamentally impact on RWM's ability to operate the GDF safely. However, the safety assessment has identified a number of areas which will be the focus of detailed optioneering and design development activities to support a full definitive assessment. A number of Forward Action Plans have been identified and these relate to improving:

- key process assumptions
- design detail
- assessment methodology
- understanding on, and impact of, the uncertainties or variabilities in the above.

Forward Action Plans relating to the construction and non-radiological assessment, the normal operations assessment and the accident assessment relate to establishing design requirements and assumptions, developing hazard management strategies and setting detailed design principles. The criticality assessment identifies FAPs relating to fissile limits and compliance.

A programme of work will be instigated as part of the RWM design and safety integrated process in order to develop a design in which an appropriate balance of hazard management strategies are developed that ensure the radiological, non-radiological and environmental risks associated with construction and operation are made tolerable and ALARP. This work programme will be integrated into the Science and Technology Plan and into the GDF design process to ensure suitable optioneering and optimisation is carried out.

6.3 Conclusions from the ESC

The generic ESC explains how the geological disposal of the UK's higher activity radioactive wastes can be accomplished in a way that ensures environmental safety at the time of disposal and in the long term after wastes have been emplaced and the disposal facility has been closed. Underpinning the ESC are:

- A safety concept that is based on ensuring that the long-term safety requirements for the GDF, as defined in RWM's generic Disposal System Specification, are met.
- A demonstration of how environmental safety, and the fundamental safety objective of the environmental regulators' GRA, can be achieved by implementing disposal concepts that are based on systems of multiple engineered and natural barriers that provide multiple safety functions. These barriers are designed to ensure that the wastes are isolated and contained for the long term after disposal by passive means.
- A waste package Disposability Assessment process that aims to ensure that waste packaging concepts and waste packages being produced in support of ongoing waste management, clean-up and decommissioning activities will meet GDF post-closure performance requirements.

- An understanding of expected barrier performance and how conditions in a disposal system will evolve, based on research findings presented in RWM's knowledge base, including the suite of research status reports, which reflect learning from UK research as well as work reported internationally.
- A consideration of the radiological and non-radiological hazards presented by the wastes and how the environmental safety of the GDF can be demonstrated with respect to these hazards in the context of the requirements of the GRA.
- An approach to safety assessment based on multiple lines of reasoning, involving both qualitative and quantitative analysis. Total system modelling has been used to develop an understanding of how different components of the engineered and natural barrier system contribute to environmental safety. Qualitative analyses have included the use of archaeological and natural analogues of material behaviour.

At the current time, no site has been chosen for a GDF in the UK and therefore the ESC is necessarily generic. That is, illustrative concepts have been identified for the disposal of higher activity waste in different geological environments. The high-level generic safety arguments presented in the ESC provide the understanding that will underpin the future development of a site-specific ESC. In particular, at each stage of the development and design of the GDF, demonstration of the post-closure safety of a disposal concept will be founded on an understanding of the environmental safety functions that will be provided by the specific engineered barriers defined for a particular combination of host rock and wasteform and the natural barriers provided by the geological environment.

The GDF needs to provide long-term isolation and containment of the wastes. A stable geological environment and well-constructed plugs and seals will ensure waste isolation for a long period for any disposal concept. The containment function may be provided in turn by the container, wasteform, buffer/backfill and geological barrier as conditions in the disposal facility evolve. These barriers work to contain any contaminants that may be released from the slowly degrading waste packages by delaying their migration through the barrier system. Eventually, conditions may arise in which small concentrations of contaminants migrate to the surface environment, although whether such pathways exist will depend on the hydrogeological characteristics of a specific disposal site.

The demonstration of how the GDF provides environmental safety requires an understanding of how conditions in the GDF will evolve over hundreds of thousands of years or more. In the generic ESC, this understanding has been achieved through:

- consideration of the features, events and processes (FEPs) that affect the environmental safety functions provided by the barrier components of the illustrative disposal concepts identified for each combination of waste group and geological environment
- assessment of the expected evolution (or base scenario) of each disposal concept to show how the disposal facility will be expected to meet environmental safety requirements; the behaviour of contaminants in groundwater and in the gas phase has been considered
- assessment of a number of variant scenarios based on the consideration of FEPs that, although considered unlikely to occur, could disrupt the performance of the GDF, and showing how the GDF will be robust to such disruptions

The assessment approach followed in the ESC is proportionate to the current state of the GDF programme in the UK. In particular, the approach to assessing the geological barrier is based on illustrations of potential geological environments for the GDF founded on expert knowledge of hydrogeological and geochemical systems. The models developed for the generic ESC are relatively simple, but of sufficient detail to facilitate understanding of the roles different barriers play in providing post-closure environmental safety. Also, the analysis

of variant scenarios has focused on those scenarios involving disruption to buffer and container performance. Variant scenarios involving factors associated with disruption to the geological barrier would be assessed in detail at a site-specific stage, when suitable data on facility design and site characteristics are available.

The approach taken in the generic ESC to assessing the environmental safety functions provided by the GDF's barrier system components is being implemented in a revised waste package Disposability Assessment process. The revised approach will continue to ensure that waste packages are compatible with post-closure requirements for environmental safety, as considered in the generic ESC.

The development of the generic ESC, including qualitative and quantitative disposal system environmental safety assessment methods, has enabled RWM to further develop its capability in demonstrating the environmental safety of geological disposal. This includes developments in RWM's capability to undertake probabilistic total system modelling and in RWM's understanding of the environmental safety functions provided by the components of multi-barrier geological disposal systems. The development of influence diagrams for each environmental safety function of the barrier components, and the incorporation of the diagrams and associated technical discussions into computer software, will enable automated interrogation of the environmental safety functions provided by GDF barriers, which will support further understanding and communication of the safety case.

Further work

The ESC concluded that there are no feasibility issues that will fundamentally impact on the long-term environmental safety of a suitably-designed GDF at a suitable site. However, there are some key topics where further research on barrier system behaviour will be beneficial to the development and application of future site-specific ESCs. These are as follows:

- Research to understand the impacts of voidage in waste packages on the evolution of conditions in a disposal facility and, in particular, on the environmental safety functions provided by the barrier system. Such research will build on RWM's recent work on the identification of screening levels against which tolerability to voidage in waste packages can be judged, in support of waste package disposability assessments.
- Research to understand the processes leading to gas generation from waste degradation in some waste packages, building on the results of RWM's recent integrated project on C-14 behaviour, such that waste package screening levels can be developed relating to gas generation that can be used in disposability assessments.
- Research to evaluate the impacts of non-radiological contaminants in waste, packaging materials and materials used in GDF construction, which may be harmful to humans and to the wider environment, including non-human biota. A methodology is needed for judging the disposability of waste packages that include non-radiological contaminants.
- Research to underpin current understanding of the techniques for characterising the migration of radionuclides and non-radiological contaminants through low-permeability fractured rock, including potential retardation processes in fractures and the surrounding rock matrix and the associated conceptual model and parameter uncertainties.
- A methodology for evaluating the impacts of natural processes on the safety functions provided by the barrier system of the GDF to support post-closure performance assessments, building on RWM's initial research to consider the effects of natural transient processes on groundwater flow and radionuclide transport. This includes

definitions of stylised deterministic scenarios of GDF performance over timescales in excess of a few hundred thousand years based on assumptions about how natural processes, such as earthquakes, subsidence, uplift and erosion, permafrost development and periods of glaciation could affect conditions in the biosphere and geological environment. Also, developing methodologies to assess variant scenarios of disposal system evolution based on consideration of potentially disruptive FEPs will be important in advance of the preparation of site-specific ESCs.

6.4 Overarching topics and key messages

This update to the generic DSSC has included work on a number of areas that span the three safety cases. These are summarised below, along with the key messages drawn from them:

- a modular design of the GDF:
  - there is flexibility in how the GDF can be implemented, in terms of its layout and the types and quantities of waste it can accept
  - complexity introduced by the inclusion of a range of different higher activity waste types and waste package types is manageable through a modular design
- treatment of uncertainly in the inventory:
  - the GDF can be implemented safely in a range of geological environments, even though the inventory for disposal may change
- a facility for disposal of all higher activity wastes (a co-located facility):
  - although Government has a strong preference to manage the inventory for disposal in one GDF, on the basis that this would result in major cost savings and lower environmental impacts, it has not ruled out developing more than one GDF
  - given a suitable site, there is no technical reason to suggest that the development of a single GDF to manage the inventory for disposal should not be possible
  - at this generic stage, the maximum capacity of the GDF cannot be determined until sufficient information has been obtained from a specific site (in particular, the characteristics of the geological environment will need to have been investigated and its safety, in combination with the engineered barriers, evaluated)
  - implementation of a single GDF can only be achieved if there is sufficient capacity at a site to manage the volume of waste, that is, if a sufficient volume of suitable rock exists in which the underground facilities can be constructed
- a balanced approach to the assessment of safety in the geological environments:
  - a wide range of geological environments exist in the UK that could be suitable for hosting a GDF
  - the GDF could be designed to suit a variety of UK geological environments, given a suitable site
- use of safety functions:
  - RWM's design and safety process is in line with ONR best practice and expectations [56]
  - RWM's approach to the implementation of a geological disposal system is in line with IAEA [57] and EA guidance [33]

  - use of safety functions in the generic ESC demonstrates RWM's understanding of post-closure complexity in terms of expected post-closure evolution and the impacts of local variability or inhomogeneity on the post-closure safety case
- retrievability:
  - it will be possible to retrieve waste during the operational lifetime of the GDF, but retrieval will become more difficult and costly as the GDF is progressively operated and then closed
- backfilling of vaults and disposal tunnels, and voidage in waste packages:
  - there is significant work in progress on the timing of backfilling
  - void space in waste packages has the potential to affect a number of the safety functions of the engineered barrier system
  - RWM's waste package specifications require voidage in waste packages to be minimised
  - research is planned, following on from the ESC findings, to understand better how voidage may affect barrier performance
- approach to optimisation:
  - optimisation is an intrinsic part of RWM's approach to site selection, concept selection and design development
  - the approach to optimisation at the current stage is focussed on non-foreclosure of options, that is, ensuring that waste packaged now is suitable for transport and disposal without unduly foreclosing options for future implementation of geological disposal at a suitable site
  - when a suitable site and design are identified and selected, RWM will optimise the design by following methods widely used for ALARP and BAT studies in the nuclear industry

6.5 Conclusions from the environmental and sustainability assessments

Main conclusions from the generic Environmental Assessment (generic EA)

The generic Environmental Assessment considers the effects that development of the GDF may have on the environment (other than those covered in the ESC). It explains that at a generic level it is not possible to determine in detail the likely extent and nature of environmental effects as these will vary with both the geological environment and surface characteristics of the site chosen for the GDF. However, it does identify a range of potential environmental effects, both beneficial and adverse. These could include, for example, changed groundwater levels due to drainage into and subsequent removal from the underground facility, or noise, vibration and dust from construction activities and vehicle movements.

The generic Environmental Assessment highlights the role of geological disposal as a critical enabler for the decommissioning and clean-up of the UK's existing civil nuclear sites. Permanent disposal of the higher level radioactive wastes generated by this work will remove the existing environmental hazard posed by the waste being stored at surface.

The assessment suggests that construction and operation of the surface facilities (and associated transport links), and the management of rock spoil from excavation of the underground facilities are likely to be the key sources of potential adverse effects. However, it is recognised that effective mitigation measures are likely to be available for many such effects - enabling them to be avoided altogether or reduced to an acceptable level. Potential

opportunities for environmental improvements associated with, for example, landscape enhancement and the creation of new wildlife habitat are also highlighted.

Main conclusions from the generic Socio-economic Assessment (gSeA)

The generic Socio-economic Assessment considers the socio-economic effects associated with the GDF, focussing on those effects likely to be felt at a local level. It explains that the GDF is likely to bring significant socio-economic benefits to a host community, maintained over a long period. Construction and operation of the GDF provide skilled employment for hundreds of people over many decades. There will also be spin-offs associated with investment in infrastructure and the use of local service industries that will support the facility and its workforce – in terms of both additional jobs and economic investment.

The generic Socio-economic Assessment explains that long-term Government investment will be linked to socio-economic assessments the developer will undertake during the siting process. The assessments could, for example, identify a need to invest in education and skills programmes.

The generic Socio-economic Assessment explains that the developer will put in place appropriate mitigation measures to address potential adverse effects. Such measures could, for example, be developed to address concerns about local property values, tourism, inward investment, the capacity of social infrastructure (such as schools and health services) and community cohesion (people's sense of belonging to a particular community).

Main conclusions from the generic Health Impact Assessment (gHIA)

The generic Health Impact Assessment provides an assessment of health and well-being issues associated with the implementation of geological disposal. In particular, it highlights the relationship between levels of employment, income and health – and that the significant socio-economic benefits associated with hosting the GDF (such as jobs and increased local investment) could also bring significant health benefits.

The generic Health Impact Assessment suggests mitigation measures in order to ensure potentially adverse effects on health and well-being are either avoided altogether, or reduced to acceptable levels. It recognises that people may be worried about potential adverse health effects - particularly the health effects of radiation, increased traffic movements on local roads, and those associated with the environmental effects of a geological disposal system (such as noise and dust generated during the construction process). To reduce levels of anxiety, the assessment notes that one of RWM's key tasks will be to ensure potential host communities understand what is being proposed and how such issues will be addressed. One way to do this could be to develop a Health Action Plan in partnership with the host community. This would set out how RWM would work with the community to improve health and well-being, and how health effects would be monitored and managed during construction and operation.

7 The Future Development of the DSSC

At present, no specific site for the GDF has been identified in the UK and hence, as outlined in Section 1.4.2, the DSSC is generic rather than site-specific.

As the siting process progresses, details of a geological environment and site-specific characteristics will become available. Until such time, the generic DSSC describes generic requirements, reflecting the fact that a site and a disposal concept have yet to be identified. It will be updated as appropriate, in order to provide feedback to the iterative development process and to support continued interaction with the regulators, disposability advice on waste packaging proposals and engagement with stakeholders. Any changes will be subject to change management procedures within the Quality Management System.

As potential sites are identified, RWM will start to develop site-specific safety cases. These will be based on specific designs proposed for specific sites. Safety cases for licensing will follow the established process for nuclear safety case development described in Section 7.1.2. In the case of the ESC, this will be developed based on site-specific understanding from site characterisation activities and in an iterative way that is informed by, and informs, the evolving site characterisation process.

The site-specific safety cases will be developed as a separate and parallel work stream to the generic safety cases. This strategy ensures that RWM has well-understood benchmark safety cases, whilst developing the site-specific ones.

One specific purpose of the site-specific safety cases, which differs from the purposes of the current generic DSSC, will be to support the development of the regulatory submissions required at various stages of the implementation programme.

7.1.1 Intrusive surface-based investigations

RWM will seek the first of these permissions, for intrusive surface-based investigations, through submission of an initial site evaluation (ISE) to the EA. In order for the EA, ONR and other stakeholders to understand the implications of granting an environmental permit, RWM proposes to provide additional documentation (‘context documents’) for regulators and stakeholders which will provide context and address safety of transport and GDF operations.

A site-specific OSC will be included in the context documentation; this is envisaged to be of equivalent standard to a Preliminary Safety Report (PSR) and developed under ONR guidance for safety case production [58], based on the conceptual designs for that site.

The PSR(s) will be produced in line with ONR and IAEA guidance and will seek to demonstrate in principle that a GDF of the specific concept design may be constructed and managed safely throughout its life-cycle.

As information from the intrusive investigations becomes available, the range of geological disposal concepts will be screened in order to identify those most suitable for further consideration. During this period, development of the site-specific safety cases will continue in parallel with the generic safety cases; site-specific safety cases will continue to inform the iterative design development whilst generic safety cases will continue to provide the basis for disposability advice. As the surface-based investigations near completion, sufficient information will be available to select a preferred disposal concept for each site. A specification will be developed for each preferred design in sufficient detail to support the selection of a single preferred site and the production of regulatory submissions for authorisation to begin underground construction and investigation at that site.

7.1.2 Underground investigation and construction

Permission to start underground investigations and construction will be sought from the EA and ONR through submission of a Preliminary Environmental Safety Evaluation (PESE) and a Pre-Construction Safety Report (PCSR) respectively. It is proposed that these will be accompanied by additional context reports based on site-specific information from the safety cases. A generic DSSC will be maintained until there is sufficient confidence in the site-specific DSSC that a generic DSSC is no longer required.

Justification of the choice of site will be supported by inclusion in the PESE of an updated site assessment, which will also need to demonstrate that the underground operations proposed would not compromise the integrity of the site to the unacceptable detriment of the environmental safety of a possible GDF. This site assessment will be informed by the site-specific safety cases.

The initial phase of the underground work will be to confirm the suitability of the site to host the GDF and provide additional information for successive stages of the detailed design. During this phase the site-specific safety cases will inform the optimisation of the detailed design. Construction work will be conducted in phases (for example, underground investigations, surface facilities, drift, underground package handling areas and vaults) and it is expected that the PCSR (which will be developed from the generic OSC) will comprise a number of separate PCSRs. It is expected that the Pre-Commissioning Safety Reports (PCmSRs), which will be required for submission to the regulators prior to commissioning of any of the facilities listed above (eg drift and vaults), will be staged in a similar manner.

Construction of the waste disposal areas and all surface and underground waste handling facilities will also require the submission of an Initial ESC to the EA.

There is no legal or permitting requirement for any site-specific TSC under current legislation but the site-specific TSC will be maintained to support the optimisation of the design.

7.1.3 Package receipt, disposal and emplacement

To commence waste package receipt and disposal operations, a Pre-Operational Environmental Safety Case and Pre-Operational Safety Report (POSR) will need to be submitted to the EA and ONR respectively for authorisation. During the operational period these safety cases will continue to be maintained as living documents to take account of any changes required, for example if additional vaults or tunnels were required to accommodate increased volumes of waste for disposal.

Transport safety documentation will at that time comprise Radiation Protection Programmes (RPPs) and Design Safety Reports (DSRs). Production of RPPs will be informed by the transport dose assessments maintained as part of the TSC throughout the generic and site-specific stages. DSRs will be compiled by transport package Design Authorities and, in the case of higher hazard wastes, submitted to a Competent Authority as part of an application for a Certificate of Approval for transport, or in the case of lower hazard wastes, used for self-approval purposes.

For most of the waste emplacement period, it is expected that emplacement will occur in parallel with construction of additional vaults and tunnels until all the areas are commissioned for the disposal of waste. In particular, the construction of the disposal areas for HHGW is not programmed to start until LHGW emplacement operations have been underway for some years. Each of these activities will require separate operational safety documentation (that is, PCSRs, PCmSRs and POSRs).

Also during the operational period, it is anticipated that parts of the GDF that have already been filled with waste may be decommissioned. Decommissioning includes removal of plant, equipment and/or services for re-use elsewhere in the GDF, or because leaving them in-situ could compromise the efficacy of back-filling and post-closure safety. However, the timing of

decommissioning will depend upon the disposal concept and the ability to maintain structural integrity. For instance, some concepts will be backfilled as each vault is filled with waste. Each separate decommissioning activity will require its own Pre-Decommissioning Strategy Report (PDmSR) to demonstrate that decommissioning can be carried out safely and effectively. Once the GDF is operational, an Overarching Operational Safety Report will be produced which will combine and summarise the outcomes from each POSR and PDmSR. The Overarching Report will need to be continually reviewed and, where necessary, updated, such that it reflects all changes to the GDF which impact on safety. This will be in addition to the periodic reviews of safety required by Site Licence Conditions.

Updates of the ESC will also be produced at a frequency to be agreed with the EA.

7.1.4 Closure

When disposal operations have been completed and a decision has been taken to seal and close the facility, it is expected that a Closure ESC will be produced. An accompanying Pre-Closure Operational Safety Report will also be produced, with the primary aim of demonstrating that the 'initial conditions' required by the ESC at the start of the post-closure period can be met.

8 Conclusions

8.1 Findings to date

The generic DSSC concludes that the GDF can be implemented safely in a range of geological environments.

The GDF can be designed, constructed and operated safely and in compliance with statutory dose limits and RWM's radiological protection criteria. Waste can be safely transported to the GDF with operator doses from routine operations below the legal limit, even under bounding conditions, and below the Basic Safety Objective for the inventory as assessed.

The generic DSSC shows how environmental safety can be assured, not only at the time of disposal, but also in the long term after wastes have been emplaced and the disposal facility has been closed.

Together, the three safety cases have confirmed and enhanced RWM's confidence that waste can be disposed of safely. RWM has confidence in the safety and environmental protection afforded by the proposed system, and that it will be possible to make the necessary safety cases for authorisation. In addition, environmental assessments show that environmental impacts from construction and operation can be mitigated and kept within acceptable levels.

The assessment of the entire inventory for disposal, as presented in the White Paper and on which the 2013 Derived Inventory is compiled, has confirmed that the safety arguments are bounding for a single GDF and that the 2010 generic DSSC remains valid.

The level of confidence has increased, through:

- quantified assessment of three illustrative geological environments
- consideration of alternative inventory scenarios
- the alignment of the generic OSC with the requirements of a PSR
- improvements in the knowledge base

A number of areas have been identified where further research and/or feedback to the system specification and design are required. These are being planned for and integrated, as appropriate, into the Science and Technology Plan and/or future actions within the iterative design development process.

8.2 Next steps

As RWM's work programme moves forward, the generic DSSC will be maintained and developed, in order to provide feedback to the iterative development process and so that RWM may continue to interact with the regulators, give disposability advice on waste packaging proposals and engage with stakeholders.

As potential sites are identified, site-specific safety cases will be developed to inform site assessment, optimisation studies and regulatory submissions. The generic safety cases will continue to be developed as a separate and parallel work stream to the generic safety cases. Eventually, site-specific development and the site-specific safety cases will reach a level of confidence and progress at which the generic safety cases are no longer necessary and all ongoing safety work will be site-specific.

RWM as an organisation will continue to evolve towards becoming a SLC and operator of the GDF. Certain responsibilities it holds now, such as representing a future transport operator, will be passed to suitable organisation(s) in readiness for emplacement operations to begin.

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Glossary

A glossary of terms specific to the generic DSSC can be found in the Technical Background.

Appendix A – Documents comprising the 2016 generic DSSC

This is a list of the documents that comprise the generic DSSC suite. Documents specifically referenced or relied upon in this Overview are listed in the References section.

Overview	
DSSC/101/01	Overview of the generic Disposal System Safety Case
Safety Cases	
DSSC/201/01	Generic Transport Safety Case Main Report (TSC)
DSSC/202/01	Generic Operational Safety Case Main Report (OSC)
DSSC/203/01	Generic Environmental Safety Case Main Report (ESC)
Transport Safety Assessment	
DSSC/301/01	Generic Transport Safety Assessment (TSA)
DSSC/302/01	Transport Package Safety Report (TPS)
Operational Safety Assessment	
DSSC/311/01	Vol. 1 - Non-radiological and Construction
DSSC/312/01	Vol. 2 - Normal operations
DSSC/313/01	Vol. 3 - Accident Safety Assessment
DSSC/314/01	Vol. 4 - Criticality Safety Assessment
DSSC/315/01	Generic Operational Environmental Safety Assessment[10] (OESA)
Environmental Safety Assessment	
DSSC/321/01	Generic Post-closure Safety Assessment (PCSA)
Environmental & Sustainability Assessment	
DSSC/331/01	Generic Environmental Assessment (EA)
DSSC/332/01	Generic Socio-economic Assessment (SEA)
DSSC/333/01	Generic Health Impact Assessment (HIA)

Disposal System Specification	
DSSC/401/01	Generic Disposal System Specification (DSS) Part A: High Level Requirements
DSSC/402/01	Generic Disposal System Specification (DSS) Part B: Technical Requirements
DSSC/403/01	Derived Inventory Report
DSSC/404/01	Inventory Scenarios Report
Design	
DSSC/411/01	Generic Transport System Design (GTSD)
DSSC/412/01	Generic Disposal Facility Design (GDFD)
Knowledge Base	
DSSC/421/01	Technical Background to the generic Disposal System Safety Case
DSSC/422/01	Disposal System Safety Case: Data Report
DSSC/431/01	Safety Case Production and Management (SCPM)
DSSC/441/01	Waste packages and the assessment of their disposability
Research Status Reports	
DSSC/451/01	Waste Package Evolution Status Report
DSSC/452/01	Engineered Barrier System Status Report
DSSC/453/01	Geosphere Status Report
DSSC/454/01	Biosphere Status Report
DSSC/455/01	Gas Status Report
DSSC/456/01	Behaviour of radionuclides and non-radiological species in groundwater Status Report
DSSC/457/01	Waste Package Accident Performance Status Report
DSSC/458/01	Criticality Safety Status Report

[10] This document supports both Operational and Environmental Safety Assessment

Appendix B – Summary of peer reviews and RWM's responses

This Appendix provides a high-level summary of the peer reviews of the main gDSSC documents, and RWM's response to them.

Overview of the generic Disposal System Safety Case - DSSC/101/01

The reviews were generally positive, stating that the overview was 'overall well written and clear, providing a useful entry point to the wider safety case…', '…adequate description of the management system under which it was produced. The structure of the suite of documents is also well described …'.

The use of more readily understandable language was suggested. RWM's response was to clarify earlier on that the document is for a regulatory audience. It therefore assumes a level of technical knowledge that would not be appropriate for a lay audience. However, some improvements were made to the consistency and clarity of language.

The reviewers asked for greater clarity about what exactly the key safety arguments and messages are and how they are substantiated, rather than simply saying that there are such arguments and evidence. RWM therefore developed a more substantive presentation of the key arguments and evidence, drawn from each of the three safety cases. Needs for future work identified in the safety cases, and how they are planned to be addressed, were also presented more explicitly.

In response to comments on the overall structure of the report, this was clarified, with some rearrangement and better signposting of each section's scope.

In relation to the scope of the safety cases, the reviewers asked for clearer terminology to describe the different types of non-radiological impacts and a clearer explanation of how accident risk is treated. This was done.

The reviewers asked for (the then) Figure 8 (or a separate figure) to show clearly the regulatory and legal requirements at each stage of the future process – for example when an Initial, Pre-operational and Closure ESC will be required. RWM thought that that figure would have become too congested and complex, and hence decided to replace Figure 8 by a text description of the project stages and documents required, including how safety cases will change in terms of scope, arguments, evidence etc.

The reviewers asked for greater emphasis on optimisation, and this was provided, giving the topic a separate subsection.

One reviewer raised potential pitfalls in having generic and specific safety cases in parallel – for example if the specific case does not sit within the envelope of the generic case. This cannot be addressed within the Overview alone as it has wider implications for other documents, as well as for RWM strategy. It should be captured in a Forward Action Plan.

Generic Transport Safety Case - DSSC/201/01 (with TSA - DSSC/301/01 and TPS - DSSC/302/01)

The overall findings were positive, stating for example that 'the reports [are] very well presented and with only a very small number of errors. The content and presentation style of them is consistent and very easy to follow…'.

One reviewer recommended that the 2016 TSA should report a comparison with the findings of the previous (2010) assessment. A comparison between some key results (HGV and train crew doses) was added, along with an explanation that, due to changes in the assessment approach, these are not on a directly comparable, like-for-like basis.

The reviewers commented on the treatment of streams for which no dose rate information is available, as in the best estimate assessment no doses are calculated for these streams

and this is optimistic. RWM therefore added an assessment of the effect of assuming, as a most pessimistic case, that all such packages have external dose rates at the maximum limit for transport.

Some errors in references to external bodies and documentation, such as changes to the internal structure of ONR and the regulatory status of the IMDG Code, were noted by the reviewers and corrected. Miscellaneous other referencing and typographical errors were also corrected.

Generic Operational Safety Case - DSSC/202/01 and Safety Case Production and Management - DSSC/431/01

The peer review's most significant recommendation was that the safety case should only claim that hazards have been identified, as there was little or no evidence that all hazards had been fully assessed and that risks were tolerable. This was particularly the case in relation to the following areas:

- the feasibility of using the shaft for transporting packages to the vaults: the reliability requirements on the lowering device, to prevent dropped loads, may not be practically achievable
- claims on dose assessments and dose reduction factors
- quality assurance of legacy packages/containers
- water ingress into the facility
- the use of terminology such as 'it is demonstrated' rather than 'demonstration is considered feasible'

With the exception of these comments, all the comments have now been suitably addressed or a suitable Forward Action Plan allocated to address the issue as the project progresses. The remaining comments, while not fully closed out, do not invalidate the judgment that the generic Operational Safety Case and the Safety Case Production and Management report are fit for purpose. In summary, the generic Operational Safety Case and the Safety Case Production and Management report are considered to be fit for purpose following this peer review, noting the early stage in the GDF design and the generic nature of that design.

Generic Environmental Safety Case - DSSC/203/01

The reviewers generally considered that the ESC presents clear and traceable lines of argument and appropriate conclusions. However, a number of areas were identified where the reviewers considered that the approach taken and the conclusions drawn could be better underpinned or explained. For example, one reviewer sought clarity on two related aspects of RWM's approach to the ESC: the assessment timeframe and the treatment of climate change. It was accepted that further discussion of these issues was merited. Discussion of the basis for limiting the timeframe for probabilistic calculations to 300,000 years has been extended, focusing on how increasing uncertainties about disposal system evolution are difficult to evaluate at a generic level on timescales in excess of hundreds of thousands of years, especially because conditions at the disposal site could be influenced by natural events on such timescales. References have been added to RWM's research on the potential implications of natural changes on the performance of the GDF. Also, further explanation has been provided regarding how, when the disposal site has been identified, site characterisation data will be used to underpin assessments of GDF performance over very long timescales. The assessments will be based on stylised deterministic calculations involving different assumptions about how natural processes, such as glaciation, could affect conditions in the biosphere and geological environment at the disposal site.

One reviewer also commented that the ESC does not present the environmental safety arguments in a way that clearly demonstrates that the environment agencies' requirements have been met, although the reviewer acknowledged that RWM is currently constrained in this respect by the absence of a disposal site. In response, information has been added that clearly states where in the ESC each requirement of the Guidance on Requirements for Authorisation has been addressed, as far as is possible at the generic stage, and an appendix has been added that provides further discussion of this topic.

Environmental & Sustainability Assessments - DSSC/331/01, DSSC/332/01, DSSC/333/01

The peer reviewers found the reports to be clear and well structured, covering an appropriate and comprehensive range of topics. However, it was felt that the objectives of the assessment work and the intended audience for the reports could be more clearly stated. This was accepted and the introductory sections were revised accordingly. It was also noted that the scope of the assessment work will have to be revisited during the siting process for the GDF to reflect site-specific issues. Again, this was accepted.

In some sections of the generic Environmental Assessment and generic Socio-economic Assessment the reviewers noted that it was not always obvious whether the conclusions were based on an assessment of mitigated or unmitigated effects. The methodology and relevant topic sections were subsequently revised to make clear that, since many mitigation and enhancement measures are likely to be site-specific, the conclusions are generally based on unmitigated effects. However, a range of potential mitigation and enhancement measures have been discussed and flagged for further consideration during site-specific assessment work.

In relation to the generic Health Impact Assessment a peer reviewer suggested RWM undertake a literature review of health pathways and associated health outcomes to better underpin the conclusions of the assessment. It was also suggested RWM should develop a scope and template for a Health Action Plan for implementation during the siting process and subsequent GDF construction and operation. Both are being considered for inclusion in RWM's future work programme.

Disposal System Specification - DSSC/401/01 to DSSC/404/01

It was suggested by peer reviewers of the DSS Part B that the 'walk-through' approach used, which considers the steps that a waste package would go through in the disposal system, is not the best approach for the specification document. Although putting all the steps leading up to disposal on the same level has the advantage of being very systematic, it does not adequately address the specific need for long-term containment that arises with higher activity waste disposal. It was suggested that the document focusses on a functional approach for the disposal system. In response to this comment, Section 3 (Disposal System Functions) has been added to describe the functions early in the document and present the high-level requirements for long-term safety. The illustrative concept descriptions are also brought forward and descriptions of the concepts key features has been added to help explain the basis for the different concepts.

Additionally, both peer reviewers noted that it was not clear how the document would be taken forward and how it would adapt to site-specific studies. In response to this, the 'Aim of the Disposal System Specification' section has been added, and 'Approach to developing the DSS' and 'Requirements Management System' sections have been re-written to explain how the DSS may develop in the future.

The reviewers commented that the Disposability Assessment process and future WAC are not explained in terms of how they affect waste packaging. Text on the relationship between the LoC and WAC has been added to address this.

When peer reviewed, the document had two sections to describe the requirements on contribution to post-closure safety for the geosphere and the engineered barrier system in

combination, and for the geosphere alone. It was not clear why this separation had been made and, in agreement with the reviewers these requirements were grouped into a single section

Generic Transport System Design - DSSC/411/01

The reviewers found that there were no technical feasibility issues with the report, and comments were mostly around the presentation of information, particularly the report objectives and scope.

The reviewers expected the transport topics to be given more prominence in the objectives and it was not clear why the main objective related to 'waste-packaging solutions'. It was also felt that there should be an objective to consider the transport of construction materials and staff to and from the site. To resolve this issue, Section 1.2 was amended to better reflect the scope of the report.

To match these revised objectives, superfluous information on Waste Packages was removed from Section 4, and the section was focused on Transport Package types. Reference was provided to the 'Waste packages and the Assessment of their Disposability' report.

Generic Disposal Facility Design - DSSC/412/01

The reviewers found that there were no technical feasibility issues with the report and the key comments were related to the presentation of information, including the report message, repetition and level of detail. In terms of the message, it was highlighted that the report too often referred to assumptions when it was discussing the illustrative designs. The reviewers thought that the report should be more definitive about what constitutes the design, even considering the generic nature of the project. The language of the report was therefore amended to provide a clearer distinction between assumptions (such as about properties of the host rock) and the illustrative designs (such as the dimensions of disposal vaults and tunnels and emplacement methods).

Several of the peer reviewers also thought that the level of detail throughout the report was unbalanced, with some sections being overly detailed and others much less so. This reflected the nature of the generic design and highlighted where previous studies had been undertaken on different aspects of the design (e.g. the inlet cell). This resulted in some of the more detailed information/text being removed from the GDFD report, and captured instead within a series of underpinning technical notes, which have been included within the future engineering work programme.

Technical Background - DSSC/421/01

One reviewer found there to be information in the Technical Background that also appeared in the Overview; as well as sections providing the technical basis behind geological disposal, the Technical Background also included information relating to the GDF implementation programme, such as on the process for finding a site. This was accepted and information of this nature removed. The reviewer also felt that the Technical Background did not contain enough detail and suggested considering it as a signposting document and combining it with the Overview which is also, to some extent, a signposting document. RWM addressed this by adding detail to the Technical Background, thereby reducing the degree of referencing to other documents.

Another useful comment was that the scope of the Technical Background was unclear from the text, and this was therefore clarified. It was also suggested that it was not necessary to include geological cross-sections, and RWM agreed and reduced the material in question to a description of the three host rock types considered. In addition, both reviewers recommended a re-ordering of sections and this was subsequently implemented.

Waste Packages and the Assessment of their Disposability - DSSC/441/01

The reviewer felt that the document provided a good summary of the Disposability Assessment process and was a useful update to previous documents. In general, the reviewer found the report clear and well-written but noted that better referencing to underlying guidance documents might improve the overall accessibility of the contents.

The reviewer commented that the document did not focus sufficiently on the role that the Disposability Assessment process plays in the generic DSSC and suggested that greater emphasis should be given to the other objectives of the Disposability Assessment process, including the role it plays in support of the delivery of geological disposal and in providing a mechanism for early engagement with regulators. RWM made changes to the report in response to these comments.

The reviewer also suggested that there was a need to improve the discussion of the role of the waste package in the post-closure period and that the report did not fully reflect the role of transport and GDF designs in the Disposability Assessment process. RWM felt that these matters were adequately dealt with, although some changes to the wording were made to reflect the reviewer's comments.

The reviewer questioned whether there was adequate discussion of how waste is prepared for disposal (i.e. 'packaged'), and that it relied on high-level statements regarding packaging processes. RWM believes that details about individual packaging processes would not have added to the usefulness of the report.

Research Status Reports DSSC/451/01 to DSSC/458/01

Peer review comments on the suite of status reports were generally positive, indicating good quality and fitness for purpose.

Constructive criticism on individual reports ranged from suggestions to improve the treatment of specific technical aspects and the structuring of some information, to recommendations to include additional references, and comments on the balance of information in different sections and of the oversimplification of specific parts of the text. A noticeable observation made by several reviewers across the suite of status reports included remarks concerning the absence of an explicit Conclusions section, judged by some reviewers as appropriate to the nature of the reports, but by others as a significant omission. RWM's view is that the breadth of technical information covered by the status reports is such that an overall Conclusions section within the status reports could introduce a risk of oversimplification and that the status reports should be viewed as a component of a safety case suite which does not benefit from a Conclusions section. The approach used has hence been to pull together key technical understanding in individual subsections though the use of blue text boxes. Based on the feedback received, however, a short 'Concluding Remarks' section was added to all documents, summarising, at very high level, the state of knowledge in key areas.

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