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International Peer Review

of the 1996 Performance Assessment

of the US Waste Isolation Pilot Plant (WIPP)

April 1997

Report of the NEA/IAEA
International Review Group

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OECD/NEA - IAEA JOINT INTERNATIONAL REVIEW OF WASTE ISOLATION PILOT PLANT 1996 PERFORMANCE ASSESSMENT

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(Replies: For the attention of C. Pescatore)

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Ref. EN/S/5242

Issy-les-Moulineaux, 9 April 1997

Dear Mr. Dials,

Please find enclosed the final report of the international peer review of the 1996 Performance Assessment of the Waste Isolation Pilot Plant (WIPP) as documented in "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant" (CCA). This technical review was commissioned by the Carlsbad Area Office of the United States Department of Energy (DOE) and jointly organised by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development and the International Atomic Energy Agency as part of their routine services to their member Countries.

The review report is based on the best understanding obtained after several months of deep involvement of the Joint Secretariat and the experts of the International Review Group (IRG) which were especially set up and appointed for this purpose. It represents the combined views of the members of the IRG and is directed to the DOE and thus drafted for a technical audience familiar with contents of the CCA. It contains information which was considered useful and worth bringing to the attention of DOE. This cover letter highlights the main findings of the review in order to place them in a broad perspective, but it does not substitute for a thorough reading and interpretation of the actual report.

The primary focus of the review was on the technical soundness of the analyses and of the DOE approach to post-closure performance assessment, examined from an international perspective. The review report does not formally cover compliance aspects with the national regulations.

Not all parts of the CCA documentation were reviewed at the same level of detail, and specific points were looked at in greater depth according to the technical background, experience and judgement of each member of the IRG. The IRG also took into account additional information provided by the DOE in the course of the review, as well as their knowledge of the WIPP studies gained from previous international contacts. To preserve independence, the IRG did not examine reviews of the WIPP by other groups.

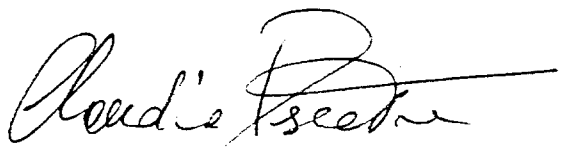
The IRG concluded that the performance assessment methodology is well-founded and has confidence in the majority of judgements and assumptions made in developing the calculational models. The quality of assessment codes and data handling is also generally good. Thus, the analyses reported in the CCA are, in the main, technically sound. The nature of the critical review has tended to identify and emphasise areas where improvements could be made, however, and comments and suggestions are also proposed for consideration by the DOE in future iterations of their assessments of the WIPP, e.g. during the re-certification phase of the facility. These should be considered within the context of the overall positive view of the IRG on the technical soundness and quality of the WIPP performance assessment as documented in the CCA. In particular, two areas are considered as deserving further attention by the DOE: (a) the implications, favourable and unfavourable, of the magnesium oxide backfill, and (b) the assumption of rapidly-reached, homogeneous conditions within the disposal rooms.

From the experience of the review, the IRG believes that, in the case of undisturbed performance, the WIPP facility would meet individual radiation dose standards typical of those used in other countries, even beyond the 10,000 years regulatory period. A judgement could not be reached for the case of disturbed performance, although supplementary analyses by the DOE indicated that a risk target, as internationally accepted, would be met in respect of a direct drilling scenario of the type specified in the regulations.

You will note that the review makes an overall judgement of the 1996 Performance Assessment of the Waste Isolation Pilot Plant rather than emphasizing views on specific aspects, and the report needs to be considered in its entirety. We trust that if the report is read from that perspective, it will prove valuable to the DOE.

On behalf of the IRG and the Joint Secretariat, we would like to take this occasion to thank you and your colleagues for your openness and assistance in the course of the review.

Yours sincerely,



Dr. Claudio Pescatore
On behalf of the IRG Chairman
and the Joint NEA/IAEA Secretariat

cc: K. Bragg (w/o encl.)
A. Bonne "
J. Bruno "
K. Kühn "
P. Lalieux "
G. Linsley "
S. Norrby "
R. Storck "
T. Sumerling "
H. Umeki "
G. Basabilvazo "

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International Peer Review

of the 1996 Performance Assessment

of the US Waste Isolation Pilot Plant (WIPP)

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International Peer Review of the 1996 Performance Assessment of the U.S. Waste Isolation Pilot Plant (WIPP)

Report of the NEA/IAEA International Review Group

Preface

In January 1996, the United States Department of Energy (DOE) requested the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA) and the International Atomic Energy Agency (IAEA) to jointly organise an international peer review of the 1996 post-closure performance assessment of the Waste Isolation Pilot Plant (WIPP). This assessment is described in the DOE document "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant", issued in October 1996 and referred to as the CCA.

The NEA and the IAEA accepted the invitation and, in June 1996, Terms of Reference for the review were agreed between the DOE, the NEA and the IAEA .

The review was carried out, in the period October 1996 to March 1997, by a team of experts invited by the NEA and the IAEA, referred to as the International Review Group (IRG). The review included an examination of the relevant parts of the CCA, a visit to the WIPP site, and focused discussions between the IRG and DOE staff and contractors.

This report presents the combined, personal views of the members of the IRG, and offers the DOE an independent, international perspective on the 1996 performance assessment of the WIPP. The protocol for the review does not foresee further exchange between the DOE and the IRG and therefore the report is final.

This report has not been checked by the DOE. The IRG has made its best effort to ensure that all information in this report is accurate and takes responsibility for any factual inaccuracies.

International Peer Review of the 1996 Performance Assessment of the U.S. Waste Isolation Pilot Plant (WIPP)

Report of the NEA/IAEA International Review Group

Contents

List of abbreviations

CCA	Title 40 CFR Part 191 Compliance Certification Application for the WIPP
CCDF	complementary, cumulative distribution function
CFR	Code of Federal Regulations
CH	contact-handled (TRU waste)
DOE	United States Department of Energy
DRZ	disturbed rock zone
EPA	United States Environmental Protection Agency
FEPs	features, events and processes
IAEA	International Atomic Energy Agency
IRG	International Review Group
LWA	Land Withdrawal Act
NEA	Nuclear Energy Agency of the Organisation for Economic Co-operation and Development
RH	remote-handled (TRU waste)
TRU	transuranic (waste)
US	United States (of America)
WIPP	Waste Isolation Pilot Plant

1. Introduction

This chapter outlines the background to the review, the composition of the International Review Group, and the process of the review, including the objective and scope. The structure of the report is also outlined.

1.1 Background to the Review

In the United States, the Department of Energy (DOE) is responsible for managing transuranic (TRU[1]) wastes generated by the production of nuclear weapons and other defence-related activities. The Waste Isolation Pilot Plant (WIPP) has been sited and designed to meet the criteria established by the US Environmental Protection Agency (EPA) for the safe, long-term disposal of such wastes. The facility is located near Carlsbad in south-eastern New Mexico and consists of above-ground and below-ground parts. The underground facility (repository) is located at a depth of 650 metres below the surface in a 600-metre-thick, bedded-salt formation.

The EPA regulations require, inter alia, that the DOE demonstrates a reasonable expectation that the WIPP repository will isolate the wastes placed in it from the accessible environment for 10,000 years. The DOE has developed an approach to demonstrating the long-term performance of the WIPP repository based on probabilistic performance assessment. This is designed to estimate how the WIPP disposal system[2] will perform during the 10,000-year regulatory period, taking account of uncertainties in events and processes which could affect the repository in the future.

Beginning in 1980, the DOE has carried out a series of iterative analyses of the long-term performance of the WIPP facility[3]. The latest, the 1996 performance assessment, is described in the DOE document "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant" [DOE 1996], hereafter referred to as the CCA. The primary purpose of the CCA is to present the information required by the EPA to assess compliance with specific regulations (see Chapter 2). The CCA consists of Volume I plus over 50 appendices.

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[1] TRU waste is defined by the EPA as waste that contains more than 100 nanocuries (3,700 becquerels) of alpha-emitting transuranic isotopes, with half-lives greater than 20 years, per gram of waste, but excluding high-level radioactive waste and certain other wastes, c.f. 40 CFR 191 §191.02(i).

[2] Disposal system means any combination of engineered and natural barriers that isolate the radioactive waste after disposal, c.f. 40 CFR 191 §191.12.

[3] These earlier performance assessment documents have not been examined as part of this review.

1.2 The International Review Group

The International Review Group (IRG) assembled by the NEA and the IAEA included seven members actively involved in national radioactive waste management programmes - from waste management organisations, national regulatory bodies, universities and scientific consultancies. The IRG was completed by two representatives each from the NEA and the IAEA who provided a joint Secretariat and contributed technically to the review.

The names and summaries of experience of members of the IRG are provided in Appendix 1. Mr. Ken Bragg agreed to act as Chairman.

None of the members of the IRG had ever worked directly on the WIPP Project (or worked as a contractor or subcontractor to the DOE). All, however, had participated in international meetings, projects and comparison exercises in which the WIPP project had been represented, and had some prior knowledge of the project and of performance assessment as practised by the DOE. In some cases, this knowledge was extensive and detailed, and gained over many years in bi-lateral or multi-lateral exchanges.

1.3 The Review Process

1.3.1 Objective

The Terms of Reference for the review were negotiated between the DOE, the NEA and the IAEA, based on a first proposal by the DOE. The significant parts of the Terms of Reference are reproduced in Appendix 2. Therein, it is stated that:

> "The objective of the international review is to examine whether the post-closure performance assessment of the WIPP in the CCA is appropriate, technically sound and in conformity with international standards and practices."

The interpretation of this objective was discussed at length within the IRG, especially the phrase "in conformity with international standards and practices".

The IRG decided to conduct its examination to answer the following broad questions stemming from above statement.

Is the WIPP 1996 post-closure performance assessment:

1. **appropriate ?**

   The IRG agreed that this should be interpreted as meaning appropriate in the context of the objective of the CCA, which is to satisfy the EPA regulations. The IRG also agreed that it should not undertake a formal comparison with the EPA regulations since this is the responsibility of the EPA. In this respect, it is emphasised that this review was organised to provide the DOE an independent, international perspective on the 1996 post-closure performance assessment of the WIPP.

2. **technically sound ?**

The IRG agreed that this item should be the primary focus of the review. For example, have adequate data and process information been used, are the conceptual models and their underlying assumptions scientifically-based or reasonable, have adequately tested mathematical and computer tools been applied ?

3. **in conformity with international practices?**

That is, are the scope of the assessment, methods of analysis and quality of application consistent with good practice in other countries ?

4. **in conformity with international guidance and standards?**

That is, are the calculated end-points consistent with international guidance[4] and standards in the manner these are formulated in other countries ?

1.3.2 Scope

The Terms of Reference identify the CCA Volume I as the primary material to be reviewed. After individual examination of this document, and joint discussions, the IRG made the following initial observations and decisions:

- The CCA has been prepared by the DOE to comply with the EPA regulations. These provide detailed guidance on how to demonstrate compliance, and are focused on the evaluation of specific performance indicators.

- The CCA Volume I does not constitute a self-contained or sufficient description of the 1996 performance assessment. Rather, it is necessary to examine many of the CCA appendices in order to find technical information at the level required by the IRG.

- The iterative programme of performance assessment of the WIPP has been the subject of a number of previous independent reviews, notably by the US National Academy of Sciences [NAS 1996]. These other reviews, several of which are summarised in Chapter 9 of the CCA Volume I, would not be examined as part of this review.

- In coming to a view on the four broad questions identified in Section 1.3.1, the IRG considered that it would also be able to examine and comment on other issues indicated by the Terms of Reference, such as the clarity and transparency of the documentation.

1.3.3 Conduct of the review

A summary of the history and conduct of the review is given in Box 1.

The IRG did not review the whole of the CCA at the same level of detail. The focus was on the DOE approach to post-closure performance assessment, technical soundness at a

[4] A list of relevant international documents is annexed to the Terms of Reference, see Appendix 2.

conceptual level, and the performance of the disposal system. Specific points were identified and examined according to the technical background, experience and judgement of each reviewer. During the review, the DOE provided additional information orally, in some cases supported by overheads. This information has been taken into account by the IRG, but has not been formally reviewed.

In their work, the IRG identified technical issues of concern, both general and detailed, made specific comments to define the issues and, in many cases, made suggestions to the DOE on how concerns might be alleviated. It is for the DOE to decide if, or when, any of the suggestions will be implemented in their work[5].

1.4 Structure of the Report

The findings of the review are presented as follows:

- Chapter 2 introduces the EPA regulations which the CCA has been designed to satisfy, identifies and comments on the requirements which have had most influence on the assessment approach adopted in the CCA, and highlights points of interest from an international perspective. The aim of the chapter is to separate observations by the IRG on points related to the EPA regulations from the technical review of work by the DOE.

- Chapter 3 comments on the 1996 performance assessment mainly from a technical perspective. In particular, it examines the technical quality of the stages of post-closure assessment - compilation of data, identification of FEPs and scenarios, treatment of processes and sub-system modelling, system modelling and calculations. Comments are also made on the CCA documentation.

- Chapter 4 summarises the results of the review. This includes observations on the specificity of the WIPP case, the evaluation of the 1996 performance assessment of the WIPP facility against the Terms of Reference, and the overall judgement arising from the experience of the review.

The report assumes that the reader is familiar with the WIPP project and the CCA and presents a minimum of introductory material related to either.

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[5] The Terms of Reference of the review do not ask for recommendations for the future programme of the DOE, and the future programme was not discussed during the review. It is understood, however, that the DOE has already taken action on some of the points raised by the IRG during the discussion meetings, and there are opportunities for further actions to be taken during the WIPP re-certification process.

Box 1: History and Conduct of the International Review

In January 1996, the Manager of the Carlsbad Area Office of the DOE approached the NEA and the IAEA to ascertain their willingness to organise a review of the 1996 performance assessment of the WIPP. In February and March, the NEA and the IAEA agreed, in principle, to carry out such a review, and formal agreement to carry out a jointly organised review was reached in June 1996. The NEA and IAEA formed a joint Secretariat and invited individual experts to participate in the review so that, by July 1996, a team covering the range of relevant expertise was identified - the International Review Group (IRG).

A copy of Volume I of the CCA was supplied to members of the IRG in October 1996. IRG members made a preliminary examination of the document and, in November 1996, met in Vienna to discuss the objectives and approach to conducting the review. The coverage of the various sections of the CCA by the IRG was discussed, and each member was assigned a selection of those CCA appendices and supporting references that he might need to examine. These documents were supplied to individual reviewers by the DOE, mainly by the end of November 1996.

Each reviewer then examined the CCA Volume I, selected appendices and references, and formulated a series of questions arising from the examination. These preliminary questions were compiled and submitted to the DOE in early January 1997 in order to have a more focused meeting between the IRG and DOE later that month. The compiled list included over 100 questions, organised into broad subject headings such as "presentation of safety assessment results", "FEP and scenario identification methods", "radionuclide inventory", etc.. Some of these questions were very specific, referring to particular data items and identified pages of the CCA; others were more general and were requests for clarification about DOE methods as described in the CCA; a few asked for supplementary information not included in the scope of the CCA, e.g. related to radiological consequences. Written answers were not provided, but the questions were used by the DOE to plan a set of focused presentations to the IRG, see below.

The DOE provided an electronic version of the CCA, including its appendices and references, to members of the IRG in early January. The reviewers were not able to take full advantage of these CD-ROMs in their main review work due to the late availability. The CD-ROMs, and the cross-references and search tools which they include, are undoubtedly useful, however, and were used later during the editing of the review report to check specific information in the CCA.

From 26 to 31 January 1997, the IRG met in Carlsbad, New Mexico. In this time, the IRG visited the WIPP facility, received focused presentations from DOE staff and contractors based on the questions previously submitted, and held meetings in closed session to review and confirm individual and joint views on the WIPP post-closure performance assessment. The presentations by the DOE were the starting point for detailed technical discussions which served to answer most of the questions originally raised by the IRG members. The visit to the WIPP facility, and associated discussions with DOE staff, were especially valuable to the reviewers in developing their understanding of the WIPP project and disposal system. During the meetings, information was provided orally, in some cases supported by overheads. This information has been taken into account by the IRG, but has not been formally reviewed.

On the final day of the week, a preliminary oral report was given to DOE representatives by the IRG Chairman.

A first draft report of the review was compiled and circulated to the IRG members for comment in February 1997. These comments were assimilated, and a second draft was produced and discussed at a meeting of the Secretariat, Chairman and consultant in Paris on 12 March 1997. A third draft was prepared and circulated to the IRG members for final comments. After incorporation of final comments, and unanimous approval by the IRG, the final report (this document) was submitted to the DOE on 9 April 1997.

2. The EPA Regulations and their Influence on the CCA

This chapter introduces the EPA regulations which the CCA has been designed to satisfy, identifies and comments on the requirements which have had most influence on the approach to performance assessment adopted in the CCA, and highlights points of interest from an international perspective. The aim of the chapter is to separate observations of the IRG on points related to the EPA regulations, from the technical review of work by the DOE, which is reported in Chapter 3.

In this chapter, factual and neutral observations are given in plain text. Opinions of the IRG are given in italics.

2.1 The EPA Regulations

The DOE was self-regulating until the Land Withdrawal Act (LWA) for the WIPP was promulgated in 1992. Amongst other provisions, the LWA designated the EPA as the regulator for radiological safety of the WIPP facility.

The design and operation of the WIPP are governed by a comprehensive set of US federal and state regulations. The regulations relevant to the post-closure radiological performance of the WIPP, which the CCA is designed to address[6], are contained in two EPA standards:

- **40 CFR Part 191** - Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes - which sets out general requirements for geological disposal systems in the US;
- **40 CFR Part 194** - Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations - which details the application of 40 CFR Part 191 to the WIPP.

In addition, the EPA has issued guidance on the interpretation of 40 CFR Part 194 in a Compliance Application Guidance document [EPA 1996].

40 CFR 191 was first issued in 1985, remanded in 1987 and re-issued in 1993. The regulation applies to spent nuclear fuel, high-level and transuranic (TRU) radioactive wastes, and sets out environmental standards for management and storage (Subpart A), disposal (Subpart B) and groundwater protection (Subpart C).

40 CFR 194 was issued in February 1996 and became effective two months later. The regulation sets out guidance specific to the WIPP project on the approach to performance assessment that the DOE should adopt and on the structure and content of the CCA. It provides detailed guidance on containment, assurance, and groundwater protection requirements, and includes paragraphs on, for example:

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[6] Compliances with other regulations are dealt with in separate submissions by the DOE.

§194.14 Content of compliance certification application.

§194.22 Quality assurance.

§194.23 Models and computer codes.

§194.25 Future state assumptions.

§194.26 Expert judgement.

§194.27 Peer review.

§194.32 Scope of performance assessments.

§194.33 Consideration of drilling events in performance assessments.

§194.41 Active institutional controls.

§194.43 Passive institutional controls.

§194.45 Consideration of the presence of resources.

Appendix 3 reproduces extracts from 40 CFR 191 and 40 CFR 194 which are most pertinent to this review, including definitions of selected terms. In the following section, where paragraph numbers of 40 CFR 191 and 40 CFR 194 are referred to, the relevant paragraphs, or parts of paragraphs, can be found in Appendix 3.

2.2 The Influence of the EPA Regulations

The DOE designed the CCA to satisfy the requirements of 40 CFR 191 and 40 CFR 194. It is not surprising, therefore, that the structure and contents of the CCA, and the 1996 performance assessment, are strongly influenced by these regulations.

The IRG has not undertaken an analysis of the EPA requirements, nor attempted to systematically check whether the DOE has fulfilled these requirements. In many instances, however, the IRG found that points on which it wished to comment were a result of the requirements of the EPA regulations. This section identifies the more important of these points[7]. This is not intended as criticism of the regulations, nor of the DOE which is obliged to follow them, but to highlight points which are of interest from an international perspective.

2.2.1 Undisturbed and disturbed performance

The EPA regulations set requirements in respect of "undisturbed performance"[8] and "performance taking account of all significant processes" (disturbed performance). The disturbed and undisturbed performance are both judged relative to a "containment

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[7] The implications of the the EPA regulations penetrate deeply into the technical details of the 1996 performance assessment. Some of the more detailed implications are perforce mentioned in Chapter 3.

[8] Term defined in 40 CFR §191.12, see Appendix 3. Note that the undisturbed performance includes the effects of human actions, potash mining and deep drilling, that may occur in the future outside the "controlled area".

requirement", based on collective dose considerations, which places a limit on the total release of radionuclides (40 CFR §191.13). The undisturbed performance is also judged relative to an individual dose limit (40 CFR §191.15) and groundwater protection requirements.

This separate consideration of disturbed and undisturbed performance is consistent with regulations in other countries. In several countries, for example, a distinction is made between expected events and processes or a normal scenario, and unexpected events and processes or altered scenarios. In most countries, the criteria applying to the two conditions are derived from the same basis - radiological risk to an individual. The EPA containment requirement, however, is based on collective dose considerations, and cannot be directly related to individual dose and radiological risk standards.

The IRG considers that it is appropriate to assess the undisturbed and disturbed performance separately, and this is in accord with practice in other countries. It is unusual, however, that a different basis for assessment should apply to each.

2.2.2 The 10,000-year regulatory period

The containment, individual dose, and groundwater protection requirements (see above and Appendix 3) all refer to a 10,000-year regulatory period. The EPA does not require any assessment beyond 10,000 years after closure, even in terms of qualitative arguments.

The reliability of performance assessment results declines at times in the far future because of the increasing uncertainty about future conditions, especially of the surface environment and human behaviour. For this reason, in most countries, it is considered that, in respect of performance in the far future, the requirement for quantitative assessments should be less stringent, with more qualitative arguments being allowed [IAEA 1994].

The Canadian, German and French regulations, for example, specify 10,000 years as the maximum time to which quantitative assessment needs be continued, but require qualitative arguments that releases will not increase dramatically beyond this time. In Switzerland, regulatory guidance indicates that calculations should be carried out at least until the estimated maximum of impacts has been reached, even if it is acknowledged that this may be beyond the limits of validity of the models.

The IRG was surprised that it did not find descriptions or arguments in the CCA indicating the possible performance of the WIPP facility beyond the end of the 10,000-year regulatory period. Such descriptions or arguments, including an indication of the mechanisms, likelihood, timing and possible maximum of impacts at longer times, would be an important element of performance assessment in most other countries.

2.2.3 The containment requirement

The major part of the performance assessment work presented in the CCA (Chapter 6 of Volume I) is to demonstrate compliance with the containment requirement (40 CFR §191.13).

The formulation of the containment requirement has several implications not already discussed:

- it is probabilistic and leads to the adoption of a probabilistic methodology to calculate the cumulative release (see also Section 2.2.5);
- it is only concerned with the total cumulative release to 10,000 years, not the timing or rates of release within this period;
- issues of individual dose and risk, as well as the biosphere, are not considered.

Results in the CCA are almost entirely probabilistic because of the focus of the CCA on compliance. The probabilistic systems modelling approach brings important benefits in investigating uncertainties in complex coupled systems and produces integrated measures of impact. Attention must be given, however, to presenting the results of the analysis in an accessible and transparent form. In particular, deterministic analyses may be useful to illustrate the model behaviour and support the probabilistic analyses[9].

Information on the temporal evolution of conditions and releases is important to understanding the physical evolution and performance of the disposal system, and can give confidence in the overall release results which are otherwise opaque. Such information is lacking in the CCA, although supplementary information was presented to the IRG during the meeting in Carlsbad[10]. Whereas the EPA requirements do not seem to exclude the presentation of results as a function of time, the focus of the DOE on compliance may have led to them not being presented.

The EPA containment requirement is based on consideration of collective dose and, moreover, relates to the total activity contained in the repository expressed in terms of EPA units (see 40 CFR 191 Table 1, reproduced in Appendix 3). The IRG found this difficult to relate to safety standards based on individual dose and radiological risk with which they are more familiar. The IRG therefore asked the DOE to provide supplementary information on doses that might be received. These are discussed in Section 3.4.4.

The IRG accepts the probabilistic approach, but found that the focus of the CCA on probabilistic estimates of total cumulative release, and lack of presentation of deterministic calculations or results as a function of time, hampered the understanding of the performance of the disposal system. It would have been helpful to present such results even if they are not required by the EPA.

2.2.4 Treatment of human actions

The EPA regulations give guidance on the assessment of future human actions at the WIPP site. They specify that:

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[9] The relative merits of probabilistic and deterministic methodologies in assessments have been discussed internationally, for example within the NEA Integrated Performance Assessment Group [IPAG 1997].

[10] "Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 CCA for the WIPP", memo by J. Helton, 12/23/96.

- the characteristics of the future (at least in respect of human actions) are assumed to remain as they are at the present day (40 CFR §194.25);
- the assessment shall consider mining, deep drilling and shallow drilling (40 CFR §194.32a);
- in respect of mining, only the effects of changes in hydraulic conductivity of hydrogeologic units should be considered (40 CFR §194.32b);
- inadvertent intrusion by drilling for resources should be assumed to be the most severe scenario, and the method of estimating the future occurrence of drilling is specified, based on the frequency of drilling in the Delaware Basin in the last 100 years (40 CFR §194.33b);
- resource recovery activities, subsequent to drilling of a borehole, need not be considered (40 CFR §194.33d);

It is likely that mining of potash will occur within the controlled area at some time during the regulatory period. The only impact that the EPA asks the DOE to consider, however, is calculated to be beneficial for long-term performance (see Section 3.1.2).

The EPA specification of how to estimate a future drilling rate, plus the assumption of random occurrence in space and time, leaves little uncertainty in the inputs for the assessment of drilling. The actual situation is that there is a very large uncertainty concerning future human actions. Moreover, the case selected for analysis considers an activity that, based on knowledge of the resources in the Delaware Basin (see Section 3.1.2), is not sustainable for more than a few tens of years into the future.

The specification by the EPA on how to assess future human actions leads to a feeling that the performance assessment is arbitrary. The IRG accepts that, given the irreducible uncertainties associated with future human actions, it may be convenient from a regulatory standpoint to define reference events or scenarios that should be the basis of compliance calculations. The IRG, however, would have liked some discussion of the assumptions adopted and, in particular, why other human actions such as resource recovery need not be considered (see Section 3.2.3) and whether the assumptions adopted in representing mining and deep drilling can be considered to be conservative or sufficiently representative.

2.2.5 Results of performance assessment and treatment of uncertainty

The EPA requires that the results of the performance assessment are assembled into complementary, cumulative distribution functions (CCDFs), and that the uncertainty of disposal system parameters should be considered to generate a set of CCDFs (40 CFR §194.34). The regulations also set conditions on the statistical accuracy of results (see Section 3.4.3).

The CCDF is a generally accepted method of depicting uncertain outcomes commonly adopted in reactor safety studies. The DOE has developed the methodology to calculate the

radionuclides releases from the controlled area[11] in the form of CCDFs that can be compared to the EPA containment requirement.

The DOE methodology adopts the Kaplan and Garrick [1981] definition of risk[12] and approach to the treatment of uncertainty. This leads to the generation of a single CCDF where each 'scenario' forms a single-point estimate of consequence and probability on the CCDF. The uncertainty incorporated in this single CCDF, which relates to uncertainty about what might happen in the future, is termed stochastic uncertainty. There is also uncertainty about starting conditions, or values of parameters that must be incorporated in the consequence models. Kaplan and Garrick refer to this as subjective uncertainty on the basis that the parameters do have some "true" or fixed value, but this is imprecisely known. Accounting for this uncertainty in disposal system parameters leads to a family of CCDFs.

The IRG observes that the separation of uncertainty related to disposal system parameters and uncertainty related to future events is presentationally useful and operationally convenient, but is to some extent misleading[13].

The above approach deals with parameter uncertainty. The EPA does not require, and the DOE does not consider, the uncertainty related to choice of features, events and processes, or choice of alternative models[14]. These sources of uncertainty are generally considered to be important internationally [IPAG 1997].

The lack of discussion of other uncertainties, not included through parameter uncertainty, would be considered a serious omission internationally when judging the results of performance assessment, although it is not required by the EPA for compliance calculations.

2.2.6 Institutional controls

The EPA regulations require the DOE to present descriptions of the active and passive institutional controls (defined in 40 CFR §191.12) that are proposed for the site. Further, the EPA allows the DOE to take credit, in terms of a reduced likelihood of human intrusion, for up to a maximum of 100 years after disposal in respect of active controls and "several hundred years"[15] in respect of passive controls (40 CFR §194.41 and 43).

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[11] Term defined in 40 CFR §191.12, see Appendix 3.

[12] According to Kaplan and Garrick, risk is composed of three elements: what can happen, i.e. what scenarios can be identified; how likely is this, i.e. what probability should be assigned to each scenario; what is the consequence, i.e. what is the result, in terms of total release, for each scenario.

[13] It supposes, for example, there is a true long-term rate of drilling applicable to the site, and that the uncertainty in time of occurrence is only a result of statistical variation. This is untrue - the future rate is highly uncertain and may not even be a physically meaningful parameter depending on the model adopted. In addition, the sampling of so-called subjective uncertainty is related, not just to present-day characteristics, but also to what those characteristics might be over the 10,000-year regulatory period.

[14] The EPA does require descriptions of alternative conceptual models that are seriously considered but assumes that one model set, that "accurately portrays the performance of the disposal system", will be used in support of an application (see 40 CFR §194.23, not included in Appendix 3).

[15] The guidance document [EPA 1996] further clarifies this point. It specifies that the EPA will allow up to approximately 700 years of credit (after closure), provided the applicant can support this assumption.

The prevailing international view is that, in the post-closure period, active institutional controls cannot be relied upon to exist for more than a few hundred years[16], which accords with the EPA regulations. Beyond this time, it is accepted that record keeping would be a useful precaution that might reduce the likelihood of future inadvertent human intrusion into the repository but cannot be relied on for long [NEA 1995]. There is no international consensus on the value of passive controls, such as markers, further in the future. Some experts consider that markers could attract unwanted interest in the site [Sumerling et. al. 1996; IAEA 1996], while others consider that markers could be effective in stimulating a search for records and are, overall, useful [SSI 1993].

The IRG observes that the EPA regulations require the applicant to propose a system of passive institutional controls, including site markers, and allow the applicant to take some credit in performance calculations for the effect that these might have. To our knowledge, no other country formally allows credit to be taken for site markers in performance calculations. There is, however, no definitive position on this internationally.

The DOE does take this credit offered by the EPA. The IRG observes that it would be more defensible to demonstrate compliance without attempting to take credit for passive site controls, the effectiveness of which must be uncertain[17].

2.2.7 Terminology

The terminology used in the WIPP performance assessment community, and in some cases formalised by the EPA regulations, is somewhat different from that used in other countries and familiar to the IRG.

The IRG was surprised, for example, that the CCA states that expert judgement is not used, whereas it is clear that the judgements of the project staff have had a very important influence on the performance assessment. This arises because the term 'expert judgement' has a specific meaning in the EPA regulations, indicating formal elicitation of experts independent of the project.

Another example is the DOE use of the term 'scenario' to mean a single simulation of the future (see Section 2.2.5), whereas internationally it is more often used to denote a general description of a possible future [NEA 1992].

The terminology in the CCA did pose some initial problems for the IRG in conducting the review, and also reduces the readability of the documents. The IRG is supportive, however, of the principle of maintaining a well-defined and consistent use of terminology between a regulator and applicant, and recognises that the prime requirement is that the CCA is unambiguous in relation to the EPA.

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[16] The value assumed varies from country to country, usually 100 or 300 years.

[17] The Appendix EPIC, on which the DOE bases its claim to assume a reduced frequency of human intrusion up to 700 years after closure, presents a partial view of the archaeological evidence. The IRG believes that this view would not be generally upheld.