Radioactive Waste Management

OECD OCDE

NIREX Methodology for Scenario and Conceptual Model Development

An International Peer Review

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- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

PREFACE

This report represents the common views of an International Review Team (IRT) established by the NEA Secretariat on behalf of Nirex, to perform a peer review of their Methodology for Scenario and Conceptual Model Development. The review is based on the study of several relevant documents, as detailed in the Terms of Reference, hands-on testing of the relevant computerised databases as well as internal discussions within the IRT, and a week-long workshop at Nirex offices in Harwell, United Kingdom.

In keeping with NEA procedures for independent reviews, Nirex was not asked to check the report. The IRT has made its best effort to ensure that all information is accurate and takes responsibility for any factual inaccuracies. The report was initially transmitted to Nirex on 13 April 1999.

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EXECUTIVE SUMMARY

The background: Nirex has responsibilities for nuclear waste management in the UK. The company's top level objectives are to maintain technical credibility on deep disposal, to gain public acceptance for a deep geologic repository, and to provide relevant advice to customers on the safety implications of their waste packaging proposals. In compliance with these internal objectives and attending quality requirements, Nirex utilises peer reviews as appropriate to keep its scientific tools up-to-date and to periodically verify the quality of its products. In October 1998 the UK Department of Trade and Industry officially requested the OECD Nuclear Energy Agency (NEA) to undertake an international peer review, on behalf of Nirex, of an important portion of their methodology for assessing the long-term safety of a deep geologic repository. The portion to be reviewed deals with the treatment of features, events and processes (FEPs) and the construction of system evolution scenarios, as well as the use of this work in determining conceptual model adequacy and model development needs. The NEA agreed to perform this work on behalf of Nirex, and formed an International Review Team (IRT) consisting of four internationally recognised experts plus a member of the NEA Secretariat.

The review: The IRT performed an in depth analysis of five Nirex scientific reports identified in the terms of reference of the review. After these documents were studied, IRT members formulated a set of preliminary questions, which were presented to Nirex. After answers were received, a week-long workshop at Nirex offices allowed for remaining questions to be answered. During this week a large amount of information and experience was exchanged, and much clarification came about, e.g., through hands-on trial of the relevant electronic databases, and discussion of the regulatory framework within which the methodology was developed.

The review was to primarily judge whether the Nirex methodology provides an adequate framework to support the building of a future licensing safety case. Another objective was to judge whether the methodology could aid in establishing a better understanding, and, ideally, enhance acceptance of a repository among stakeholders: the scientific community, the community of public and industrial policy makers, and the public. This report documents the general findings of the review.

The work reviewed: Methodologies for conducting safety assessments include at a very basic level the identification of features, events, and processes (FEPs) relevant to the system at hand, their convolution in scenarios for analysis, and the formulation of conceptual models to be addressed through numerical modelling. This work is iterative in nature. It cannot be done only once. Lessons learned from these types of analyses should influence site investigations and design activities. In turn, as a site becomes better characterised, and as a design matures, these analyses need to be continually checked and modified accordingly.

The Nirex performance assessment methodology development process consists of a number of iterative stages that are broadly identified as follows:

Stage 1: FEPs identification, screening, and analysis.

Stage 2: Construction of scenarios and definition of conceptual models.

Stage 3: Development of numerical models.

Stage 4: Software development.

Stage 5: Confidence building.

The IRT focus was on stages one and two, primarily. However, it became apparent to the IRT that a review of these stages was not possible without at least some knowledge of the feedback loops between all five stages, and without appreciating to at least some degree the greater contexts in which all five stages operated. These contexts included the regulatory framework, the Nirex corporate goals and technical work plans, and the previous focus of Nirex work on the development of a deep underground rock characterisation facility at Sellafield.

The Review results: The main conclusion of the IRT is that Nirex has developed a potentially sound methodology for the identification and analysis of FEPs and for the identification of conceptual model needs and model requirements. The work is still in progress and is not yet complete.

However, the IRT members were impressed with the potential of the Nirex methodology in supporting the construction of a licensing safety case, especially in a risk-based approach.

The methodology deserves to be made better known outside Nirex. To this effect, and also to aid Nirex in its interactions with its stakeholders, the IRT recommends that Nirex more comprehensively and transparently document the methodology. The present documentation is too fragmented, and a number of areas have been identified where the work is either inadequately or inaccurately described. A single document that places the methodology into the wider decision-making context to repository development would allow the future reader, or reviewer of the methodology, or potential user or stakeholder, to judge its technical relevance and to identify where, in the overall decision process, the reader may be expected to be consulted or may expect to obtain specific information.

On specific points, the Nirex methodology introduces potentially useful tools for scenario and conceptual model development. Some of these tools would be useful also to waste management programmes which are not contemplating a risk-based approach to safety assessment. The organisation of FEPs in a Master Directed Diagram (MDD) with accompanying searchable databases with relevant information provides a well-structured, updateable description of the knowledge base for the disposal system from the point of view of post-closure safety. In particular, coupled with an adequate review process, this tool could allow the issue of comprehensiveness to be positively tackled.

The presentation of conditional risk of scenarios in a “weight risk diagram” together with the concept of “subsuming” allows subsequent analyses to concentrate on the few most safety-relevant scenarios, while maintaining an upper bound estimate of risk. The approach of using the MDD and the Interaction Matrix, to specify which FEPs and interactions between FEPs are to be included in conceptual models, provides assurance that the modelling of selected scenarios reflects the overall system description as documented in the MDD. The specification, in the Nirex methodology, of the conceptual models in terms of FEPs and their interactions is subsequently used to assess the applicability of already existing models and to identify potential needs for further model development. Even if no further model development is judged necessary, this approach enhances confidence in the assessment models.

The databases contain written information justifying decisions made. The depth of information is adequate for the present, conceptual stage of repository development, but more in-depth and specific information would be needed for supporting a licensing or public inquiry case. In particular, the role of expert judgement would need to be clarified further and the relevant input by experts will need to be documented more traceably and transparently.

A challenge to Nirex will be to describe in understandable terms such intricate technical concepts as “subsuming”, “weight-risk diagrams”, and the definition and uses of the “base scenario”. The IRT recognises the inherent difficulties of describing highly technical concepts and approaches to varied audiences, including non-technical ones. On the other hand, an effort needs to be made in this area, for the IRT itself had difficulties in fully understanding this part of the methodology before the direct interaction with Nirex.

The IRT recommends further that Nirex make available its computerised master directed diagram and interaction matrix systems to stakeholders and other interested parties. If properly managed, e.g., through a “user group”, review of these tools, as well as experience with these tools across a number of specific applications, could lead to important insights and improvements. Ultimately, such broader usage of these tools would favour the acceptance of the Nirex methodology by the wider community of radioactive waste management organisations and stakeholders.

1. PURPOSE AND CONDUCT OF REVIEW

Background

Nirex has responsibilities for nuclear waste management in the UK. The company's top level scientific objectives are to maintain technical credibility in deep disposal, to gain public acceptance for a deep geologic repository, and to provide relevant advice to customers on the safety implications of their waste packaging proposals. In compliance with these internal objectives and attending quality requirements, Nirex utilises peer reviews selectively to keep its scientific tools up to date and to periodically verify the quality of its products.

In October 1998 the UK Department of Trade and Industry officially requested the OECD Nuclear Energy Agency (NEA) to undertake an international peer review, on behalf of Nirex, of an important portion of their methodology for assessing the long-term safety of a deep geologic repository. The portion to be reviewed deals with the treatment of features, events and processes (FEPs) and the construction of system evolution scenarios, as well as the use of this work in determining conceptual model adequacy and model development needs. The NEA accepted the task to perform this work on behalf of Nirex, based on an agreed upon Terms of Reference document, and formed an international review team (IRT) consisting of four internationally recognised experts plus a member of the NEA Secretariat. The review started in October 1998.

Scope of the review

The Nirex Methodology for Scenario and Conceptual Model Development (the "Nirex methodology" hereafter) consists of a number of iterative stages that are broadly identified as follows:

Stage 1: FEPs identification, screening, and analysis.

Stage 2: Construction of scenarios and definition of conceptual models.

Stage 3: Development of numerical models.

Stage 4: Software development.

Stage 5: Confidence building.

These stages are designed to produce a clear and comprehensive trail of all the information considered, the decisions taken, and supporting justifications.

The Terms of Reference indicate that the IRT was:

"to undertake a peer review of the full process, with particular emphasis on the methodology for the development of scenarios and conceptual models".

Indeed, although the IRT focus was primarily on stages one and two, it became apparent that a review of these stages was not possible without at least some knowledge of the feedback loops between all five stages, and without appreciating to at least some degree the greater contexts in which all five stages operated. These contexts included the regulatory framework, the Nirex corporate goals and technical work plans, and the previous focus of Nirex work on the development of a deep underground rock characterisation facility at Sellafield.

In performing the review due account was taken of the fact that the "process is not yet complete" and that it was the methodology per se that was the subject of the review, and not its application to any specific site.

Conduct of the review

The review procedure consisted of:

- A start up meeting in October 1998, following a presentation of the methodology by L. Bailey (Nirex) at the annual meeting of the NEA Performance Assessment Advisory Group.

- A detailed review of the five Nirex reports (see Box 1).

- The submission to Nirex of an initial set of questions and the subsequent evaluation of their answers.

- A week-long direct interaction with Nirex staff and their contractors at the Nirex offices in Harwell in January 1999. During this week a large amount of information and experience was exchanged, and much clarification came about, e.g., through hands-on trial of the relevant electronic databases, and discussion of the broader context within which the methodology was developed and is meant to be utilised.

- Internal discussions within the IRT that led to the finalisation of the present report in April 1999.

Box 1 ***Nirex documents that received an in-depth review***

"Overview of the FEP Analysis Approach to Model Development", S/98/009
"Conceptual Basis of the Master Directed Diagram", S/98/010
"Overview Description of the Base Scenario Derived From FEP Analysis", S/98/011
"Modelling Requirements for Future Assessments Based on FEP Analysis", S/98/012
"Development and Application of a Methodology for Identifying and Characterising Scenarios", S/98/013

About this document

Much detailed advice was given orally to Nirex during the week-long interaction with the IRT in Harwell. While that information has been taken into account in preparing this report, not all information has been recorded herein. The present document presents, therefore, only the main findings of the review. Furthermore, the report assumes some familiarity with Nirex documentation, and increasingly so in the more technical sections.

In keeping with standard practices to guarantee independence, the contents of this document have not been checked by Nirex, and any omission – or factual inaccuracy – is the sole responsibility of the IRT[1].

The document is organised as follows:

- Following this introductory chapter, Chapter 2 provides a review of the Nirex methodology at an executive level. Namely, general observations and recommendations are given regarding transparency, traceability, comprehensiveness, and documentation of the methodology.

- Chapter 3 provides a summary of the technical observations on the main elements of the methodology.

- Chapter 4 contains the main conclusions of the review.

The report is completed by three appendices: Appendix 1 provides detailed technical observations on specific parts of the methodology; Appendix 2 reproduces the main text of the Terms of Reference of the review; Appendix 3 contains the professional profiles of the members of the IRT.

Throughout the document, observations are in regular type, while recommendations, if any, are italicised.

1. After submission of the review report NEA/RWM/PEER(99)1 to Nirex a few minor, mostly editorial changes have been made by the IRT. These changes are reflected herein.

2. OBSERVATIONS AND RECOMMENDATIONS AT AN EXECUTIVE LEVEL

In reviewing the Nirex methodology, the following questions were borne in mind:

- Has the methodology the potential to provide a rigorous and adequate framework for the eventual development of a detailed safety case in support of a license application of a deep geological repository? This includes the question whether the methodology is clear and comprehensive.

- Will the methodology be useful in helping Nirex

    I. maintain scientific credibility on deep disposal;

    II. gain public acceptance for a deep geological repository ?

Important considerations to this effect relate to the potential of the methodology to provide a comprehensive set of FEPs and relevant scenarios and conceptual models, a basis for traceable and transparent safety assessments, and an approach and documentation that are responsive to the participation and information needs of a varied audience.

Comprehensiveness

Comprehensiveness refers to being able to answer the following question "have we thought about it and, addressed it appropriately?"

Comprehensiveness can never be accomplished in one step, and will have to be judged against a record of continuous and open reviews, the most recent of these reviews having given evidence of no new major findings. The Nirex documentation correctly recognises that comprehensiveness can only be sought and achieved in relation to a specific site, a specific type of waste, and a specific regulatory context. For instance, at present, due to the regulatory context, the methodology focuses on only one specific quantitative safety measure (risk), whereas in the future, Nirex may have to consider additional safety indicators and provide additional lines of reasoning for making a safety case.

The IRT is of the view that the methodology has the potential for producing and documenting a comprehensive set of FEPs, scenarios and conceptual models, in a risk-based approach. The methodology is also general enough to be applied at a wide range of sites and conceptual designs, although the judgement needs to be reserved on how the methodology would apply in supporting other safety indicators than risk, or in supporting multiple lines of reasoning. Indeed the "weight-risk diagrams"* and the decisions to "subsume"* are closely associated with the risk approach.

The Nirex documentation addresses the issue of comprehensiveness most clearly for the MDD. Indeed, the MDD is very advanced – in terms of its comprehensiveness – given the current repository development stage. The Interaction Matrices (IM) and the Scenario Selection process are less advanced in terms of comprehensiveness, and need additional, specific attention.

The IRT appreciated that the content of the MDD and the selected scenarios and conceptual models have been compared with the NEA FEPs-database. International comparison with information and decisions made in other waste management programmes is also a useful component in any argument for comprehensiveness. Such comparisons should be undertaken and communicated to other programmes.

Review by external experts is important for arguing comprehensiveness. To that effect, the role of experts and the use of expert judgement needs to be described accurately and transparently. The current Nirex documentation is wanting in this respect, although it may be adequate for the present development stage of the UK programme. For instance, the IRT found it unclear if a given reference to expert judgement meant it was a formal or an informal elicitation process, and could not determine the affiliation of the expert(s). It was not made clear, at times, whether: (i) expert judgements involved a single Nirex scientist, (ii) formal or informal elicitation meetings internal to Nirex and documented in notebooks, or (iii) formal or informal elicitation meetings with participation of outside experts also documented in notebooks. In the case of a formal elicitation process, it is generally recognised that specific requirements need to be stated and met, including a justification of the number of experts in order to provide a reasonable degree of inclusiveness of legitimate variations in scientific opinion.

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* Dealt with further on page 22.

The IRT considers that the methodology is a promising one for preparing a safety study in support of a licensing case. It is recommended that Nirex clarifies (or explores) how and when the methodology can be applied when using other safety indicators.

For a licensing case, or external enquiry, it should be made clear what process and criterion was used for expert elicitation, and the documentation should be easy to consult. The method and outcome of the comparison of the MDD with the NEA and other FEP databases needs to be better documented. A comparison of the MDD and the IM with interaction matrices or influence diagrams of other programs should be considered.

Traceability

A safety assessment is traceable, when informed reviewers are able to reconstruct the decision trail that took the analyst to specific models and analyses.

The Nirex methodology is "traceable" in principle. Namely, the IRT not only found that the methodology had no built-in impediment to traceability, but that the MDD, especially in concert with the FANFARE software, is a tool that allows good traceability in the construction of Conceptual Models and in the definition of the Base and Variant Case Scenarios. Still, it is not only the method, but also the thoroughness and attention to documentation that will determine whether an application of the method is traceable. To that effect, the documentation of decisions and arguments concerning the interactions among FEPs and among conceptual models needs to be more fully elaborated. Documentation of decisions connected to scenario selection also needs further attention and development.

It is recognised that, to a certain extent, there is a tension between the needs to produce a comprehensive documentation and to facilitate the task of the reader to determine what has been done and why. The planned hierarchy of documents, with higher-level documents being simplified and lower-level documents being referred to for details, is likely to help Nirex achieve the right balance between traceability and transparency.

Overall, it is recommended that the documentation procedures and search capabilities in FANFARE and other databases be further developed.

Transparency

Transparency is a term used to describe the ability of different audiences of understanding, at a reading of the documents or use of the electronic tools, what these are meant for and their role in the overall methodology. Transparency favours the correct use of these materials.

The MDD, FANFARE and the other databases, will be important tools for improving the transparency of what is being considered in a safety assessment. The transparency of the Nirex databases needs to be further improved to that effect.

In reviewing the Nirex documentation, the IRT found that transparency was reduced by not using terms consistently (several slightly different definitions of the terms FEP, conceptual model, and scenario) and by writing official Nirex documents in a style and language suited mostly to a Nirex audience or their close associates. Other technical reviewers and, at least, informed stakeholders, need to be borne in mind in future efforts. For instance, at a technical level, "subsuming" is a concept that needs better and more direct explanation; at a more general level, it must be considered that, in a public setting, "risk" has more than one definition or connotation.

Overall, the Nirex documentation is fragmented and, in part, repetitive. It is thus difficult, especially for external reviewers, to understand the methodology and fully judge its merits. The task of understanding and judging was facilitated for the IRT by the week-long interaction with Nirex and its contractors, but not every reviewer will enjoy this possibility. Thus an important effort should be made to make the methodology more transparent. In order to allow a judgement to be formed more easily on the merits of the Nirex methodology, its documentation needs to make reference to the context of its application, in terms of the safety objectives, the conceptual waste disposal system, the maturity of components of the project such as site investigations, design, and performance assessment, as well as the importance of having appropriate resources. These items are also addressed in the following two sections.

It is recommended to further develop the documentation in the databases, and to augment several definitions, and to check the use of terms for *consistency throughout the documentation. An overview document unifying the concepts at hand would be useful*[2].

Placing the methodology in a wider context

The Nirex methodology is meant to support the post-closure safety case for a deep geological repository in view of a license application. A safety assessment is, however, also a valuable support to decision-making at various stages in repository development. Such decisions range from judgements made within a safety assessment project team to overall programmatic decisions made by the regulators, the government or other stakeholders. The current documentation does not discuss how the methodology could be adjusted to support important decision making during the different development stages of a repository. The IRT believes, however, that the methodology is potentially valuable in the development stages before licensing as well as in the final safety confirmation before closure.

At all repository development stages, Nirex will not only need to satisfy the technical requirements of the regulator, but also the technical and non-technical needs of other stakeholders. The Nirex methodology should be structured and described in a way that communicates openness to external suggestions, i.e. that revisions are possible. Thus the diagrams with iteration loops should include external dialogue with regulators and other stakeholders. In particular, external input for information to be stored in the MDD should be elicited and its relevance evaluated.

A general recommendation is to produce a new, single-volume overview document that gives a more comprehensive picture of the methodology and places it in a better defined context. The iterative nature of applying the methodology within a maturing project needs greater emphasis. It is furthermore recommended to use this comprehensive overview document to reach out to the regulator, stakeholders, and the public in a constructive dialogue. Connections to programmatic decision points should be added. The place of the current effort in the overall process leading up to the licensing of a facility and beyond should be seen, so that suggestions for considering additional FEPs, for example, can be communicated early enough to have a potential impact.

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2. This will be discussed further in the following section.

Resources

Technical plans, or descriptions of methodologies, tend not to address the resources that will be needed to implement the methodology. Applying the Nirex methodology to support a licensing safety case will require significant resources.

The IRT cannot give further comment on this item. It is noted, however, that the methodology itself can help strike a balance between the need for being comprehensive and the need to focus on matters important to safety when resource constraints exist during repository development.

The importance of assuring that appropriate resources and time scales be made available should be referred to in the documentation of the methodology.

3. SUMMARY OF TECHNICAL OBSERVATIONS ON THE MAIN ELEMENTS OF THE NIREX METHODOLOGY

FEPs analysis and the Master Directed Diagram (MDD)

The first stage of the Nirex methodology involves FEPs identification, screening and analysis. The FEP identification is achieved by developing a Master Directed Diagram (MDD), which is a structured diagram showing how performance assessment endpoints like "Radiological Risk" depend on several FEPs, which in turn depend on even more detailed FEPs. Furthermore, for each FEP the database contains an "encyclopaedia entry" providing FEP definition, information as to why a FEP is included, in what circumstances it is likely to be relevant and the author and date of the FEP entry and dates of revisions of the text. The user can access these entries by several means including "clicking" directly on the graphical display of the MDD tree structure or by using word search facilities.

The organisation of FEPs in a Master Directed Diagram (MDD) with accompanying searchable databases provides a well-structured up-to-date description and review of the knowledge base for the disposal system from the point of view of post-closure safety. It represents an important contribution to the literature because of the originality of aspects of its conception, the quality of its implementation and its many potential uses. This tool would also be useful to programmes not contemplating a risk-based approach to safety assessment.

The concept of a FEP is applied in an unusually broad sense. Branches of technology or science, like "dosimetry", "radiotoxicology", as well as performance measures, are all considered as FEPs. This broad use of the term may be justified, but its definition should be changed to reflect its actual use. Alternatively, different terms may be used to identify some of the present Nirex FEPs.

The MDD is documented in a computer database using the FANFARE software. The software is user-friendly and easy to update. Review of the technical content of the MDD was outside the scope of the NEA peer review. It is recommended that the search capabilities of FANFARE be further developed (page 18).

It is further recommended that FANFARE be made externally available, and that provisions be made to take care of comments, suggestions etc. from such external users. The IRT also recommends expanding the scope of documentation within FANFARE to include all relevant decisions made during scenario selection and conceptual model development.

Scenario development

The first part of the second stage of the Nirex methodology is scenario construction. In its documentation Nirex describes a scenario as “a broad brush description of a possible future evolution of the system”. In the context of the MDD a scenario is specified in terms of a set of FEPs and their interactions. The FEPs are selected by classifying the FEPs in the MDD into “scenario defining FEPs” and “scenario FEPs”. Many of the scenario defining FEPs are further classified into a “base scenario” selected to provide a broad and reasonable representation of the natural evolution of the system and its surrounding environment. The remaining scenario-defining FEPs are grouped into different scenario classes for consideration as variant scenarios. By using a weight-risk diagram and the concept of subsuming, those scenario-defining FEPs implying greatest conditional risk are identified for further analysis.

The Nirex methodology introduces potentially useful tools for scenario development. The presentation of conditional risk of scenarios in a “weight risk diagram”, together with the concept of explicitly masking a scenario with lesser risk by one with greater risk, or “subsuming,” allows subsequent analyses to concentrate on a few important scenarios, while maintaining an upper bound estimate of risk.

While understanding that the weight-risk diagrams and the accompanying idea of subsuming are very valuable, a weakness of the methodology is the fact that attention may be diverted from consideration of possible interactions (concurrence) of the subsumed scenarios. The applicability of the methodology depends heavily on the initial estimates of risk and associated uncertainties. It is thus essential that the rationale for the simplified risk estimates used in the early phases of scenario development are properly documented.

Future documentation should contain a clearer discussion of how and, at which stages, weight risk diagrams are used. The notion of subsuming is new and advantageous, but the strong point of the method (maintaining an upper bound estimate of risk) should be more carefully explained.

It would also help the reader considerably if the concept of weights was better explained. It should be made clear that weights are bounding estimates of the probability of the existence of a scenario or scenario representation, or of a given sector of its time line at a given point in time. These are complex, but useful, concepts.

The base scenario has a special role to play, not only because it indicates a sort of natural, expected evolution, but also because it is the point of departure for constructing variant scenarios by adding more FEPs. The base scenario should be better defined and explained.

The IRT considers that the representation of single scenario FEPs by time lines is a helpful and transparent approach in qualitatively assessing the time evolution of a scenario. It captures, in an abstract way, the complex time-dependence of environmental processes, and may reduce the need for a more quantitative calculational approach.

Conceptual model development

The second stage of the Nirex methodology also involves definition of conceptual models. In the Nirex methodology conceptual models are regarded as “a word picture of sufficient detail that it can be developed into mathematical equations and data requirements”. The conceptual model should provide information concerning the scope of the model and its interaction with other parts of the system. The conceptual model development starts with the set of FEPs representing a scenario selected from the scenario development part of the methodology (see previous section). In order to highlight interactions between FEPs, the FEPs for the selected scenario are organised into an “Interaction Matrix diagram”. The information in the Interaction Matrix diagram is subsequently used to specify needs for mathematical model development. In particular, the question is asked if the conceptual model can be treated with an existing mathematical model, if adjustments to existing models are necessary or if an entirely new model development is needed in order to properly represent the conceptual model.

One of the strengths of the Nirex methodology is the use of the MDD and the Interaction Matrix to organise FEPs for defining conceptual models. The model requirements derived from these analyses allow assessment of the applicability of current models – and define overall requirements for new model development.

Ideally, the methodology would allow model specification in full consistency with the general considerations in the MDD and in the scenario definitions. In practice, model selection always needs to include judgmental aspects and a full record of traceable and justified decisions from the MDD into the actual model specification is not attainable. Still, the documentation supporting selections made could be improved. For example, the Interaction Matrix (IM), which is a necessary complement to the MDD since the MDD is not a practical tool for displaying all interactions between FEPs, should properly document the nature of the interactions, and not only the rationale for the importance scoring.

4. CONCLUSIONS

The main conclusion of the IRT is that Nirex has developed a potentially sound methodology to the identification and analysis of FEPs and to the identification of conceptual model needs and model requirements. The work is still in progress and is not yet complete. However, the IRT members were impressed with the potential of the Nirex methodology in supporting the construction of a licensing safety case, especially in a risk-based approach.

The methodology deserves to be made better known outside Nirex. To this effect, and also to aid Nirex in its interactions with its stakeholders, the IRT recommends that Nirex more comprehensively and transparently document the methodology. The present documentation is too fragmented, and a number of areas have been identified where the work is either inadequately or inaccurately described. A single document that places the methodology into the wider decision-making context to repository development would allow the future reader, or reviewer of the methodology or potential user or stakeholder, to judge its technical relevance and to identify where, in the overall decision process, the reader may be expected to be consulted or may expect to be able to obtain specific information.

On specific points, the Nirex methodology introduces potentially useful tools for scenario and conceptual model development. Some of these tools would be useful also to programs which are not contemplating a risk based approach to safety assessment.

The organisation of FEPs in a Master Directed Diagram (MDD) with accompanying searchable databases with relevant information provides a well-structured, updateable description of the knowledge base for the disposal system from the point of view of post-closure safety. In particular, coupled with an adequate review process, this tool could allow the issue of comprehensiveness to be positively tackled. The presentation of conditional risks of scenarios in a “weight-risk diagram” together with the concept of subsuming allows subsequent analyses to concentrate on the few most safety-relevant scenarios, while maintaining an upper bound estimate of risk. The approach of using the MDD and the Interaction Matrix, to specify which FEPs and interactions between FEPs is to be included in conceptual models, provides assurance that the modelling of selected scenarios reflects the overall system description as documented in the MDD. The specification, in the Nirex methodology, of the conceptual models in terms of FEPs and their interactions is subsequently used to assess the applicability of already existing models and to identify potential needs for further model development. Even if no further model development is judged necessary, this approach enhances confidence in the assessment models.

The databases contain written information justifying decisions made. The depth of information is adequate for the present, conceptual stage of repository development, but more in-depth and specific information would be needed for supporting a licensing or public inquiry case. In particular, the role of expert judgement would need to be clarified further and the relevant input by experts will need to be documented more traceably and transparently.

A challenge to Nirex will be to describe in understandable terms such intricate technical concepts as “subsuming”, “weight-risk diagrams”, and the definition and uses of the “base scenario”. The IRT recognises the inherent difficulties of describing highly technical concepts and approaches to varied audiences, including non-technical ones. On the other hand, an effort needs to be made in this area, for the IRT itself had difficulties in fully understanding this part of the methodology before the direct interaction with Nirex.

The IRT recommends further that Nirex make available its computerised master directed diagram and interaction matrix systems to stakeholders and other interested parties. If properly managed, e.g., through a “user group”, review of these tools, as well as experience with these tools across a number of specific applications, could lead to important insights and improvements, and, ultimately, would favour the acceptance of the Nirex methodology by the wider community of radioactive waste management organisations and stakeholders.

Appendix 1

DETAILED OBSERVATIONS AND RECOMMENDATIONS

FEPs analysis and the development of the MDD

General

The MDD is a tool for providing a well structured up-to-date description and review of the knowledge base for the disposal system from the point of view of post-closure safety. It represents an important contribution to the literature because of

- the originality of parts of its conception;
- the quality of its implementation;
- its many potential uses.

Originality: combination of FEPs with factors and issues that need to be looked at to satisfy safety demonstration and illustration requirements. In principle, the methodology can be carried over to other environmental problems.

Quality of implementation: a computer-based, user-friendly, well documented system, easy to update.

Potential uses and purposes: a management tool (i) to check the status of present understanding; (ii) to facilitate review by and dialogue with other audiences than Nirex staff; (iii) to facilitate a judgement of comprehensiveness. With regard to the latter point, the IRT understands the useful distinction drawn by Nirex between comprehensiveness and completeness, and agrees that this document will provide Nirex with a tool that can provide a comprehensive – fit for purpose – set of FEPs.

The MDD is more than a structured FEPs list. It is a potentially effective tool for writing down the scheme for evaluating potential repository impacts in a structured way, and should constitute an important part of the presentation of the safety case. However, the methodology is not yet complete, and will be adjusted some as it is applied in the implementation of a full safety case.

The MDD is thus an important achievement as a management tool and a contribution to the literature on safety assessment. The IRT encourages Nirex to make the MDD approach to information management better known in the literature. Indeed, *the IRT recommends that Nirex make available its computerised master directed diagram and interaction matrix systems to stakeholders and other interested parties. If properly managed, e.g., through a "user group", review of these tools, as well as experience with these tools across a number of specific applications, could lead to important insights and improvements. Ultimately, this would favour the acceptance of the Nirex methodology by the wider community of radioactive waste management organisations and stakeholders*.

Terminology

The IRT notes that the use of the term "FEP" in the Nirex methodology is not fully consistent with the definition given in the glossary (taken from the NEA definitions). The term is applied in an unusually broad sense. Even concepts related to human knowledge or subject matters, like "dosimetry", "radiotoxicology", or even the performance measure itself, are considered FEPs. The IRT recognises that the top-down approach of the development of the MDD naturally leads to such an extension. Specifically, it relaxes the need to describe different FEPs on a similar abstraction level, whereas the latter is needed in a FEP-based approach for developing influence diagrams or interaction matrices.

The IRT recommends that the definitions given should better reflect the actual use of the words in the methodology. It is important to acknowledge internationally accepted definitions, but in cases where there is methodology development, the new setting must be carefully explained.

FANFARE

The IRT finds the FANFARE software to be a very useful tool. It also has a need for further development. The IRT accepts that there is more than one way to create the MDD in terms of how general FEPs are decomposed into more specific ones. This means that there could be difficulties in finding some commonly used FEPs in the system. For example, not having been a part of the team constructing the MDD, the IRT sought to trace certain major themes through the MDD by searching for very high category words such as “glaciation” and a few others. What was found is that the MDD contained the effects of these larger constructs, suggesting there was an effort to achieve comprehensiveness. However, there was no roadmap for an outsider to follow, to determine what FEPs would be influenced by the effects of these super-categories of what the IRT thought would be commonly assumed system drivers.

It became apparent to the IRT that FANFARE does not fully cover the documentation of decisions and arguments concerning the interaction of FEPs and interactions between conceptual models (see also, Conceptual Models and the Interaction Matrix page 34). Also the traceability of decisions connected to scenario selection still seems to need further development.

The IRT recommends that the search capabilities of FANFARE be further developed. It is also recommended that FANFARE be made externally available and that provisions be made to take care of comments, suggestions etc. from such external users. The IRT also recommends expanding the scope of documentation within FANFARE to include all relevant decisions made during the scenario selection and conceptual model development processes.

Screening criteria

In general, greater clarity on screening criteria would help the transparency of the work. One particular comprehensiveness issue revolves around the criteria for deciding when to stop developing the MDD in more detail. It is understood that the rule “helpful to modelling” is not a screening criterion, but more a “stopping rule” to give guidance on the appropriate level of detail for FEP decomposition. Still, the rule did not fully appeal to the IRT, since one stated aim for the method as a whole is to clarify the needs for modelling, and this information can hardly be available at the outset when screening criteria are being formulated.

The IRT recommends that the iterative nature of the entire process, including the review of screening criteria and “rules” applied in the process as experience is gained, be made more transparent.

Interactions between FEPs

The IRT feels that the Interaction Matrix (IM) is a necessary and important complement to the MDD, since MDD is not well suited to display the full spectrum of interactions between the FEPs. *This should be better acknowledged in the documents.*

Furthermore, the IM appears to be somewhat less extensively treated in the documentation than the MDD. This may reflect a longer occupation with the latter. *It is expected that in a full application of the methodology this apparent discrepancy in treatment would not recur.*

Scenarios

General

The Nirex methodology introduces some new and potentially useful tools for scenario development. In particular, the IRT wishes to mention the weight-risk diagram and the notion of subsuming.

The weight-risk diagram is a useful tool since subsuming arguments need to separate weight and conditional risk. For discussions with the public, whose risk perception may depend not only on the product of the two factors but also on their actual values, the weight-risk diagram is a useful representation. The IRT team would like to have seen *a clearer discussion in the documentation of how and at which stages weight-risk diagrams are used* (e.g., walking through an illustrative example on a scoping evaluation for identifying important scenarios, on subsuming, on the simplification of timelines etc.).

The notion of subsuming is new and is perceived by the IRT as a valuable development in scenario analysis. Its advantages become apparent when the aim is not only to calculate the risk from a representative set of scenarios but further to obtain an estimation of the total risk – without employing a full probabilistic analysis technique. *The fundamental advantage of the method (maintaining an upper bound estimate of risk) should be more carefully explained.* It should be given more weight than the secondary benefit of not having to estimate the weight of the subsumed scenario representations in the actual applications. (The reason being that the weights could be shown to be already included in the estimate for the weight of the scenario subsumed into.) Potential shortcomings are associated with the fact that subsuming implies dropping the case from further analysis. *Potential shortcomings should, however, be further explored in the document.*

Terminology and clarity

It would help the reader considerably *if the weights were explained more fully* as being an overestimate of probabilities at a given point in time for having a scenario, a scenario representation, or a given sector of its time-line in existence. This is of course related to, but not identical to, the notion of the probability of having a certain scenario realised in the set of possible futures. The weight in this application applies more directly to the problem of calculating the risk to an individual at a given time.

It is noted that the term base scenario is generally used to describe any state of the system that at the point of time has the characteristics of the base scenario, even if the future evolution contains a FEP that causes departure from the characteristics of the base scenario proper. This is not completely consistent with the definition of a scenario given in the beginning as being a broadbrush description of a possible future, which implies a complete time history. The IRT acknowledges that the inexact use of the term base scenario in the methodology is a convenient and common practice. *However, the IRT feels the definition of the term scenario should be clarified, and kept consistent throughout the documentation*. The actual use of the word should be explained, especially as regards the base scenario and as it is used in the assignment of weights to scenario representations and time line sectors.

Base Scenario

The base scenario has a special role to play in the Nirex methodology, not only because it indicates a sort of natural, expected evolution, but also because it is the point of departure for constructing variant scenarios by adding more FEPs. It thus matters how it is chosen, since multi-FEP additions become increasingly complex to handle in the analysis of the risk. The IRT observes that, here, the base scenario implies much more realism than is usually implied in other assessments which use words like “base case” to represent quite simplified but convenient descriptions of the system.

The importance of the base scenario requires that the selection of FEPs to be included be very carefully motivated. The present criterion “more likely than not to be relevant" may be too weak in this sense, even if the IRT also realises that judgements are unavoidable in this selection process. *If possible, the base scenario should be given a better definition.* The word "natural" within brackets does not give the full or correct indication of what was considered, and was initially misleading to the IRT.

The IRT will not provide comments on the actual content of the base scenario, since this is outside the scope of the review.

Variant Scenarios

In the identification and definition of scenarios, the IRT found the weight-risk diagrams and the accompanying idea of subsuming very valuable tools. The importance of the weight-risk diagrams to the methodology, and their inherent complexity, necessitate a very careful and clear explanation of their bases and uses to the reader.

Subsuming is done mainly for the scenario representations after evaluating their conditional risk curves. However, there is also subsuming on the level of scenario defining FEPs if the consequences of the FEPs are considered similar. It is rightly noted that in those operations one must pay attention to the possibility that the FEPs may interact differently with other FEPs (in multi-FEP variant scenarios). In the documentation one refers most often to subsuming of scenarios instead of scenario representations as would, usually, be more precise.

A weakness of the method is seen in the fact that attention may be diverted away from possible interactions (concurrence) of the subsumed scenarios. In special cases such interactions could give rise to a higher conditional risk than was estimated for the single scenarios, including the scenario subsumed into. *Therefore, care must be taken not to lose sight of the possible continued importance of a subsumed FEP within multi-FEP scenarios.*

Regarding subsuming it was not clear before the presentations at Nirex that the base scenario risk curve is in fact replaced by a step curve. Neither was it clear that this curve would in fact need to be stepped up in the subsuming process if subsumed scenarios have higher conditional risk at some point in the time sequence. Replacing the risk curve with a step curve or even a horizontal line is perfectly legitimate in order to derive an upper bound to the risk as required for meeting the regulatory requirements. However it implies a loss of valuable information and the resultant curves cannot be used to explain the time evolution of the total risk from the repository as will most likely be needed for the presentation of results to a broader public. *In fact, more generally, for communication with the public the IRT sees a reason for taking a broader view not restricted to the assessment basis nor to just the kind of information needed for presenting the case to the regulator.*

The applicability of the methodology seems to depend quite a lot on the initial estimates of risk and associated uncertainties. Despite the iterative nature of the overall process, it appears unlikely that initial risk estimates for FEPs that become subsumed will be checked in more detail later in the process. *It is thus essential that the rationale for the simplified risk estimates used in early phases are properly documented.* The structure of such documentation does not yet seem to be fully clear and needs further development. The IRT realises that it is necessary to strike a balance between the detail of documentation and the resources spent in developing it, however.

The representation of single scenario FEPs by time-lines seems to be a helpful and transparent approach in qualitatively assessing the time evolution of a scenario. The approach of developing simplified combined timelines (time interval matrices, etc.) also seems to be structured, and promising, to handle the difficult problem of analysing multiple FEP scenarios accounting for their time dependency. The approach seems to go well beyond practices in many other programs. Still, it is difficult to see how the approach could be realistically applied above the 3-level FEPs scenarios.

The development of a simplified time line, it seems, relaxes the need to develop complex time-dependent computer models of environmental processes. The IRT thus thinks that the importance of developing fully time dependent computer models may be overstated in the documentation. Such models tend to be hard to validate and also difficult to handle practically (not to mention the development costs). *Attention is, however, required to not lose important information in the simplification steps. Again it seems that proper documentation of the rationale for decisions taken are key for maintaining comprehensiveness and traceability.*

Conceptual models and the interaction matrix

General

One of the strengths of the Nirex methodology appears to be the use of FEPs to organise conceptual models. The methodology seems useful both for providing justification for existing mature conceptual and computational models as well as for preparing the specifications for models to be developed.

Terminology

The meaning of "conceptual model" is not fully clear. The stated meaning as "a group of FEPs" (S/98/012, p. 3.3) and their interactions is not the NEA/PSAG definition given in the glossary. *Since the apparently used definition seems to be useful in the context of Nirex's method, the glossary should be adjusted accordingly.*

The interaction matrix

The Interaction Matrix is a necessary complement to the MDD since the MDD is not a practical (or transparent) tool for displaying all interactions between FEPs. *The IRT suggests that this should be made more transparent in the documentation.*

The status of the interaction matrix appears to be less mature than the MDD. The step from the formal approaches to documenting interactions and specifying requirements for model development has only been taken in an illustrative fashion to this point. The database documenting decisions on interactions is still incomplete. This includes such basic features as documenting the rationales for assigning interaction scores.

The IRT recommends that a searchable database for interactions be developed (preferably combined with FANFARE). The nature of the interactions, and not only the rationale for scoring, should be properly documented, since the diagonal elements of the matrix could consist of many different aggregated FEPs from the MDD. The content of the IM, including the selection of names, should be technically reviewed and be potentially updated.

Detailed model requirements

The model requirements derived from the IM (and the MDD) are useful in order to assess applicability of current models – and to define overall requirements for new model development. However, there seems to be a lack of traceable documentation of all decisions.

The method of classifying models appears to be useful. It helps in auditing previous modelling capabilities. The classification (ABCEF) is not sufficient for deciding on priorities for further model development, one also needs to consider the potential contribution to risk.

The MDD/IM based audit only provides overview requirements. Out of these detailed requirements specifications need to be developed, which requires use of information from other sources than the MDD/IM. This is certainly acknowledged in the methodology, but this again raises questions on how to further develop fully traceable documentation for model development specification.

Appendix 2

TERMS OF REFERENCE OF THE INTERNATIONAL PEER REVIEW (MAIN TEXT)

Background

The Nirex methodology to model development proceeds through a number of carefully controlled and recorded stages and has been designed to produce a clear and comprehensive audit trail of all the decisions taken, together with their justifications. This methodology is summarised in Figure 1. Independent peer review is regarded as a very important part of the methodology, building confidence at each stage and hence in the overall result.

As illustrated in Figure 1, Nirex has already completed three independent peer reviews, covering certain stages of the model development process, as follows:

1. A brief, preliminary review of the Master Directed FEP diagram (MDD), its structure and usability and the classification of scenario-defining FEPs. The review also considered the usability of FANFARE, the software which provides access to the MDD. This review was performed in September 1996 by Safety Assessment Management Ltd.

2. A more detailed review of the MDD and the identification of conceptual models for the base scenario. This review was performed by QuantiSci and completed in January 1997.

3. A software engineering peer review of the TDPSA code. This recently completed review has been conducted by the software house, EDS Defence Ltd, and has involved a number of stages, conducted in parallel with the development of the TDPSA code. The initial phase, examining the software requirements and design documentation began in June 1996; the final phase, involving detailed examination and testing of the latest TDPSA code version completed in May 1998.

To complete the peer review of the entire model development methodology and process, Nirex has invited an NEA team to undertake a peer review of the full process, with particular emphasis on the methodology for the development of scenarios and conceptual models. Details of the context, objectives, scope and timetable of the peer review by the NEA are detailed hereafter.

Context of the review

Since the rejection of the RCF planning appeal, Nirex top-level Company scientific objectives are concerned with:

- maintaining scientific credibility on deep disposal;
- gaining public acceptance for a deep geological repository; and
- providing relevant advice to customers on the safety implications of their waste packaging proposals.

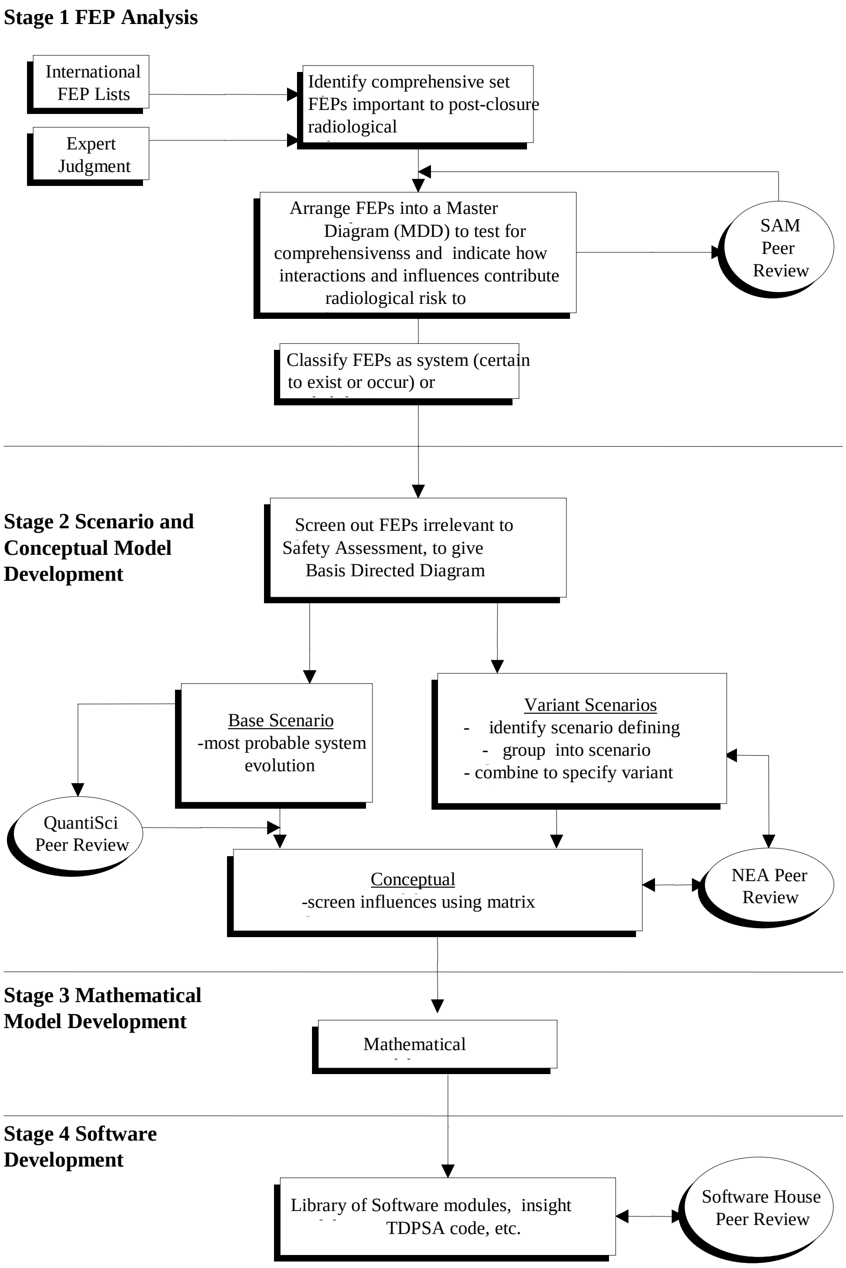
These objectives require Nirex to keep abreast of world wide developments in science, regulation, technology and politics for deep disposal, as well as to evaluate and build confidence in safety assessment methodologies.

Objectives for peer review

The review should examine – from the point of view of current international practice – the Nirex adopted approach to FEP, scenario and conceptual model development methodology and determine whether this approach has the potential to provide a rigorous and adequate framework for the eventual development of a detailed safety case in support of a deep repository licensing application.

It is accepted that the reviewers may have preferred an alternative approach themselves, but they should not be biased by this if the Nirex approach can be shown to be adequate and rigorous.

Figure 1: The Nirex Approach to Model Development



Scope of the peer review

It is intended that this review should build upon the earlier peer reviews (see Figure 1), particularly that conducted by QuantiSci. Therefore it is envisaged that the reviewers would wish to focus their efforts upon the methodology for the identification and development of scenarios and conceptual models, leading to the software modelling capability requirements. However, it will be necessary to review these elements within the context of the full model development methodology.

Thus, the scope of the peer review should include:

1. high-level review of the MDD, including its comprehensiveness in terms of the FEPs included and the overall approach to FEP analysis;

2. critical appraisal of the definition and construction of the base scenario;

3. critical appraisal of the approach to the identification of the scenario-defining FEPs, their grouping into scenario classes and the proposed methodology for combining scenario-defining FEPs to develop variant scenarios;

4. review of the methodology for the identification and development of appropriate conceptual models, consideration of the influences between conceptual models using the matrix diagram and the identification of modelling requirements.

Supporting documentation

In support of the above peer review aims, the following documentation (all of which is due for publication) will be provided to the peer review team:

1. the report, "Overview of the FEP Analysis Approach to Model Development" (80 pages);

2. electronic copy of the MDD and its underlying FEP database, the report "Conceptual Basis of the Master Directed Diagram" (25 pages);

3. the report, “Outline Description of the Base Scenario” (approx. 80 pages);

4. the report, “Development and Application of a Methodology for Identifying and Characterising Scenarios” (approx. 80 pages);

5. electronic (Excel spreadsheet) copy of the matrix diagram, the report, “Modelling Requirements Document for Future Assessments Based on FEP Analysis” (approx. 80 pages).

The UK regulatory guidance, “Disposal Facilities on Land for Low and Intermediate Level Radioactive Wastes: Guidance on Requirements for Authorisation”, will also be provided as background material, setting the context for the Nirex model development requirements.

Documentation ancillary to the review

It should be recognised that although proceeding according to a clearly defined strategy, the practical implementation of the Nirex FEP analysis and model development process has evolved over the project, with the continual gaining of experience and insight. Furthermore, the process is by no means complete, it is expected to develop further as and when new software models are developed for use in any future assessments. A number of unpublished project notes have been produced, which will be made available to the peer review team if required, as evidence of the management and evolution of the process. These notes should be regarded as discussion documents or working notes, which have been superseded by the documents for publication. The main project documents likely to be of interest include:

- the FANFARE design documents and User Guides (for accessing the MDD);

- the Technical Commentary for the MDD;

- conceptual Model Descriptions and FEP lists;

- methodology Guidance Notes and Records of Meetings.

Review timescales

An overview presentation of the model development approach is planned for the NEA PAAG meeting on 14-16 October 1998, which may provide a further useful introduction for any members of the peer review team present at that meeting.

It is anticipated that the peer review team will meet at Nirex offices in Harwell, Oxfordshire for a period of about a week in January 1999. Nirex will welcome any initial comments arising from the documentation and will endeavour to address specific points prior to the peer review meeting. Nirex will also ensure that all key personnel involved in the project are available to be called upon as required during the peer review meeting and will arrange appropriate presentations to respond to any issues raised by the peer review team.

The peer review team will make a brief presentation of their conclusions at the end of the review week and a formal report of their findings will be produced as soon after the meeting as practicable, but in any case before the end[3] of March 1999.

3. The IRT members' individual workload and schedule have necessitated delaying this report until mid-April 1999.

Appendix 3

PROFESSIONAL DETAILS OF THE MEMBERS OF THE INTERNATIONAL REVIEW TEAM

Abraham E. Van Luik (USDOE/YMP, USA) – Chairman

Abraham Van Luik received his Ph.D. in 1978 from Utah State University. His dissertation was a model of the physical chemistry of the Great Salt Lake, Utah, which was published in the American Chemical Society's Symposium Series # 93. He also holds a MSc. in soil chemistry from Utah State University. His BSc. is in chemistry, from the University of California at Los Angeles.

Prior to becoming part of the repository program, Dr. Van Luik did mined land reclamation and radioactive waste site characterisation work at Argonne National Laboratory and Rockwell's Hanford Operations, respectively. While a Project Manager at Argonne National Laboratory in 1982, he took charge of two regional surveys, and technically contributed to one, describing the potential crystalline rock bodies that could be further studied as part of the site selection process for a nuclear waste repository.

In the fall of 1983 Dr. Van Luik provided on-site assistance to the Office of Civilian Radioactive Waste Management (OCRWM) in Washington, D.C., in repository performance assessment. In 1985, he joined the Pacific Northwest Laboratory and managed the Performance Assessment Scientific Support (PASS) Program, an interdisciplinary effort contributing to the state of the art in the assessment of geologic repository performance.

From 1988 to 1990, Dr. Van Luik returned to Washington, D.C. for a temporary assignment supplying on-site assistance to OCRWM. Upon his return to the Pacific Northwest Laboratory, he managed the International Program Support Office (IPSO), which supported international technology exchange activities related to radioactive waste disposal and environmental remediation for the DOE's Office of Environmental Restoration and Waste Management and the international programs of OCRWM.

In 1991 Dr. Van Luik joined the Performance Assessment Department of the M&O Contractor in Las Vegas. He managed the department until he was asked to become part of the new Project Management

Organization (PMO). In 1995 Dr. Van Luik took advantage of the opportunity to become a federal employee and took charge of the technical oversight and direction of the Yucca Mountain Project's performance assessment function, which is his current assignment.

Dr. Van Luik is the Senior Technical Advisor for Performance Assessment within the Office of Licensing and Regulatory Compliance.

Johan Andersson (Golder Grundteknik, Sweden)

Johan Andersson has a MSc. in Engineering Physics, a PhD in Water Resources Engineering and a DPhil in Hydraulics. After four years of post doctoral research on modelling flow and transport in porous media and crystalline rock he became a project manager at the Office of Nuclear Waste at the Swedish Nuclear Power Inspectorate (SKI).

At SKI Dr. Andersson managed the inspectorate's integrated performance assessment projects and played a leading role in reviewing the industry's research programmes, in presenting information to the public and in establishing an environmental impact assessment process with the actors involved in future licensing of nuclear waste repositories. He has been a member of the Core Group of the Performance Assessment Advisory Group of the OECD Nuclear Energy Agency, and of the scientific committee on groundwater of the Swedish National Board for Environmental Protection.

Dr. Andersson is at present a Manager of the Nuclear Waste Service Group at Golder Grundteknik, Sweden, which is a part of Golder Associates Co. The group provides consulting services on projects concerning performance assessment of radioactive waste repositories, subsurface hydrogeolology, site evaluation and licensing issues. He has an extensive list of publications on modelling groundwater flow and transport, on the Environmental Impact Assessment of nuclear waste repositories as well as on different licensing issues.

Claudio Pescatore (OECD/NEA) – Secretariat

Claudio Pescatore holds a Ph.D. in nuclear engineering from the University of Illinois, Urbana-Champaign (USA). He has 19 years' experience in the field of nuclear waste covering low-level waste, high-level waste and spent-fuel storage and disposal.

Dr. Pescatore joined the Brookhaven National Laboratory in 1982 and was directly involved in the study of high-level waste and spent-fuel disposal concepts in basalt, salt, and tuff formations: reliability and modelling studies of waste package materials during storage and disposal, analyses of gaseous and aqueous pathways for radionuclide migration, peer reviews of environmental impact assessments studies and site characterisation plans. In 1989 he was nominated group leader for Radioactive Waste Performance Assessment. Till 1995, he was also adjunct Professor of Marine Environmental Sciences at the University of New York, Stony Brook.

Dr. Pescatore joined the NEA/OECD Secretariat in 1992 in the Division of Radioactive Waste Management and Radiation Protection, where he has been Acting-Head of the Division. Within the NEA/OECD Secretariat he has been in charge of the Agency's Performance Assessment Programmes, with additional contributions in the field of site characterisation. He has been at the centre of several recent international initiatives such as the ASARR and GEOTRAP projects, and the GEOVAL'94 symposium. He was a Secretariat member of the international peer reviews of SKI's Project-90, of the Post-closure Performance Assessment of AECL's Environmental Impact Statement of the Disposal of Canada's Nuclear Fuel Waste, and co-ordinated the joint NEA/IAEA international peer review of the 1996 Performance Assessment of the US Waste Isolation Pilot Plant (WIPP), SKI's SITE-94 project as well as the present review of the Nirex methodology for scenario and conceptual model development.

Peter De Preter (ONDRAF/NIRAS, Belgium)

Dr. De Preter is an agronomic engineer from the Catholic University of Leuven (1985). In 1990 he obtained a PhD in agronomic engineering (research field: colloidal chemistry) at the same university.

In 1990 he joined ONDRAF/NIRAS, the Belgian Agency for the Management of Radioactive Waste and Enriched Fissile Material. From 1990 to 1994 he worked in the disposal group on several research programmes (migration/diffusion of radionuclides, hydrogeology, glass and metal corrosion, biosphere modelling, performance assessment for deep and surface disposal).

From 1994 through 1998 he was section head for "Concept and Safety" (1994-1996) and for "Safety and Impact Analyses" (1997-1998) with research and development responsibilities in performance assessment, near field chemistry, hydrogeology, site selection methodology, environmental impact (programme for near- surface disposal of low level waste) and disposal concept and safety assessment, interactions waste – near field, far field radionuclide migration, gas production and evacuation, biosphere modelling (programme for deep disposal of high and medium level waste).

Dr. De Preter's current position is "Safety" process supervisor, which covers all radiological and non-radiological safety-related activities of radio-active waste management (transport, decommissioning, waste conditioning, storage, disposal).

Johannes O. Vigfusson (Swiss Nuclear Safety Inspectorate, Switzerland)

Dr. Vigfusson earned his Ph.D. degree in theoretical physics in 1975 from the University of Zurich, Switzerland. Here he did research in statistical mechanics for 12 years before he joined HSK, the Swiss Regulatory Authority, in 1987. His research career also took him to the USA, where he was a Visiting Professor at the City College of New York and a Visiting Fellow at Princeton University.

Since joining HSK, where he heads a performance assessment group, Dr. Vigfusson has been actively involved in almost all regulatory reviews of safety assessments of Swiss radioactive waste management projects. These have included interim storage facilities as well as radioactive waste repository projects. He participated in HSK's review in 1996 for the first licensing step of Nagra's low- and intermediate-level radioactive waste repository project at Wellenberg, Switzerland.

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