FEPs Analyses and Scenario Development for Low-Level Radioactive Waste Disposal Sites

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Presented on August 29, 2012 during the

Workshop on Performance Assessments of Near-Surface Disposal Facilities:
FEPs Analysis,
Scenario and Conceptual Model Development, and
Code Selection

U.S. NRC Auditorium, Rockville, MD

August 29-30, 2012

Goal and Content

- Purpose of this presentation is to present a proposal on how FEPs analyses can be integrated into the performance assessment process associated with low-level waste disposal.
- Content of the presentation:
  - Rationale for FEPs Analyses and Scenario Development
  - In Context of the PA Process
  - Role of Qualified Specialists Analyzing FEPs
  - Identification and Categorization of FEPs
  - Systematic Screening of FEPs
  - Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50
  - Scenario and Conceptual Model Development After 10 CFR 61.50 Screening

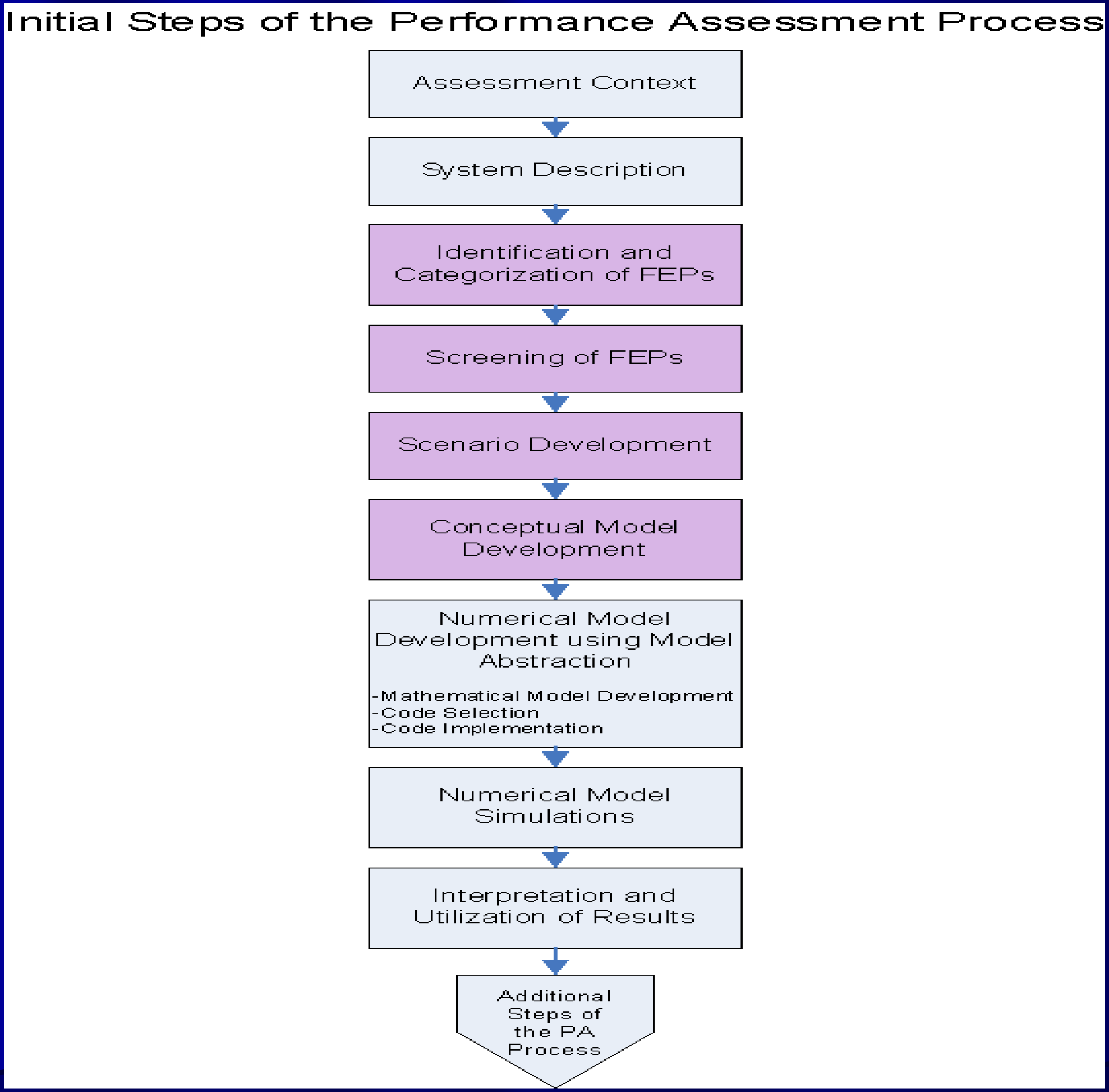
Rationale for FEPs Analyses and Scenario Development

- A FEPs analysis indentifies important phenomena and interactions to help develop the *conceptual site model* of a disposal system.
- A FEPs analysis helps avoid omissions of critical *processes and features* during model abstraction.
- FEPs analyses and scenario development are increasingly seen as a means to *build confidence* in the results of a PA, especially if the time period of potential hazard has increased.
- 10 CFR 61 does not discuss the FEPs process, however large quantities of depleted uranium, or waste generated from large-scale blending, were not being considered for disposal at that time.
- Part 61.12 does discuss specific technical information that is required including natural events or phenomena and their relationship to the principal design criteria.

Rationale for FEPs Analyses and Scenario Development

- Confidence increases with the completeness of the analysis and the assuredness that as much as possible has been done so that nothing important has been overlooked.
- *Future uncertainty* is handled directly by describing alternative futures and by allowing for a mixture of quantitative analysis and qualitative judgments.
- *Scenario development* provides an important area for communication between licensees, stakeholders, regulators, and others with an interest in disposal safety.
- The communication provides an opportunity to discuss and reach a *consensus* on areas of specific importance and how best to evaluate their consequences.
- The aim is to investigate the importance of particular sources of uncertainty and provide meaningful illustrations of future conditions to assist in the *decision-making process*.

In Context of the LLW PA Process



In Context of the LLW PA Process

- Scenario development is part of the iterative performance assessment procedure and is influenced by, and uses information from, previous modeling and consequence calculations.
- The level of effort afforded a FEPs analysis, i.e., the level of detail, comprehensiveness, completeness, and degree of iteration, is directly tied to the time span and severity of the hazard emanating from the waste.
  - A time period of a thousand years and more will have more uncertainty and assumptions than a shorter time span. There will be more FEPs to identify, screen, and integrate into one or more conceptual models.
  - The level of effort for the disposal of LLW will generally be less than that for HLW or for SNF.
  - The level of effort for the disposal of LLW containing predominately short-lived radionuclides will generally be less than a proposed LLW disposal site that would contain larger quantities of depleted uranium or other long-lived wastes.

Role of Qualified Specialists Analyzing FEPs

- ‘Decision making in the presence of uncertainty is largely a qualitative and judgmental exercise.’
- This means the qualifications and working ethics of the analysts are critical.
- The process should draw on many experiences relevant to the performance of the disposal system and from a range of specialists that is necessary.
- Information should be obtained from different sources, a variety of methods, and from all relevant disciplines.
- Both a broad range of people and sources should increase the completeness of the FEPs analysis.
- Better to identify and categorize a range of broadly-defined FEPs and be comprehensive in a broad sense rather than in a detailed sense.

Identification and Categorization of FEPs

- International and National Compilations of FEPs
  - NEA 2000: FEPs for Geologic Disposal…: An International Database
  - IAEA 2004: Safety Assessment Methodologies for Near Surface Disposal…
  - DOE 1996: Compliance Certification Application (WIPP), Appendix SCR, Attachment 1
- System Description
- Identification and Categorization of FEPs at Present
  - Consider identifying and categorizing the features and processes during the first effort with a site that is assumed to be in steady-state, i.e., a site that is not undergoing noteworthy changes
- Identification and Categorization of FEPs in the Future
  - Identify features and processes that may occur in the future based on the past natural history of the area and scientific studies. Identify events at the site that are likely to occur in the future; the longer the period of performance, the longer the list of possible events.

Systematic Screening of FEPs

- Regulatory
  - FEPs can be screened out based on inconsistencies with applicable regulations.
  - 10 CFR 61 contains Federal requirements and performance objectives applicable to land disposal of radioactive waste.
  - Part 61.50 entails the disposal site suitability requirements for the land disposal of LLW.
  - The procedure to determine if some of the Part 61.50 criterions will be met is complimentary to the FEPs process.
  - Discussed further later in this presentation.

Systematic Screening of FEPs

- Human activity
  - A *special* category of FEPs are those related to future human activities. Two subcategories exist:
    - 1) *Activities related to mankind:* Alter the future state of the site [scenario], e.g., man-induced climate change, extreme groundwater drawdown causing aquifer compaction, etc.
    - FEPs related to human activities that can affect the future state of the site should be analyzed in the same manner as all other FEPs.
    - Example - The FEPs analysis of the WIPP site resulted in the development of human-induced future scenarios; other natural scenarios were screened out.

Systematic Screening of FEPs

- Human activity

  - 2) *Receptor activities:* Provide new paths of exposure to a person [exposure scenario] on a local level (on or near the site), e.g., drilling a well, living on the site, etc. Does not create an alternative future state.
  - The consequences from one or more *plausible* stylized exposure scenarios should be considered. *Stylized* because exposure scenarios are designed to bound the exposure to the receptor while avoiding speculation about future human activities.
  - 10 CFR Part 61 prescribes the consideration of human intrusion as a requirement, but also presents types of human intrusion scenarios which need to be considered.

Systematic Screening of FEPs

- Time Period
  - The NRC LLW disposal regulations do not currently specify a period of performance.
  - Declining activity of waste, time of peak consequences, significant processes, and geologic and geomorphic stability play an important role on how far into the future an analysis of FEPs should extend.
  - One purpose of the FEPs analysis is to estimate when the geologic and geomorphic stability of a particular area may no longer be given, and abrupt physical and geologic events occur.
  - Once geostability is no longer given, more events will need to be included in alternative scenarios so future uncertainty is not ignored.

Systematic Screening of FEPs

- Probability and Consequence
  - There are several possible approaches to estimating probabilities and/or consequence ranging from strict calculations and modeling approaches to judgment estimates.
  - Commensurate with the risk of LLW disposal, the level of effort required for the strict calculations of probability are in most cases too high.
  - Scientifically-informed expert judgment should be sufficient to illustrate alternative future possibilities to be considered within the PA process.
  - The emphasis is on the role of *qualified specialists* analyzing FEPs and developing scenarios, and on documenting the *technical basis* or justification for each FEP that has been excluded.
  - A *well-documented systematic*, *transparent* screening approach will help increase the quality of the FEPs analysis.

Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50

- Part 61.50 entails the disposal site suitability requirements for the land disposal of LLW.
- The process to determine if some of these criterions will be met is complimentary to the FEPs process.
- The criterions from Part 61.50 that best lend themselves to the process of FEPs analysis are 61.50(4), (5), (7), (8), (9), and (10).
- Since these are regulatory requirements, the FEPs process should begin with analyzing the FEPs related to 61.50(4), (5), (7), (8), (9), and (10).
  - If FEPs required by Part 61.50 are absent, or detrimental FEPs are present at the site, the location is eliminated as a potential disposal site and additional analysis of FEPS would be superfluous.

Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50

- Part 61.50(4) states "*Areas must be avoided having known natural resources which, if exploited, would result in failure to meet the performance objectives of subpart C of this part.*"
  - Review categories of FEPs for known natural resources, i.e., for natural material of value in the current market. Review prevalence at and near the site. Avoid possible speculation on the future worth of other minerals or materials.

Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50

- Part 61.50(5) states "*The disposal site must be generally well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year flood plain, coastal high-hazard area or wetland, as defined in Executive Order 11988, "Floodplain Management Guidelines.*"
  - This criterion must be looked at with respect to the site as they currently are and to conditions as they may occur in the future. There are two main geomorphic zones to consider: i) coastal areas, and ii) flood plains and wetlands. NRC staff would review a FEPs analysis for
    - Vulnerability to Erosion at Present
    - Vulnerability to Flooding at Present
    - Vulnerability to Erosion in the Future
    - Vulnerability to Flooding in the Future
    - 100-year Floodplains and Wetlands at Present
    - 100-year Floodplains and Wetlands in the Future

Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50

- Part 61.50(7) states "*The disposal site must provide sufficient depth to the water table that ground water intrusion, perennial or otherwise, into the waste will not occur. ..... In no case will waste disposal be permitted in the zone of fluctuation of the water table.*"
  - NRC staff would review a FEPs analysis for
    - Sufficient Depth to the Water Table at Present
    - Sufficient Depth to the Water Table in the Future

- Part 61.50(8) states "*The hydrogeologic unit used for disposal shall not discharge ground water to the surface within the disposal site.*"

Screening of Features, Events, and Processes Based on the Requirements in 10 CFR 61.50

- Part 61.50(9) states "*Areas must be avoided where tectonic processes such as faulting, folding, seismic activity, or vulcanism may occur with such frequency and extent to significantly affect the ability of the disposal site to meet the performance objectives ……*"

- Part 61.50(10) states "*Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering occur with such frequency and extent to significantly affect the ability of the disposal site to meet the performance objectives …..*"

Scenario and Conceptual Model Development After 10 CFR 61.50 Screening

- Nominal (Undisturbed) Scenario and the Present-day Conceptual Model
  - Building a single scenario and associated conceptual model that combines and represents the important current and future phenomena and their interactions at an appropriate level of detail is a complex process.
  - Approaches to scenario formation have to rely to a significant extent upon the judgment of those performing the study, because in most cases the list of factors are normally too extensive to allow all possible combinations to be equally considered.
  - Most studies indicate the usefulness of defining a nominal scenario; it is commonly used as a yardstick against which the potential importance of additional FEPs can be judged.
  - The nominal scenario is a well-defined, connected sequence of FEPs that includes present-day feature and processes, but usually does not include future disruptive events, e.g., severe earthquake.

Scenario and Conceptual Model Development After 10 CFR 61.50 Screening

- Alternative Scenarios and the Associated Future Conceptual Models

  - Alternative scenario(s) include the remaining FEPs that are not incorporated in the nominal scenario.

  - Important is, that the complete set of **scenarios** represents the <u>full range of possible future states</u> of the system,

    and that the complete set of associated **conceptual models** incorporate <u>all of the retained FEPs</u>.

  - This step will have been considerably simplified by the screening of specified FEPs based on the requirements of Part 61.50.

Scenario and Conceptual Model Development After 10 CFR 61.50 Screening

- Identification of Alternative Scenarios Requiring Construction of a Separate Numerical Model
  - Determine the number of numerical models needed and if one code is sufficient, e.g., some events and there consequences may require an additional code.
  - Determine which conceptual models cannot be treated by parameter variation, e.g., prospect of modeling both porous flow vs. fracture flow with one code.

Terms and Definitions

Working Glossary

- ***Feature*** is an object, structure, or condition that has a potential to affect system performance. Features are not characteristics of the components of the system, but an identification of the components themselves.

- ***Event*** is a natural or human-caused phenomenon that has a potential to affect system performance and that occurs during an interval that is <u>short</u> compared to the period of performance.

- ***Process*** is a natural or human-caused phenomenon that has a potential to affect system performance and that occurs during <u>all or a significant part</u> of the period of performance.

- ***Phenomena*** can refer to either a process or an events. Typically a phenomena acts upon a feature.

Working Glossary

- ***Scenario*** is one possible set of future events and processes. It broadly describes conditions of a site and how a future site might evolve, but does not describe how a (disposal) system will later function. A scenario can be developed by using a well-defined, connected sequence of FEPs that outline a possible future state of a system. Usually, the *nominal scenario* does not include disruptive events (e.g., earthquakes, volcanoes) while *alternative scenarios* of the same site may or may not include disruptive events depending on the results of the FEPs analysis.
- ***Exposure scenario*** is a subset of scenarios and describes the end process by which people may become exposed to radiation. Exposure scenarios are a mechanism and a set of assumptions concerning how an exposure takes place, including assumptions about the exposure setting, and the characteristics and activities of the person that can lead to exposure.
- ***Conceptual model*** is a qualitative description of a system and a "best estimate" on how the system works. Simplifying assumptions are usually necessary in developing conceptual models. There may be multiple conceptual models for the same scenario, e.g., two conceptual models of the same system with two dramatically different groundwater discharge points.

- IMPORTANT is that the complete set of <u>scenarios</u> represents the full range of possible future states of the system, and that the complete set of associated <u>conceptual models</u> incorporate all of the retained FEPs.

Working Glossary

- ***Code*** is a set of software commands, or a computer program, used to solve mathematical equations representing physical processes.
- ***Model*** is any physical device or mathematical tool representing field situations. A numerical mathematical model can simulate an approximation of the real world, e.g., groundwater flow, using mathematical concepts and equations that are solved using a code.
- ***Model Abstraction*** is a simplification process for reducing the complexity of a conceptual model so that it can be represented in a mathematical model, and/or for reducing the complexity of a simulation model while maintaining the validity of the simulation results.
- ***Code Implementation*** is when a computer code is used as a tool to solve the mathematical equations thereby simulating the model system.