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PERFORMANCE ASSESSMENT STRATEGY FOR LOW-LEVEL WASTE DISPOSAL SITES

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1 INTRODUCTION

This paper describes U.S. Nuclear Regulatory Commission (NRC) staff views on predicting the performance of low-level radioactive waste disposal facilities. Under the Atomic Energy Act, as amended, and the Low Level Radioactive Waste Policy Act, as amended, the NRC and Agreement States license land disposal of low-level radioactive waste (LLW) using the requirements in 10 CFR Part 61 or comparable state requirements. The purpose of this paper is to briefly describe regulatory requirements for performance assessment in low-level waste licensing, a strategy for performance assessments to support license applications, and NRC staff licensing evaluation of performance assessments. NRC's current activities in developing a performance assessment methodology will provide an overall systems modeling approach for assessing the performance of LLW disposal facilities. NRC staff will use the methodology to evaluate performance assessments conducted by applicants for LLW disposal facilities. The methodology will be made available to states and other interested parties.

2 RELEVANT REQUIREMENTS

Performance assessments of LLW disposal facilities are needed to demonstrate compliance with performance objectives in Subpart C of 10 CFR Part 61. A performance assessment is a systematic quantitative analysis of radionuclide release, transport, and dose to man. Two performance objectives require performance assessment: (1) protection of the general population from releases of radioactivity [61.41] and (2) protection of individuals from inadvertent intrusion [61.42]. Demonstrations that a proposed facility can be expected to meet these two requirements are based almost entirely on results of site-specific performance assessments.

The performance objective in 61.41 states that concentrations of radioactive materials released to the general environment via groundwater, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. In addition, this performance objective requires that licensees expend reasonable efforts to maintain releases of radioactivity to the general environment as low as reasonably achievable.

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The second relevant performance objective is 61.42, which states that the design, operation, and closure of land disposal facilities must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after removal of active institutional controls over the disposal site. The purpose of this requirement is to protect inadvertent intruders from receiving whole body equivalent doses greater than 500 millirems during a reasonably short period of exposure to waste.

In 10 CFR Part 61.13, NRC requires that license applicants demonstrate compliance with the performance objectives in Subpart C of 10 CFR Part 61. These demonstrations must include:

> (1) Analyses demonstrating adequate protection of the general population from releases of radioactivity via air, groundwater, surface water, soil, plant uptake, and exhumation by burrowing animals; and
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> (2) Analyses of individual protection from inadvertent intrusion demonstrating compliance with waste segregation and classification requirements and that barriers are adequate to deter inadvertent intrusion.

Compliance demonstrations for the two other performance objectives in 61.43 and 61.44 are based more on hydraulic engineering, nuclear engineering, geotechnical engineering, occupational health physics, operations management, and other types of assessments than on performance assessment.

3 APPROACH TO PERFORMANCE ASSESSMENTS

The overall approach to performance assessment used by the applicant to demonstrate compliance with the performance objectives should consist of two phases. In the first phase, the applicant should identify a complete set of possible release scenarios and pathways, and eliminate those which are trivial, restricted, or obviated by other scenarios. Combinations of events that have an extremely low probability of occurrence need not be considered. The applicant should provide details of the process used to eliminate potential pathways and scenarios. The remaining set of defensible pathways and release scenarios represents the conceptual model of the waste disposal system.

In the second phase of the performance assessment, the applicant should quantitatively analyze site performance based on the conceptual model to estimate doses to maximum exposed individuals and demonstrate compliance with performance objectives. Applicants' performance assessments should be supported by use of modular systems modeling, which quantifies potential release and transport of radionuclides through significant environmental pathways. NRC staff expects that at a minimum, depending on site conditions and facility design, the systems modeling will consist of the following discreet submodels:

infiltration and leaching, near-field transport within and near disposal units, groundwater transport, atmospheric transport, plant and animal uptake, and human dose. The results of individual models should be available for inspection to assist in understanding estimated doses. The NRC staff will compare results of the systems modeling with general population dose requirements in 10 CFR Part 61.41 and the 500 mrem dose criterion relative to the inadvertent intruder protection requirement in 61.42.

In support of compliance demonstrations for performance objective 10 CFR 61.41, performance assessment should provide a calculated equivalent annual dose to the maximally exposed individual with corresponding maximum and minimum values. In support of compliance demonstrations for the intruder performance objective in 61.42, the performance assessment should provide a description of assumed scenarios used to estimate dose to inadvertent intruders, maximum calculated doses to inadvertent intruders and corresponding maximum and minimum values of dose.

The radioactive source term in the systems model used to estimate releases should be derived from waste generator information, inventory databases, and projections of waste volumes and activities. Transport modeling of environmental pathways and dose modeling should consider a reasonable range of scenarios, including reasonably foreseeable and unlikely natural and human induced conditions. The probability of given scenarios will be based on expert judgement and historical data. The source term should be representative of expected release of radionuclides from various waste forms under alternative environmental conditions and should consider degradation of engineered barriers such as cover systems and waste packaging. The source term inventory should be used to justify the necessary duration of the performance assessments. For example, relatively large quantities of transuranic and other long-lived radionuclides in the waste warrant assessments of long duration, on the order of thousands of years, compared to wastes that primarily contain short-lived radionuclides.

NRC staff expects that the applicant will use more complex models to demonstrate an understanding of individual systems components, to support results of the systems model, and to defend the inherent simplifying assumptions of the systems model. Use of complex models may be essential to characterize the site or disposal system and is expected to vary in scope and rigor depending on the complexity of the particular system component. Examples of such sophisticated models might be three-dimensional, finite element groundwater codes used to assess hydrologic boundary conditions and temporal variability of water levels if physical characteristics or groundwater monitoring suggests the need to understand the system at an advanced level of sophistication. Use of codes that mechanistically describe the behavior of engineered materials in terms of degradation with respect to containment or structural stability may be required depending on the facility's reliance on such materials.

Reasonable conservatism should be built into performance assessment from the beginning. A simple deterministic modeling approach is preferred for its efficiency, cost effectiveness, and defensibility. Based on available data and knowledge of the system or similar systems, assumptions and generalizations should be formulated to avoid underestimating release and transport of radionuclides or the exposure of the inadvertent intruder. Worst case analyses are not necessarily required to demonstrate that the public and the environment will be adequately protected; however, realism should be tempered with healthy pessimism. Any decrease in the original conservatism used in the analysis will require more complex modeling efforts, more data, and a rigorous defense. Therefore, the simple conservative, but realistic, approach is considered the best starting point for performance assessments.

Modeling must be defensible. The most suitable model will be that which is consistent with the modeling objectives and easiest to use considering the complexity of the system and the data which can practically be obtained for the site and intended facility. The model should be verified for appropriateness of application, validity of assumptions, accuracy of algorithms, and representativeness of input data. A critical consideration for the user will be the adequacy of the data available and uncertainty associated with the data. Generally, more complex models require more abundant and detailed data, while less sophisticated models rely more on simplifying assumptions and more generalized data. Where data is inadequate for complex models, there may be a temptation to use approximations based on assumptions. In this case, a more complex model provides no more support for licensing decisions than does a simple systems model.

The modular nature of systems models allows for substitution of results from complex models used to characterize the physical system of the site, for results of simpler submodels. For example, characterization modeling may indicate that model simplification is not supportable, as more complex modeling supports site and facility acceptability. In such a case, it may be acceptable to substitute results of a more sophisticated analysis for results of a simpler submodel, provided that the results are logical and consistent with the complexity of the particular subsystem. This approach allows flexibility and reduces effort when only parts of the system need sophisticated modeling in order to ensure that the results are technically defensible. Benefits of this approach can be significant when the more-sophisticated model provides added assurance that the disposal site and facility will perform in an acceptable manner.

Intruder analyses, on the other hand, tend to be logical discussions of cause and effect. Those discussions are supported by technical analyses of the longevity of materials used in the intruder barrier if one is used, and the long-term stability of the design when depth of burial is considered the intruder protection medium. Generally if the waste classification system of 10 CFR Part 61 is followed and waste segregation, disposal site stability, and intruder protection measures specified in the regulations are met, additional analyses are not necessary. If, however, an applicant projects waste production for a state or compact different from the analyses used by the NRC

staff to develop the waste classification requirements of 10 CFR Part 61, the applicant may need to consider new scenarios and analyses to demonstrate compliance with performance objective 61.42. Such analyses should be similar to those presented in NUREG-0782 and NUREG-0945, prepared in support of the requirements of 10 CFR Part 61.

Performance assessments should include assessments of uncertainty associated with dose estimates based on analysis of uncertainties in model output, assumptions, and calculations. Dose estimates should be presented as expected values accompanied by a range of maximum and minimum values to portray reasonable associated uncertainties. Dose estimates should be presented as a function of time, considering half-lives of specific radionuclides and expected waste inventories and durability of natural and engineered barriers.

Finally, NRC staff expects all codes used by the applicant to support the license application should be sufficiently documented, verified, and benchmarked in accordance with NUREG-0856 to assure that independent, technically competent reviewers can successfully reproduce the performance assessment modeling and develop comparable, defensible results. Data collection and modeling should be performed using an acceptable quality assurance plan following the guidance provided in NUREG-1293. Models should also be at least partially validated by calibration and by comparison with independent data collected at the site.

4 NRC STAFF EVALUATIONS LLW PERFORMANCE ASSESSMENTS

The burden of proof to demonstrate compliance with the regulatory requirements of 10 CFR Part 61 resides with the license applicant. NRC staff performance assessments provide an independent evaluation of the design performance of LLW disposal facilities by confirming or verifying assertions and conclusions submitted by the applicant in support of license applications. The results of performance assessments are, however, only part of the demonstration of compliance with NRC requirements. Expert judgment and operational experiences should also be considered to ensure adequate protection of the public and the environment from any potential adverse effect of LLW disposal.

NRC staff is currently upgrading its capability to conduct independent performance assessments in support of license application reviews. NRC staff has engaged Sandia National Laboratory (SNL) to develop a performance assessment methodology that will provide an overall systems modeling approach to be used in assessing compliance with the performance objectives of 10 CFR Part 61. The methodology will integrate models needed to describe release, transfer, and dose, and will include the mathematical codes and code documentation needed to implement the methodology.

As a critical first step in developing the performance assessment methodology, SNL is compiling a list of viable pathways for release and migration of radionuclides from LLW facilities and for intruder scenarios, and generically

assessing their relative importance. SNL will complete the following interim products prior to completing the documented methodology: 1) identification of pathways, 2) ranking of pathways, 3) identification of quantitative models for the methodology, 4) integration of quantitative models, and 5) implementation and documentation of the methodology. Additional products that will be available include an evaluation of existing codes needed to implement the methodology and a self-teaching curriculum (SNL, 1988). The methodology developed by SNL will assist NRC and applicants in defining an acceptable set of procedures for assessing performance of LLW disposal facilities. NRC will make these products available to states as they are developed.

In addition to the work being done at SNL to support NRC's performance assessment capabilities, NRC has employed Brookhaven National Laboratory (BNL) to develop a source term leaching model to be used in conjunction with the performance assessment methodology (BNL, 1988), and Pacific Northwest Laboratory (PNL) to compile hydrogeologic databases for several existing LLW sites and perform hydrogeologic assessments to gain insight into historical LLW facility performance. PNL's work should facilitate development of scenarios and approaches to model groundwater transport for performance assessments.

Following the guidance presented in Chapter 6 of the NRC's Standard Review Plan for LLW License Applications (NUREG-1200), the staff will critically evaluate and comment on an applicant's performance assessment, emphasizing (1) definition of the physical system, (2) integration of system and subsystem models, (3) basis for selection of model input, model validation and verification (4) model application, (5) analysis of uncertainties and sensitivities, and (6) application of the modeling results in support of the license application. The amount of independent modeling to be conducted by NRC staff is determined based on technical judgment, the level of confidence the staff has in the codes and models used by the applicant, and the relative significance of the modeling results with respect to the compliance demonstration.

The staff may also perform relatively simple and conservative or best-estimate assessments to evaluate the validity of performance assessment results submitted in support of license applications. Simple models and codes are preferred, provided their use can be defended considering the full range of processes and phenomena that may significantly affect the performance of the waste disposal system. Staff modeling should be compatible with the quality and amount of data available to support performance assessments. NRC staff analysis will ensure sufficient data have been provided by the applicant to assure that performance modeling is representative of the disposal system. The NRC staff will review the applicants' modeling and evaluate whether the applicants' performance assessment provides reasonable assurance of compliance with the regulatory requirements.

Review of the application and preparation of comments does not necessarily require NRC staff execution of performance assessment codes. The NRC staff may, however, conduct independent performance assessment modeling in selected

areas to confirm and verify the design performance of LLW disposal facilities. While staff does not necessarily need to develop and use independent models and codes to confirm performance assessments that support license applications, the performance assessment methodology developed by SNL will define procedures acceptable to NRC staff for assessing the performance of LLW disposal facilities.

A typical level of independent NRC review would consist of the following elements:

(1) Critical review of the applicant's performance assessment, including commenting and evaluating responses to the comments;

(2) Selected audits of model applicability using simple, conservative models;

(3) Independent verification of the most significant performance assessment results using computer codes that have been verified, benchmarked, and documented in accordance with NRC guidance; and

(4) Assessment of uncertainties inherent in performance assessments and determination whether that they have been adequately reflected in the results.

5 SUMMARY

License applicants for LLW disposal facilities must conduct performance assessments to demonstrate compliance with performance objectives 10 CFR PArt 61.41 and 61.42. License applicants should use performance assessment to support compliance demonstrations with 61.41 and 61.42. Performance assessments should consist of (1) identification of defensible pathways and scenarios through which radionuclides may escape from the disposal facility, or by which intruders could be exposed to radioactivity, and (2) quantitative analyses of site performance in terms of estimated human doses based on the pathways and scenarios. NRC staff expects that the applicants's performance assessment will be supported by modular systems modeling, that is supported, as appropriate, with more complex modeling, expert judgement, and operational experience.

The NRC staff reviews performance assessments submitted by license applicants for LLW disposal facilities to confirm or verify assumptions and conclusions used to demonstrate compliance with the requirements in 10 CFR Part 61. These reviews consist of thorough evaluations of the applicant's conceptual modeling, input data, computed results, documentation and verification of computer codes or other techniques used in the assessment, and quantification of uncertainties associated with predicted results. In addition, NRC staff reviews may be supported by systems modeling to confirm the design performance of LLW disposal facilities. If determined prudent by NRC staff, the systems modeling may be

supported by more complex analyses of individual systems components to defend simplifying assumptions and results of the systems modeling.

NRC is preparing to review license applications for LLW disposal by refining procedures for conducting performance assessment, improving models for estimating release of radionuclides from LLW forms, and developing more insight into radionuclide transport and site performance at existing LLW disposal facilities. NRC will make products from these activities available to states and other interested parties as they are developed.

REFERENCES

Brookhaven National Laboratory, August, 1988, Quarterly Progress Report, Low-Level Waste Source Term Evaluation, WM-3276-6.

Sandia National Laboratories, March, 1988, Work Plan, Performance Assessment Methodology Development--LLW Disposal Safety Assessment.

U.S. Nuclear Regulatory Commission, 1988, "Licensing Requirements for Land Disposal of Radioactive Waste," Code of Federal Regulations, Title 10, Part 61.

- - -, 1988, "Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility," NUREG-1199, Rev. 1.

- - -, 1988, "Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility," NUREG-1200, Rev. 1.

- - -, 1987, "Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility," NUREG-1293.

- - -, 1983, "Final Technical Position on Documentation of Computer Codes for High-Level Waste Management," NUREG-0856.

- - -, 1982, "Final Environmental Impact Statement on 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste," NUREG-0945.

- - -, 1981, "Draft Environmental Impact Statement on 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste," NUREG-0782.