PERFORMANCE ASSESSMENT - THE NEBRASKA EXPERIENCE

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ABSTRACT

The performance assessment review for the proposed Nebraska low-level radioactive waste facility is presently estimated to be about 75% complete. The progress made to date on the performance assessment technical review of the license application and related independent modeling activities can be attributed to a planned effort and process. This dual process of technical review and independent modeling was established early in the project from the combined guidance given in NUREG-1200, NUREG-1300, and DOE/LLW-62T and documented in a Performance Assessment Process Instruction. A formal scenario analysis and pathway analysis were conducted to identify those transport mechanisms which are most limiting relative to the facility's performance objectives. Independent modeling of these critical release mechanisms was then undertaken to establish bounding cases and provide insight into the pathway modeling methodologies utilized by the applicant. The results from these screening models has become the bases for estimating human exposure at selected receptor locations.

INTRODUCTION

In July of 1990, the first ever license application for an above-grade, concrete, low-level radioactive waste (LLRW) disposal facility was submitted by US Ecology to the State of Nebraska for review. The application consisted of a Safety Analysis Report (SAR) and an Environmental Report (ER) which describe the proposed Boyd County, Nebraska facility and its operation.

The segregation and control of the technical review of the license submittal was previously defined by the State licensing authorities in a hierarchy of documents including a Quality Assurance Plan and Licensing Program Plan. These governing documents identify the authority, responsibility, process and auditing functions for each level of management in the project.

The application was subsequently divided into eight functional areas using the SAR Standard Review Plan (SRP), NUREG-1200, and the ER Environmental Standard Review Plan (ESRP), NUREG-1300. The selected areas were:

- General Information
- Facility Operation
- Site Characterization
- Quality Assurance
- Design and Construction
- Environmental Issues
- Performance Assessment
- Financial Assurance

Each functional area was assigned a Review Manager and an appropriate staff of Technical Reviewers representing the various engineering, scientific and other disciplines necessary to facilitate the technical reviews of the application.

This paper describes the methodology utilized by the State of Nebraska for conducting the review of the Performance Assessment sections of the SAR and ER. The approach to the technical review of the Performance Assessment portions of the application and technical review team modeling activities is discussed below.

PERFORMANCE ASSESSMENT - A DUAL APPROACH

The goal of the Performance Assessment (PA) process selected for the proposed Boyd County facility is to state with reasonable certainty that the facility will meet the performance objectives specified in Nebraska's Title 194, Rules and Regulations for the Disposal of Low-Level Radioactive Waste; Title 180, Chapter 1, Regulations for the Control of Radiation - Ionizing; and applicable NUREGs adopted for the application review by the State licensing authorities. Titles 180 and 194 have been created by the State of Nebraska, as an Agreement State, and correspond to 10 CFR 20 and 10 CFR 61, respectively. The method chosen for implementing and coordinating the review of the PA sections of the SAR and ER consists of a dual approach. This approach augments the technical review of the application (SAR and ER) with limited independent modeling of human exposure and those radionuclide transport pathways considered important based on the characteristics of the site and the surrounding area. These independent modeling efforts support the technical review of the application by identifying those technical areas which are critical to the licensing process and by providing insight into the pathway modeling methodologies utilized by the applicant. Thus, the dual PA method allows the Technical Reviewers to develop a more comprehensive understanding of the applicant's calculational methods and results by actually conducting site-specific screening calculations to determine and verify bounding scenarios, pathways, and receptor locations.

The first effort of the dual PA process was the technical review of the application. Review was begun by conducting technical reviewer training on the use and implementation of NUREGs 1200 and 1300. It was decided that a requirement-by-requirement methodology be adopted by each technical review team to ensure complete and consistent coverage of the review plans. For example, for each requirement listed in the SRP, reviewers determined whether the application adequately addressed the requirement. If not, a comment was drafted and submitted requesting additional information, clarification, or justification from the applicant. Technical Reviewers were also instructed to maintain the requirement-by-requirement status of assigned SRP sections for use as the applicant responded to the first round comments so as to expedite subsequent reviews.

The independent modeling activities were coordinated through a process which was established in accordance with recommendations and guidance given in DOE/LLW-62T, Guidelines For Radiological Performance Assessment of

DOE Low-Level Radioactive Waste Disposal Sites; NUREG/CR-5532, A Performance Assessment Methodology for Low-Level Waste Facilities; and NUREG/CR-5453, Background Information for the Development of a Low-Level Waste Performance Assessment Methodology. The Technical Reviewers were organized into small functional groups which focused narrowly on source term, groundwater, surface water, air dispersion, infiltration, environmental monitoring, and human exposure. Each of these groups is responsible for conducting the independent modeling activities as deemed necessary by the group and PA Review Manager.

The source term group worked closely with the various pathway modeling groups to establish the radionuclide inventory available for transport through a given pathway. The pathway modeling groups then performed screening calculations to determine radionuclide concentrations in the medium and at the location of interest. The results obtained from each pathway modeling group were then coordinated and combined by the human exposure group to determine integrated dose values.

The narrow focus and diversity of these disciplines lead to some minor communication problems. However, these communication problems were overcome by scheduling interactive meetings at appropriate times. Additionally, it was decided that a majority of the Technical Reviewers on the Site Characterization review team would also serve on the various PA review teams, because the foci of these review areas are highly dependent and interrelated. To ensure consistent direction for each group and to coordinate their activities, a Performance Assessment Process Instruction was developed as described below.

PERFORMANCE ASSESSMENT PROCESS INSTRUCTION

The Performance Assessment Process Instruction (PAPI) facilitates the dissemination of PA information and modeling which is common to all review disciplines. This 31-page Instruction, modeled after guidance given in DOE/LLW-62T, NUREG/CR-5532 and NUREG/CR-5453, defines the comprehensive process for conducting license application review activities related to PA and creating conceptual and computational models for evaluation purposes. It includes responsibilities, a general PA process and tables of the scenarios and site-specific pathway models to be considered for the proposed facility.

The PA modeling activities governed by the PAPI included scenario development and selection, pathway analysis, and receptor location selection, source term assessment and definition (including phantom curie analysis), groundwater modeling, infiltration modeling, air dispersion modeling, and surface water modeling. A brief discussion of each of these areas follows.

Scenarios, Pathways, and Receptor Locations

For the technical review of proposed scenarios, pathways, and receptor locations, SRP 6.1, Release of Radioactivity - Introduction, was consulted. Regarding scenario and pathway analysis, SRP 6.1 suggests, "The overall approach that should be taken is to first identify a complete set of possible release scenarios and pathways, and then by argument and/or assessment, to eliminate those that are insignificant, very unlikely, or both. The intent is to arrive at a set of bounding release/transport scenarios without performing lengthy evaluation of minor variations of similar scenarios."

A PA scenario analysis was conducted beginning with Tables 6.1-1, 6.1-2, and 6.1-3 from SRP 6.1 and Table A.1 from ESRP 4.8.1. These tables were modified in accordance with the above guidance to arrive at a complete set of scenarios to be used for subsequent evaluation of the proposed Nebraska facility. Additionally, a skyshine scenario, nuclear criticality scenario, and tornado scenario were added to the possible scenarios for evaluation due to the design of the facility, the presence of fissile material and local weather phenomenon, respectively. The final set of scenarios identifies the scenario number, scenario description, radiation type, primary release/transport mechanism, generic receptor locations, the periods of concern, and pathways for which evaluation would be necessary.

The pathway analysis and dose calculations that are performed in the assessment depend on the scenarios which describe public use of the disposal facility or public access to radionuclides released from the facility. Table I contains a sample scenario table from the PAPI. This table identifies typical scenarios impacting off-site individuals.

The pathway analysis was performed in accordance with NUREG/CR-5453, Volume 2, Assessment of Relative Significance of Migration and Exposure Pathways. This guidance provided by L.R. Shipers and C.P. Harlan suggests beginning with a complete model of all possible pathways and then through evaluation of the likelihood and significance of each source-to-medium, medium-to-medium, and medium-to-man links, eliminating those links determined to be unimportant for the proposed facility. Additionally, the long chains of medium-to-medium links are typically unimportant due to the dilution effect which occurs because 100% of the radionuclides are not normally transferred from one medium to another. Because pathway assessment is highly site specific, a detailed pathway analysis was conducted to enhance Technical Reviewer understanding and arrive at site-specific models.

The patterns of human access to radioactive waste or to radionuclides released from a disposal site need to be specified to identify the appropriate transport and exposure pathways to be assessed. Figure 2-1 in NUREG/CR-5453, Volume 2 contains the Potential Migration and Exposure Pathways for Near-Surface Low-Level Waste Disposal Facilities. The proposed Transport Pathway Models, shown below and on page 5 (Figs. 1, 2, and 3), for the Boyd County LLRW disposal facility were developed by eliminating pathways using the guidance out of NUREG/CR-5453, Volume 2. Figure 1 represents the site-specific pathway model which is applicable to the analyses for the pre-closure scenarios. Figures 2 and 3 represent the site-specific pathway models for undisturbed and disturbed facility performance after closure. Undisturbed performance assumes that 1) the containment structure and soil remain intact and perform as designed to provide adequate shielding and minimize infiltration, 2) large amounts of gaseous waste and/or organic waste which results in radionuclide-tagged decomposition gases are not disposed of at the facility, and 3) the disposal facility was designed with a minimum of 3 meters of soil cover and includes a concrete containment structure so that plant and animal intrusion is unlikely. Disturbed performance includes such disruptive events as wind and water erosion, earthquakes and landslides, containment structure subsidence or collapse, and intruder

TABLE I

Example Scenario Table - Off-Site Impacts On Individuals

SCENARIO NUMBER	NUREG-1200 SCENARIO	RAD. TYPE[1]	RELEASE/ TRANSPORT MECHANISM	HUMAN ACCESS LOCATION	THEORETICAL PERIOD(S) OF CONCERN[2]	PATHWAYS[3]
(11)	Waterborne dispersion of contamination unearthed by plants and animals	a,b,g	Surface water runoff	Nearest off-site watershed	O,C,S,I,P	F, G, N, O, P, Q, W, X, Y, AB
(12)	Waterborne discharges from disposal cells (e.g., from drains)	a,b,g	Surface water runoff	Nearest off-site watershed	O,C,S,I,P	F, G, N, O, P, Q, W, X, Y, AB
(13)	Waterborne dispersion of contamination associated with demolition activities	a,b,g	Surface water runoff	Nearest off-site watershed	C	F, G, N, O, P, Q, W, X, Y, AB
(14)	Radionuclide leaching and migration	a,b,g	Groundwater	Well water at down-gradient site boundary and nearest off-site watershed and nearest source of population water	O,C,S,I,P	D, E, K, L, M, U, V, AA
(15)	Release through biotic pathways	a,b,g	Biota	Biota in human food chain	O,C,S,I,P	AC

1. a = alpha, b = beta, g = gamma
2. O = Operational period (30 years), C = Closure period (2 years), S = Surveillance period (5 years), I = Active institutional control period (100 years), P = Passive institutional control period (363 years)
3. Pathways represent one or more medium-to-medium links, beginning with a source-to-medium link and ending with a medium-to-man link.

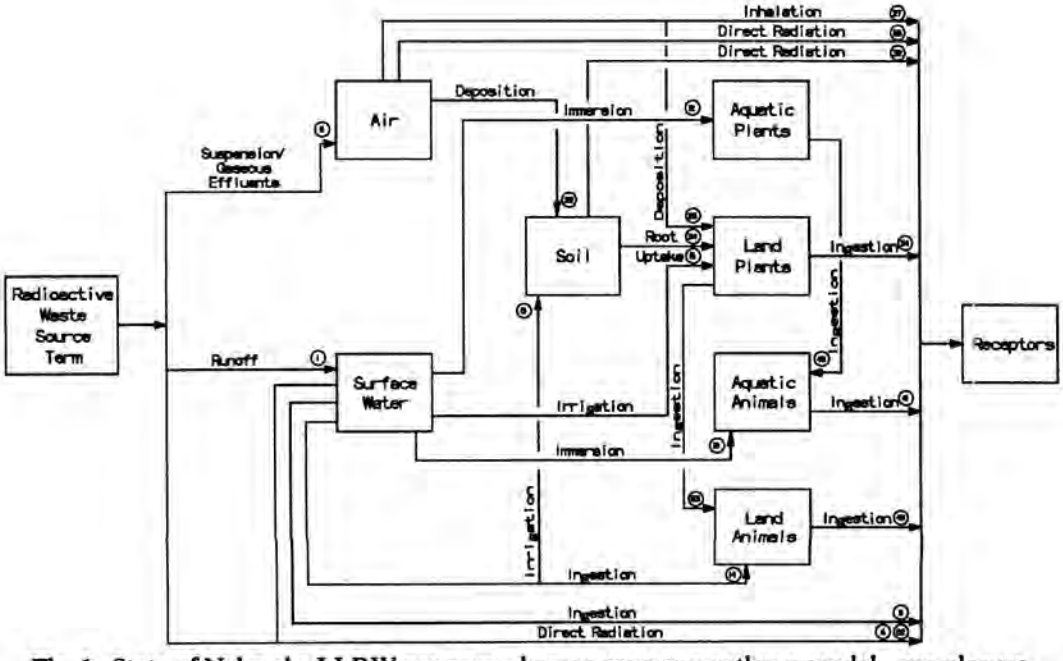

Fig. 1. State of Nebraska LLRW program - human exposure pathway model - pre-closure.

activities (construction, drilling, resource exploration, etc.). These pathway models are being used along with the initiating scenario events that result in the release of radionuclides to evaluate the radionuclide transfer models for each time period of concern throughout the life of the facility.

The pathway analysis is being used to determine the setup of the GENII dose assessment code which was also used for air dispersion modeling. The various pathways available within GENII will be toggled on or off depending upon the scenario being evaluated and the results of the pathway analysis to achieve site-specific dose results for comparison with the applicant's results.

Receptor location selection was conducted to establish "worst case" common points of analysis for the various pathway modeling groups. This allows each group to determine radionuclide concentrations versus time at common points for

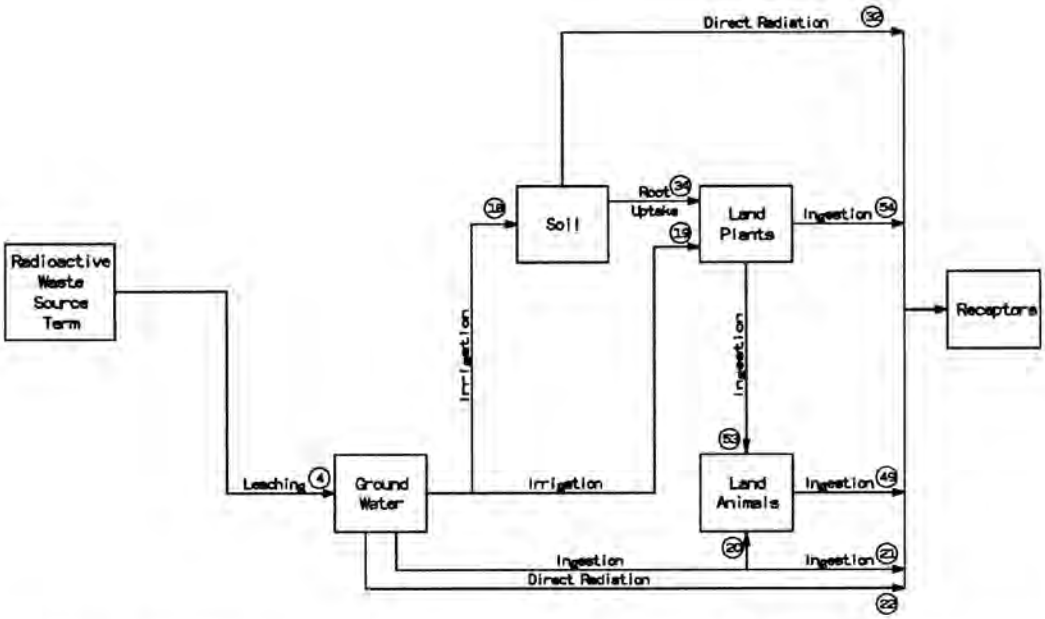

Fig. 2. State of Nebraska LLRW program - human exposure pathway model - undisturbed performance (post closure).

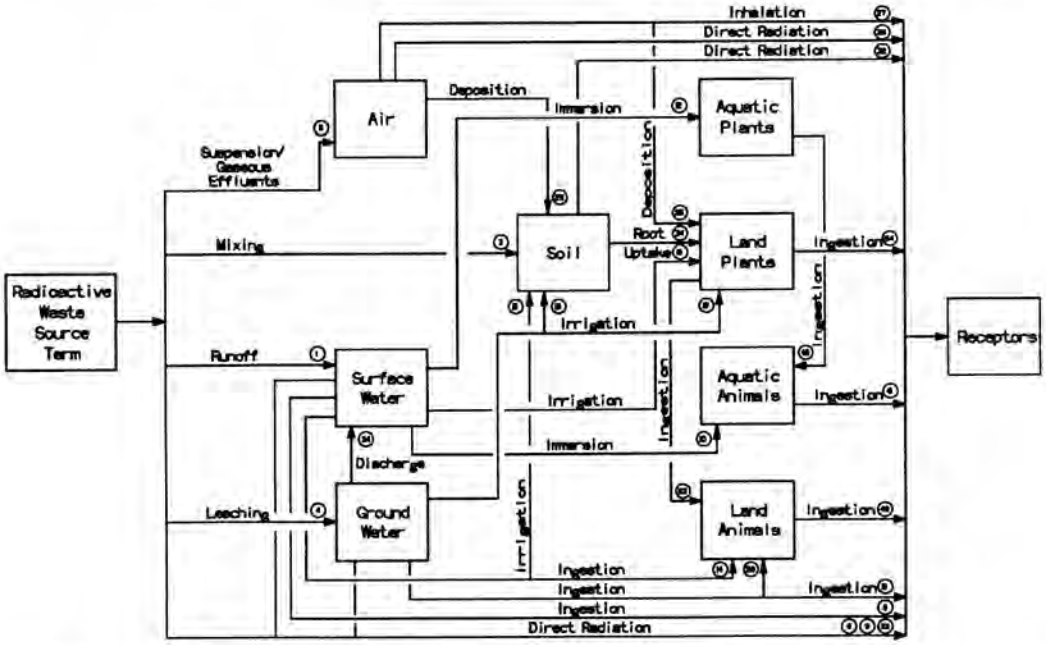

Fig. 3. State of Nebraska LLRW program - human exposure pathway model - disturbed performance (post closure).

input into the GENII dose assessment code. The necessary data for radionuclide concentration in groundwater, air, and surface water at the designated receptor locations will be entered and processed by GENII to determine total dose from all significant pathways and exposure media. This allows the review and assessment of the adequacy of the receptor locations selected by the applicant and comparison of dose calculations.

In order to facilitate analysis with the various scenarios, pathway models, and receptor locations, a control system has been established which uniquely identifies all scenarios, their pathways, and the receptor locations of interest. Initially, all scenarios which are determined to be applicable to the facility are numbered. Then, for each identified scenario, the pathways of concern for that scenario are identified and recorded on the scenario tables (see Pathways column in Table I). A pathway constitutes one or more medium-to-medium links, beginning with a valid source-to-medium link and ending with a valid medium-to-man link (see Table II). Alphabet characters are used to uniquely identify each pathway. Lastly, the receptor locations selected for the facility from the pathway analysis are uniquely numbered.

The purpose of this control system is to ensure that all scenarios, pathways, and receptor locations are included in

the human exposure models and to identify the scenarios, pathways, and receptor locations which are most limiting relative to the performance objectives. For example, S11P0DR03 refers to scenario 11, pathway D, receptor location 3. From Table I, scenario 11 is the radionuclide leaching and migration scenario. This scenario contains pathways D, E, K, L, M, U, V, and AA as determined by the site-specific pathway analysis. The pathway of interest, however, is D. From Table II, pathway D contains the source-to-medium link LEACHING and the medium-to-man link INGESTION. Note that some scenarios have several pathways while others only have one. The number of pathways associated with a given scenario is directly related to the initial release mechanism from the waste form to the medium of interest. Finally, receptor location 3 is a point on the site boundary as identified on a site-specific receptor location map. The Receptor Location Map for the proposed Nebraska facility was unavailable for inclusion in this paper.

TABLE II

Example Pathway to Transport Links Cross-Reference

Transport Pathway Designator	Transport Medium to Medium Links (See Fig. 1)	
A*	6	Direct Radiation
B*	5, 27	Suspension/Gaseous Effluents - Inhalation
C	5, 28	Suspension/Gaseous Effluents - Direct Radiation
D	4, 21	Leaching - Ingestion
E*	4, 22	Leaching - Direct Radiation
F*	1, 8	Runoff - Ingestion
G*	1, 9	Runoff - Direct Radiation

* During Post-Closure, Applicable to Disturbed Facility Performance Only

Source Term Definition

According to NUREG-1200, SRP 6.1.1, Determination of Types, Kinds, and Quantities of Waste, "The staff will review the projections of radioactive waste provided by the applicant and verify that the projections are reasonable. The staff will also verify that sufficient information has been provided to enable an independent evaluation of the releases expected from the disposal facility and to perform the safety evaluations called for in SRP 6.1." From this instruction a source term assessment was conducted to confirm the applicant's projections. Subsequent to the completion of this assessment the applicant revised its source term using a "phantom curie" analysis to significantly reduce the inventories of several problem radionuclides. "Phantom curies" are those curies of a given radionuclide which are included in the source term as a result of the conservative assumption that the lowest level of detectable material is contained in the waste package being disposed. The analysis to reduce the assumed over-estimation deals with the more precise measurement of the quantity of radioactive material through the use of scaling factors. These scaling factors tie the quantity of one isotope to other radioactive materials which are easier to detect and measure. This modification of the source term has resulted in expanding the scope of the assessment to include the "phantom curie" reduction techniques being proposed by the applicant.

Groundwater Modeling

For groundwater review and assessment, SRP 6.1.5.1, Transfer Mechanism - Groundwater, states "The staff will perform independent calculations of radionuclide concentrations. The staff's preliminary results will be compared with the applicant's results for conservatism. If the results are similar, no further analysis is warranted." Several groundwater modeling computer codes were evaluated in order to select those best suited scientifically and economically for the PA activities. The PAGAN code was selected for conducting the screening analyses in accordance with recommendations given in NUREG/CR-5539, A Self-Teaching Curriculum for the NRC/SNL Low-Level Waste Performance Assessment Methodology. It had undergone sufficient quality assurance rigor and was operable with the amount of information that had been provided in the application and the amount of time allotted for technical review. In order to conduct the type of detailed groundwater analyses required, Dr. Kozak, principal author of the PAGAN code, was contacted to provide assistance. With the Nuclear Regulatory Commission's support, he provided explicit modeling consultation to the Groundwater Modeling team.

In addition to the use of the PAGAN code for screening calculations, the applicant's FEMWATER/BLT groundwater models are being reviewed in accordance with NUREG-1200. These models have been significantly altered by the applicant due to the large finite element grids proposed and the addition of several subroutines to modify the leach rate. With these modifications, the code is no longer compatible with the original FEMWATER/BLT code and not presently executable by the Groundwater Modeling team. To gain insight into the effects and bases for these modifications and the requirements for running the applicant's model, Dr. Sullivan, principal author of the FEMWATER code, is presently scheduled to provide assistance.

Infiltration Modeling

The infiltration modeling group considered the CREAMS and HELP computer models for calculating infiltration. Due to the simplicity of the CREAMS code data requirements and setup, it was selected for performing screening calculations. The engineered barrier cap on the facility after closure was incorporated into the infiltration modeling using simplified analytical water balance solutions.

To determine the impact of a "wet" or "dry" period on groundwater level, the FEMWATER model proposed by the applicant was modified to reflect historical rainfall data for "wet" and "dry" periods. The groundwater level range has an important impact on the time credit given for transport through the unsaturated zone and will be compared against similar information proposed by the applicant.

Air Dispersion Modeling

For air dispersion modeling, the GENII code was selected. It is being utilized for performing PA modeling runs. Computational models were developed and are being used to

verify the atmospheric transport and dispersion models and results presented by the applicant. Air dispersion modeling using the GENII code has also been used to assess the capability of the applicant's model to account for the physical characteristics of the site and to account for the physical and chemical characteristics of releases (e.g., particle size).

Surface Water Modeling

Sophisticated surface water modeling has not been utilized for the proposed Nebraska facility. Due to the existence of surface water retention ponds prior to closure and the engineered barrier cap covering the facility after closure, surface water drainage patterns on-site can be adequately modeled using relatively simple flow models. Presently, only the sizing of the surface water retention ponds and drainage patterns on-site have received detailed reviews.

PERFORMANCE ASSESSMENT - CURRENT STATUS

State of Nebraska PA technical review activities are estimated to be about 75% complete. However, the process is expected to continue and be revised well into the future as actual source term and environmental monitoring data are collected during operation of the facility and beyond. The screening calculations performed by the PA team have given indications that:

1. The source term inventory of long-lived radionuclides is extremely important and should be estimated with precision to avoid being confronted with overly conservative results. The long-lived radionuclides tend to dominate the dose calculations for groundwater ingestion at the site boundary.
2. The dominance of the long-lived radionuclides tend to diminish the importance of accurately determining the expected life of concrete vault structures while placing the emphasis on groundwater infiltration rates through the unsaturated zone and leaching rates from the site-specific waste forms.
3. Direct radiation, airborne releases, and surface water releases tend to contribute less significant doses when compared to groundwater releases for normal operations.

RECOMMENDATIONS

1. The regulator should prepare site-specific pathway models and identify scenarios applicable to the proposed facility early in the PA process to facilitate a thorough review of the applicant's pathway modeling and analyses.
2. From the site-specific pathway analysis and scenario analysis, the regulator should utilize independent modeling activities for those radionuclide release mechanisms and initiating scenarios determined to be most limiting relative to the performance objectives. These bounding mechanisms and scenarios should be modeled to provide bounding results for comparison with the applicant's results.
3. The PA methodology presented in DOE/LLW-62T should be utilized to coordinate, schedule, and implement the independent modeling efforts. The technical review comment process should be the avenue for obtaining the data required for the modeling.
4. The technical review team should be segregated into pathway modeling groups to perform technical review of the application along with independent modeling of the transport mechanisms of concern. The PA review of the application and modeling should be closely coordinated with the review team for Site Characterization as these activities are interrelated.
5. A source term modeling group should be established to interact with the various pathway modeling groups to ensure precise definition of radionuclide inventory released or available for release. The source term has been found to be one of the most critical areas with regard to meeting the facility's performance objectives. As such, sufficient time should be allotted to reviewing and modeling the radionuclide inventory and the release mechanisms from the proposed facility.
6. The regulator should perform screening calculations using the applicant's site characterization data early in the review process to identify the significant release parameters independently of the applicant's descriptions and results.
7. The applicant's descriptions of proposed models of radionuclide transport and human exposure should be reviewed using the results of the independently prepared models and screening calculations.

REFERENCES

1. NUREG-1200, Rev. 1, "Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility - Safety Analysis Report," January 1988.
2. NUREG-1300, "Environmental Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility," April 1987.
3. Nebraska Department of Environmental Control Title 194, "Rules and Regulations for the Disposal of Low-Level Radioactive Waste," December 1987.
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5. DOE/LLW-62T, "Guidelines For Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites," July 1988.
6. NUREG/CR-5532, "A Performance Assessment Methodology for Low-Level Waste Facilities," 1990.
7. NUREG/CR-5453, "Background Information for the Development of a Low-Level Waste Performance Assessment Methodology," 1989. Volumes 1-5.
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