98-0000892

Department of Energy

Washington, DC 20585

March 11, 1998

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DNF SAFETY BOARD

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W.
Suite 700
Washington, D.C. 20004

Dear Mr. Chairman:

Enclosed is a memorandum of acceptance and a compliance evaluation for the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility," WSRC-RP-92-1360, December 1992. Site completion and Headquarters review and action on this performance assessment is a deliverable pursuant to the commitment in Task Initiative VII.B.5.b.1 identified in the Department of Energy's (DOE's) Implementation Plan, Revision 1, for the Defense Nuclear Facilities Safety Board Recommendation 94-2.

The assessment evaluates the projected performance of the Savannah River Site Saltstone Disposal Facility relative to the low-level waste performance objectives in DOE Order 5820.2A. As reported previously, the Headquarters review found that, with conditions, the assessment was technically valid and provided a reasonable expectation of meeting the DOE Order 5820.2A performance objectives in all areas except groundwater protection. Originally there was insufficient information to draw a conclusion about the groundwater protection performance objective. The necessary information has been provided and the conclusion of the Headquarters review is that the assessment is acceptable in meeting the groundwater protection performance objective. This assessment, combined with a composite analysis, now under review, will provide the basis for issuance of a disposal authorization statement for the Saltstone Disposal Facility.

As you and your staff are aware, DOE is currently reevaluating the high-level waste salt separation process. Any impacts to Saltstone that may occur as a result of the alternative selected will be revisited at that time.

DOE has completed the actions for the Saltstone Disposal Facility performance assessment identified under this commitment and proposes that this part of the commitment be considered complete.

Sincerely,

James M. Owendoff

James M. Owendoff
Acting Assistant Secretary
for Environmental Management

Enclosure

cc: Mark B. Whitaker, Jr., S-3.1

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memorandum

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DNF SAFETY BOARD

DATE: FEB 18 1998

REPLY TO ATTN OF: EM-35

SUBJECT: Conditional Acceptance of the Saltstone Disposal Facility Performance Assessment

TO: Frank McCoy, Acting Deputy Manager
Savannah River Operations Office

The Office of Waste Management (EM-30) has conducted a review of the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility, December 1992," or compliance with Department of Energy (DOE) Order 5820.2A. In the course of this review, EM-30 requested a review of the performance assessment by the Peer Review Panel (PRP). Based on input from the PRP and the evaluation by Headquarters staff, the performance assessment is conditionally accepted. A compliance evaluation of the performance assessment is included as an attachment to this memorandum. By complying with the conditions below, you are authorized for continued interim operations of the Saltstone Disposal Facility until issuance of a disposal authorization statement.

Consistent with the *Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 94-2 Implementation Plan, Revision 1*, (April 1996) full approval of the performance assessment is contingent on a composite analysis which evaluates the potential offsite radiological impacts of the Saltstone Disposal Facility in conjunction with other radioactive sources that will remain at the Savannah River Site. Upon approval of the *Composite Analysis, E-Area Vaults and Saltstone Disposal Facilities* (WSRC-RP-97-311) by Headquarters, the performance assessment will be approved and a disposal authorization statement issued.

The subject performance assessment is hereby conditionally accepted by EM-30. The conditions that must be met are:

1. The site is to address the requirement for an as low as reasonably achievable analysis in accordance with the latter part of DOE Order 5820.2A, Chapter III, 3.a.(2). The detail of this analysis should be commensurate with the calculated doses.

2. An addendum to the performance assessment, or a revised performance assessment, is to be issued by June 30, 1998. The addendum is to include the additional information developed by the site in response to number one above and the supplemental information provided subsequent to submittal of the performance assessment (e.g., in response to requests from Headquarters and the PRP). The addendum or revision must be distributed to all known holders of the performance assessment. The purpose of this condition is to ensure that the documentation that was the basis for Headquarters' acceptance is readily available to any party interested in the performance assessment.

3. By December 31, 1998, the site is to develop a plan that commits to a schedule and budget for conducting studies to address the uncertainties surrounding the critical factors affecting performance of a degraded system. The performance assessment analyses showed that, with the assumptions made about flow through cracks , the migration of nuclides from degraded vault and saltstone was very dependent on the performance of the lower clay and gravel layer. For example, the plan could address closure studies that support the hydraulic conductivity of the cover over the vault, improved modeling of the degraded vault, or both.

4. Any contemplated changes in the design of the Saltstone Disposal Facility that were not analyzed in this performance assessment are to be analyzed, and the analysis submitted to and accepted by Headquarters prior to construction. This is consistent with the philosophy in the July 21, 1995, memorandum, "Interim Policy on Regulatory Structure for Low-Level Radioactive Waste Management and Disposal" as it applies to maintenance of performance assessments and to constructing new facilities.

5. The site is responsible for maintaining this performance assessment in accordance with the 1996 guidance, *Maintenance of U.S. Department of Energy Low-Level Waste Performance Assessments.* This includes the acquisition of field data needed to improve confidence in the analyses and reduce critical uncertainties.

If your staff has any questions regarding the conditional acceptance of this performance assessment and the process for getting full approval, they should contact Virgil Lowery of my staff on (301) 903-7142.

James A. Turi for

Mark W. Frei
Acting Deputy Assistant Secretary
for Waste Management
Environmental Management

Attachment

Compliance Evaluation of the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility," WSRC-RP-92-1360, December 1992

1.0 Summary

The Office of Planning and Analysis (EM-35) concludes from its review of the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility" (WSRC, 1992), additional information provided by Savannah River Site personnel after the performance assessment was submitted, and the Performance Assessment Peer Review Panel report, that there is a reasonable expectation that the Department of Energy (DOE) Order 5820.2A low-level waste performance objectives will be met. The analyses presented in the performance assessment and supplemental documentation result in the following conclusions relative to the performance objectives:

- The all-pathways doses for either intact or degraded (cracked) vaults will be less than the performance objective of 25 mrem/yr based on meeting a 4 mrem/yr performance measure for drinking water (see fifth bullet below). The drinking water is the dominant pathway in the all-pathways analysis.
- The air pathway performance objective of dose less than 10 mrem/yr for an offsite receptor will be met based on an extremely conservative analysis that resulted in a calculated dose of 10 mrem/yr via the air pathway for a person residing 15 cm above exposed saltstone, in a confined space, for a complete year.
- A maximum radon flux of 0.1 pCi/m^2/s, compared to a performance measure of 20 pCi/m^2/s, is estimated assuming very conservative conditions. The conservatisms include assuming no attenuation of the radon is provided by moisture in the Saltstone or by the soil cover over the Saltstone vaults.
- Dose to a hypothetical intruder from chronic exposure is calculated to be 0.6 mrem/yr versus a performance objective of 100 mrem/yr. Dose from acute exposure is expected to be less than that from chronic exposure, therefore, the 500 mrem/yr performance objective will also be met.
- Doses from intact vaults and saltstone and degraded vaults and saltstone are calculated to be 0.001 mrem/yr and 0.6 mrem/yr, respectively, via the drinking water pathway versus a performance measure of 4 mrem/yr for radionuclides migrating from the disposal facility. Maximum doses during the 1000 year

compliance period are not reported, therefore, the reported peak doses which occur beyond 1000 years are used to evaluate compliance. Sensitivity/ uncertainty analyses were conducted by identifying the modeling parameters to which the results were most sensitive, there individually evaluating the impacts of by using higher and lower input values than those used for the base cases and by using a statistical method that samples multiple parameters and tests various combinations. Those parameters with the greatest impact resulted in calculated doses higher by a factor of up to 300. This result of a conservative sensitivity/uncertainty calculation, considered in light of the other conservatisms employed in the modeling, is judged to be consistent with a reasonable expectation that the performance target for protecting groundwater will be met. However, it does emphasize the necessity to conduct a maintenance program aimed at reducing uncertainties in the values of input parameters and the modeling results.

The performance assessment included analysis of the migration and groundwater concentration of nitrates. Since the nitrates are not radioactive, they are not considered in this compliance evaluation.

2.0 Performance Measures

This evaluation is developed in relation to the requirement in DOE Order 5820.2A, Chapter III, 3.b.(1), which states, "Field organizations with disposal sites shall prepare and maintain a site specific radiological performance assessment for the disposal of waste for the purpose of demonstrating compliance with the performance objectives stated in paragraph 3a." The Department has developed a document called the *Interim Format and Content Guide and Standard Review Plan for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments* (DOE, 1996a) that interprets how the performance objectives are to be applied.

2.1 Performance Objectives

Consistent with the *Interim Format and Content Guide and Standard Review Plan,* the following three performance objectives in DOE Order 5820.2A, Chapter III, paragraph 3.a are applicable to the evaluation of this performance assessment:

> Assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground water, soil, plants and animals results in an effective dose equivalent that does not exceed 25 mrem/yr to any member of the public. Release to the atmosphere shall meet the requirements of 40 CFR 61. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable.

Assure that the committed effective dose equivalents received by individuals who inadvertently may intrude into the facility after the loss of active institutional control (100 years) will not exceed 100 mrem/yr for continuous exposure or 500 mrem for a single acute exposure.

Protect ground water resources, consistent with Federal, State and local requirements.

Consequently, the performance assessment is reviewed and evaluated primarily to determine whether it provides a reasonable expectation that the above-listed performance objectives will be met. The determination involves comparison of the results of the cases analyzed with the performance objectives and the performance measures that have been developed to supplement or interpret the performance objectives (see Section 2.2). The sensitivity/uncertainty analyses are evaluated to ensure that the cases analyzed are reasonably conservative (i.e., the values of the parameters selected for the cases analyzed are in the conservative portion of the range of applicable values and results of the cases analyzed are in the upper range of results from the sensitivity/uncertainty analyses, but are not at the highest end of the range). Also, the results of the sensitivity/uncertainty analyses, taken together, should indicate that it is likely that the performance objectives will not be exceeded (i.e., results of the sensitivity/uncertainty analyses lie below as well as above the cases analyzed).

In addition to this performance assessment, the Department has committed to preparing a composite analysis that evaluates the combined potential impacts of the Saltstone Disposal Facility and other radioactive source terms expected to be left at the Savannah River Site. The Savannah River Operations Office has submitted to Headquarters a composite analysis addressing the Saltstone Disposal Facility and the E Area Vaults. Headquarters review of that composite analysis and the conclusions of the current review will be the basis for issuing a disposal authorization statement for the Saltstone Disposal Facility.

2.2 Interpretation and Other Criteria

This section interprets the application of the performance objectives in the evaluation of the Savannah River Saltstone Disposal Facility performance assessment. Each performance objective is discussed with respect to interpretation and how it is considered in the remainder of this compliance evaluation.

The first performance objective addresses three topics; exposure of a member of the public via all pathways, releases to the atmosphere, and maintaining releases to the environment as low as reasonably achievable. These are referred to as performance measures to distinguish them from the verbatim performance objectives in DOE Order 5820.2A. They are addressed separately in the disposal facility performance section (Section 4.0) of this compliance evaluation.

The first performance measure is for protection of a member of the public. In order to distinguish a "member of the public" from an intruder, the member of the public is assumed to reside outside the boundary of the land controlled by the government. In the Saltstone performance assessment, a point of assessment has been selected that is 100 m from the disposal facility. This is conservative in that it is well within the current and expected future site boundary; it is also consistent with the requirements expected to be in the draft revised DOE Order on radioactive waste management. The performance assessment is to provide a reasonable expectation of not exceeding the 25 mrem in a year dose limit for 1000 years following closure of the Saltstone Disposal Facility. Additionally, the performance assessment analysts conservatively extended these analyses to the time of peak dose. Since the analyses were performed when there was no direction on the time of compliance, the analysts did not report results at 1000 years. Therefore, results at the 1000 year time of compliance are inferred from the reported results. This compliance evaluation considers the analyses beyond 1000 years as support to the reasonableness of the modeling.

Evaluation of exposure via the air pathway is to be conducted to provide a reasonable expectation of complying with 40 CFR 61, Clean Air Act regulations. These regulations establish a 10 mrem in a year air pathway dose limit for DOE sites and specifically exclude radon from the dose evaluation. The practice of excluding radon is used in the air pathway analysis and extended to the all-pathways analysis. Instead, radon is evaluated separately using the ground surface flux limit from the Uranium Mill Tailings regulations. Acceptable limits for emanation of radon from the disposal facility are based on a flux limit of 20 $pCi/m^2/s$ at the ground surface. As with the all-pathways performance measure, the time of compliance for both elements of the air pathway performance measure is 1000 years. The point of assessment for the 10 mrem in a year dose limit is 100 m from the edge of the disposal facility and for the radon flux is at the ground surface over the disposal facility.

For inadvertent intruder analyses, it is generally assumed that a hypothetical, temporary intrusion into the waste site occurs shortly after 100 years, the assumed time of active institutional control in DOE Order 5820.2A. The time of intrusion is not to be assumed to occur beyond the 1000 year time of compliance. The time of the onset of intrusion can be extended beyond the default value of 100 years if adequate justification is provided (e.g., engineered features, marker systems, continued DOE presence for facility decommissioning).

The reasonableness of intruder analyses is based on selecting reasonable scenarios and reasonably conservative parameter values for evaluating the scenarios. Thus, although in the Saltstone performance assessment sensitivity/uncertainty analyses were performed on selected parameter values, they were not needed to assess compliance with intruder performance objectives.

In this evaluation of the intruder scenarios, doses to the intruder are assumed to come from the exposure to, and ingestion and inhalation of, material exhumed from the site. This may occur via a variety of pathways, but the analysis is not expected to include consumption of contaminated groundwater. The impacts of groundwater contamination are already evaluated with respect to the all-pathways and groundwater protection performance objectives.

A tiered approach is now used in determining compliance with the groundwater protection performance objective. The first tier is compliance with applicable federal, state, or local regulations for groundwater protection from a low-level waste disposal facility. The second tier is compliance with negotiated agreements. The final tier of the groundwater protection protocol is for sites to be consistent with their groundwater protection plan as developed under DOE Order 5400.1. Unless otherwise prohibited, the potential use of groundwater can be taken into account in evaluating compliance with a groundwater performance measure. As with the previous public exposure performance measures, the point of compliance is at 100 m from the disposal facility and the time of compliance is 1000 years.

3.0 Technical Adequacy Review

Headquarters staff has reviewed the combined performance assessment and supplemental information provided by the Savannah River Operations Office (see References) and has concluded that the documents present a technically acceptable analysis of the long-term performance of the Saltstone Disposal Facility. This conclusion is based on a review of the referenced analyses and the review and report of the DOE Low-Level Waste Performance Assessment Peer Review Panel.

At Headquarters' request, the Peer Review Panel performed a preliminary review of the Saltstone performance assessment while it was in draft form. The Peer Review Panel provided comments to be considered in finalizing the performance assessment. The preparers of the performance assessment considered and responded to these comments. The resolution of the comments is addressed in Appendix G of the performance assessment.

Upon submittal of the current version of the performance assessment, Headquarters requested that the Peer Review Panel conduct a review of the performance assessment for consistency and technical quality. The Panel reported the results of its review in the letter to Headquarters (Kennedy, 1993c). In the course of its review, the Peer Review Panel requested additional information or analyses from the Savannah River Site personnel. The site provided two sets of supplemental information in response to Panel requests and one set of unsolicited supplemental information (Cook, 1993a, 1993b); these supplements constitute part of the basis for the Panel's finding that the performance assessment is technically acceptable.

An issue regarding compliance with the groundwater protection performance objective evolved as part of the Headquarters' review (Cowan, 1996; Roles, 1996). The issue involved two specific topics. The first topic was how the site was complying with the tiered implementation of the groundwater protection performance objective. The second topic concerned whether the naturally-occurring radioactive material in the flyash and slag had been adequately considered in the analysis.

It should be noted that the Saltstone Disposal Facility performance assessment was prepared and submitted to Headquarters prior to the development of the three-tiered process for applying the groundwater protection performance objective. In an agreement with the State of South Carolina (Morgan, 1985), the Savannah River Operations Office committed to complying with state environmental protection regulations. One of these regulations imposes the Safe Drinking Water Act maximum contaminant levels for protection of surface and groundwater. Savannah River Site personnel indicated that the State's interest was to ensure that the site meets the groundwater protection requirements in current time as demonstrated by groundwater sampling and analysis. To this end, the State imposes monitoring requirements in the State-issued Industrial Solid Waste Disposal Permit (Anderson, 1996). Site personnel reported that the State views the long-term evaluation via a performance assessment to be an internal DOE concern. It was determined that the site is complying with the second tier of the groundwater protection implementation guidance as evidenced by the issuance of a permit by the State for operation of the Saltstone Disposal Facility.

The second element of the groundwater protection issue dealt with the impacts of naturally-occurring radioactive material in the Saltstone formulation. Flyash and slag are used in the Saltstone formulation. The processes that generate these by-products enhance the concentration of naturally-occurring radioactive materials. The issue was whether these naturally-occurring radionuclides had been accounted for in assessing the potential radiological impacts to an offsite member of the public. The site provided screening calculations showing that the levels of radionuclides in the flyash and slag were not a concern in the analysis (Schepens, 1997; Fowler, 1997).

4.0 Disposal Facility Performance

Disposal facility performance relative to the performance measures is discussed below. An abbreviated restatement of the performance measures is given in italics. These performance measures correspond to the performance objectives listed in Section 2.1, Performance Objectives.

The disposal facility addressed by this performance assessment comprises up to 15 concrete vaults that do or will contain salt solution that has been solidified with a combination of slag, fly ash, and cement. Most of the vaults are 60 m by 180 m by 7.6 m high, divided into 12 30-m by 30-m cells. One of the vaults is composed of 6 cells and is half as wide as the other vaults. The vaults are permitted as an industrial waste landfill by the State of South Carolina.

The closure concept for the Saltstone Disposal facility involves a layered barrier over the saltstone vaults that incorporates drainage layers intended to route infiltrating water to an array of drainage channels that will move the water away from the facility. The barrier includes a lower clay and gravel drainage layer immediately on top of the vaults, an upper drainage barrier above that, then top soil that is to be planted with a shallow-rooted bamboo. The plant cover is to reduce the rate at which the surface would be eroded by runoff and to inhibit the growth of deeper-rooted plants that have a greater potential of transporting radioactivity to the surface. The plant cover also reduces the amount of infiltration by recycling water back to the atmosphere through transpiration.

Section 2.3 of the performance assessment describes the source of waste to be disposed of at the Saltstone Disposal Facility. The principal feed stream is a salt solution resulting from the process used to pre-treat high-level waste. The other feed stream is waste water arising from the F/H Areas Effluent Treatment Facility. The projected inventory of radionuclides to be disposed of in the Saltstone Disposal Facility is presented in Section 2.6 of the performance assessment.

Acceptance of the following results is predicated on technically valid analyses having been performed. As noted in Section 3.0, it is the conclusion of this review that a technically valid analysis has been performed. It should be noted however, acceptable performance of the Saltstone Disposal Facility has been shown to be dependent on the functioning of the lower gravel/clay barrier that sits on top of the vaults (Cook, 1993a). Therefore, based on the analyses presented, it is imperative to the success of Saltstone disposal that the closure concept is further developed and field tested to demonstrate that the necessary barrier performance can be achieved.

4.1 ***Dose to a member of the public to be less than 25 mrem in a year.***

Based on the analyses in the performance assessment and supplemental material, there is a reasonable expectation that the dose limit of 25 mrem in a year via all pathways will be met. This conclusion is based on the rationale provided in the performance assessment that drinking groundwater dominates the dose to an offsite receptor for the various groundwater exposure scenarios, that a performance target of 4 mrem is used for the drinking water pathway, and that the dose from the air pathway is relatively insignificant.

In conducting the assessment of saltstone, the analysts considered four cases. The cases comprise combinations of an intact or failed upper drainage barrier with an intact or failed vault and saltstone. The upper drainage barrier controls how much of the 124 cm annual precipitation reaches the lower clay and gravel barrier on top of the vaults. If the upper drainage barrier is functioning as designed, infiltration is controlled to 2 cm/yr (see later discussion of barrier performance assuming different hydraulic conductivity values). In the failed upper drainage barrier cases, infiltration is assumed to be 40 cm/yr, the same as the ambient soil.

For the cases analyzed in which the vault and saltstone are intact, the hydraulic conductivity of the materials has an overriding impact on flow to the groundwater. Hydraulic conductivities of 10^{-10} and 10^{-11} cm/s, supported by laboratory studies, are used for the vault concrete and saltstone, respectively. The analysis considered physical and chemical degradation of the vaults and concrete. Physical degradation in the form of crack development is recognized as a possibility. A number of recognized chemical degradation processes were analyzed to determine potential impacts to the integrity of the concrete. Analyses indicate that sulfate attack of the concrete is not significant over the first 10,000 years. Carbonation is predicted to penetrate about 6 inches over the first 10,000 years, but will have a minimal impact on reinforcement steel corrosion. Calcium hydroxide leaching is conservatively estimated to have effects starting beyond 5000 years. And reinforcement steel corrosion (oxidation) is projected to start at about 500 years, but is not expected to be significant until beyond 2000 years. Therefore, over the 1000 year time of compliance, it appears that there would be minor impacts to the integrity of the concrete. It is further expected that the impacts would be in the form of crack development as opposed to disintegration and crumbling of the concrete.

The performance assessment analysts acknowledge the difficulty they had in developing a realistic model for the degradation of concrete. Therefore, a number of conservative simplifying assumptions were used for the purpose of analyzing degraded concrete and saltstone cases. The assumptions are that cracks exist at the time of closure, they fully penetrate the vault and saltstone, they are spaced 3 m apart and have a width of 0.005 cm. It is further assumed that the cracks do not heal as a result of filling with soil or through precipitation reactions associated with carbonation.

In the four cases analyzed in the original performance assessment, it was assumed that the lower clay and gravel barrier sitting on top of the vaults remained intact with a hydraulic conductivity of 7.6×10^{-9} cm/s. The lower clay and gravel barrier is relevant only for the cases involving degraded concrete and saltstone because the lower hydraulic conductivity of the vaults and saltstone controls the flow and transport when the vaults and saltstone are intact.

In the supplemental information, site personnel presented and interpreted additional calculations which evaluated, among other things, higher hydraulic conductivities for the vault and saltstone, and for the clay in the upper and lower barriers (Cook, 1993b). The revised analyses use a hydraulic conductivity for the clay of 10^{-7} cm/s which is more representative of that achievable in field applications. The higher hydraulic conductivity results in an increase from 2 cm to 4 cm in the amount of annual precipitation that infiltrates the fully functioning upper barrier. The more important impact of the higher hydraulic conductivity is that it increases the amount of water penetrating the lower gravel and clay barrier and entering the degraded concrete through the cracks.

The performance assessment lists 47 pathways that could lead to exposure of an offsite receptor. The predominant means of moving nuclides from saltstone to the environment is through leaching and groundwater transport. Therefore, those pathways that are associated with groundwater are expected to be the most important. These pathways include drinking contaminated groundwater, consuming vegetables watered with contaminated groundwater, ingestion of contaminated soil on the surface of vegetables, consuming meat and milk from animals that drink contaminated groundwater, direct exposure to soil contaminating groundwater, and inhalation of soil containing radionuclides from irrigation with contaminated groundwater. The other pathways are considered to be insignificant because they are easily bounded by conservative analyses (e.g., exposure via the air pathway is analyzed for an intruder residing directly above saltstone), are recognized as having a minimal impact on dose compared to other pathways, or result in significant dilution so as to be inconsequential (e.g., transport to surface waters).

The performance assessment further evaluates the pathways contributing to the all pathways dose in terms of the drinking groundwater pathway alone. The conclusion of this evaluation is that the combination of the higher performance objective for all-pathways (25 mrem/yr versus 4 mrem/yr for drinking water) and the losses resulting from transferring from one medium to another supports the conclusion that the all-pathways performance objective will be met if the 4 mrem/yr drinking water performance measure is met. This conclusion is based, in part, on the air pathway being inconsequential as is discussed below. The performance assessment presents comparisons of the expected dose from drinking water versus the dose from other pathways for four radionuclides (Tc-99, Sn-126, Cs-137 and Pu-239). The four radionuclides, three of which are key radionuclides in the groundwater analysis, represent a range of distribution coefficients (Kd's of 1.5 to 4500 ml/g) and a range of plant to soil concentration ratios (0.02 to 2.4). Based on the assumptions and parameters used, the dose from groundwater would exceed the dose from the other pathways by a factor of two for Tc-99, by a factor of 0.7 for Sn-126, by a factor of two for Cs-137, and by a factor of seven for Pu-239. The fact that the performance objective for the all-pathways dose is a factor of six higher than the drinking water performance measure leads to the acceptability of the conclusion. Therefore, compliance with the all-pathways performance objective is assumed if the drinking water performance measure is met.

In order to have a manageable suite of radionuclides for which detailed analyses are performed, the performance assessment analysts conducted screening analyses. The first screen was to eliminate radionuclides with a half-life of less than five years from further consideration. Recognizing that the radionuclide concentrations in saltstone will meet the Nuclear Regulatory Commission Class A limits, the 20 half-lives that would occur during the 100 year active institutional control period assumed for intruder analyses would result in insignificant levels of these radionuclides remaining. The second screen is extremely conservative in that it compares the radionuclide concentration in the saltstone pore fluid with the drinking water concentration that would result in a dose of 4 mrem/yr. Radionuclides were selected for further analysis if the pore fluid concentration exceeded the drinking water concentration limit that corresponds with a dose of 4 mrem/yr. The following ten radionuclides were included in the detailed analyses as a result of the screening process: H-3, C-14, Se-79, Sr-90, Tc-99, Sn-126, I-129, Cs-137, Pu-238, and Am-241.

Analyses of the four cases originally included in the performance assessment showed that four of these radionuclides dominate the doses via the drinking water pathway. For the intact vault cases, only Se-79 and I-129 are significant. For the degraded vault cases, the same two radionuclides and Tc-99 and Sn-126 are significant. The other nuclides account for peak doses of less than 10^{-8} mrem/yr.

Sensitivity and uncertainty analyses were performed on various processes and related parameters to determine how significant they were to facility performance. The following processes and associated parameters were analyzed:

- distribution coefficient (Kd) in the saltstone which controls both the pore fluid concentration for a constituent as well as how rapidly it leaches from the saltstone;

- fluxes to the water table from intact vaults as affected by

    - concrete hydraulic conductivity;
    - concrete diffusivity;
    - concrete porosity;
    - saltstone hydraulic conductivity;
    - saltstone diffusivity;
    - backfill hydraulic conductivity;
    - soil capillary pressure;
    - vault infiltration rate; and
    - vault roof geometry.

- increased hydraulic conductivity of the vault and saltstone.

- fractional (portion of the entire inventory) release rate for degraded vaults as affected by

    - depth of perched water;
    - crack width;
    - crack spacing; and
    - distribution coefficient.

- clay and gravel barrier hydraulic conductivity.

- groundwater flow and transport as affected by

  - recharge;
  - vertical and horizontal hydraulic conductivity of the three geologic layers underlying the Saltstone Disposal Facility.

An analysis of doses from the 10 key radionuclides was conducted using the most conservative (lowest) distribution coefficient expected for the constituents in intact saltstone. This maximizes the concentration of the constituent in the pore fluid. Even though there would be some retardation for all constituents except those with a zero distribution coefficient no retardation was assumed in the analysis. The analysis found that, with the exception of Cs-137, the peak concentration of all of the radionuclides in the groundwater was less than the concentration that would cause a dose of 4 mrem/yr. The Cs-137 concentration exceeded the limiting concentration by 10%. However, there are two factors that the analysis did not account for that would mitigate the impact of the Cs-137. First, the travel time through the vadose zone to the groundwater for a constituent with a distribution coefficient of zero is estimated to be 7500 years. The distribution coefficient used in the analysis for Cs-137 is 1 which means the travel time through the vadose zone would be even longer. Therefore, the calculated peak Cs-137 concentration in the groundwater would occur well beyond the 1000 year time of compliance. The second mitigating consideration is that no credit was taken for radioactive decay for the travel time in the vadose zone. Due to the long travel time and the nominal 30-year half-life of Cs-137, if radioactive decay were taken into account, the peak concentration in the groundwater would be negligible.

In evaluating the sensitivity to those factors listed above under the heading of fluxes to the water table, it was found that the results were most sensitive to the conductivity and diffusivity of concrete and saltstone. A statistical analysis using a method called Latin Hypercube Sampling was used to test the combined impacts of these four parameters. In Latin Hypercube Sampling, the computer samples the range of values for each parameter based on the defined distribution and performs the analysis with the sampled values. One hundred runs were made with the maximum peak flux being about 50 times higher and the minimum peak flux being about 1.25 times lower than the reference result. The reference result was based on an analysis that predated the cases used in the performance assessment and therefore did not include the lower clay and gravel layer sitting on top of the vaults. The conclusions of the analyses would not be different because of the presence of the lower clay and gravel layer because the concrete and saltstone conductivity and diffusivity are the controlling parameters. It is noted that decreasing the saltstone hydraulic conductivity by two orders of magnitude only reduces the flux by 30%. This small response occurs because the transport is dominated by diffusion rather than advection at lower hydraulic conductivities. As in the above case, peak flux to the groundwater occurs well beyond the 1000 year time of compliance because the analysis was conservative and assumed a constituent with a Kd of zero. Short- to medium-lived radionuclides would decay prior to reaching the groundwater, further reducing the peak flux.

Analyses of the impacts of increased hydraulic conductivity in the vaults and saltstone was performed separate from the above-discussed analysis for the four radionuclides significant to the groundwater pathway analysis (Se-79, Tc-99, Sn-126, and I-129). In one simulation an increase in the hydraulic conductivities by 2 and 3 orders of magnitude for the vault concrete and saltstone, respectively, were used. In a second simulation, in addition to increasing the hydraulic conductivity, the effective diffusion coefficient was increased by two orders of magnitude. The results show a significant increase in dose, in response to the increased conductivity, however, the resulting doses were on the order of 0.1 mrem/yr, significantly less than the 4 mrem/yr target.

The sensitivity/uncertainty analyses for the degraded vaults evaluated the impacts of the depth of perched water sitting on the vaults, the spacing between cracks, the width of cracks and the distribution coefficient. The analysts argue that the semi-analytical approach used for modeling the cracks provides a significant degree of conservatism, but that the uncertainties associated with the model and scenario are not amenable to quantification. The analysis shows that the results are relatively insensitive to the crack width, and most sensitive to depth of perched water, crack spacing and the distribution coefficient. There appears to be a linear relationship between release fraction and the depth of perched water and the crack spacing.

In association with the supplemental analysis in which the analysts revised the hydraulic conductivity used for the upper and lower barriers, an additional sensitivity/uncertainty analysis was performed. The additional analysis assigned a hydraulic conductivity to the lower clay and gravel layer equal to that of the native soil (10^{-5} cm/s) which is two orders of magnitude greater than the hydraulic conductivity used in the supplemental analysis. To examine the sensitivity to the hydraulic conductivity doses from the four radionuclides significant to the groundwater pathway were calculated using this greater hydraulic conductivity. The resulting doses were 200 to 300 times higher than those calculated for a hydraulic conductivity of 10^{-7} cm/s. The peak doses from drinking water would be 30 mrem/yr (Tc-99), 40 mrem/yr (I-129), and 80 mrem/yr (Se-79) compared to the dose limit of 4 mrem/yr. The dose from the fourth radionuclide (Sn-126) remained below 4 mrem/yr at the higher hydraulic conductivity. Note however that these peak doses occur beyond the 1000 year time of compliance (from 2400 to 15,000 yr). Doses at the time of compliance are not available from the information presented. These results are partially a function of the assumption that all of the water flows through the cracks in the degraded vault. The doses projected by these simulations are recognized as being unrealistically high because the lower clay and gravel barrier would be minimally susceptible to degradation from drying, erosion, and biointrusion due to the protection provided by the overlying sediments. However, the analyses do point out the importance of the lower clay and gravel layer to controlling doses to acceptable levels and the need to conduct confirmatory studies.

Sensitivity/uncertainty analyses of groundwater flow and transport were performed using a constituent with a distribution coefficient of zero. Recharge was evaluated at rates of 2 cm/yr (11 times the recharge used in the four base cases) and 40 cm/yr. There was a small effect on water table level from the 2 cm/yr recharge and essentially no significant effect on the peak concentration. At the 40 cm/yr recharge, there was a modest effect on the water table and a reduction in peak concentration of about 48%. This indicates that the recharge in the range expected through the Saltstone Disposal Facility (a few centimeters or less) has much less effect on flow than recharge from around the facility.

The hydraulic conductivities in three dimensions were tested for the three hydrologic units underlying the Saltstone Disposal Facility using the Latin Hypercube Sampling method. The results show that the flow regime is most sensitive to the vertical component of the middle unit (an aquatard) and the horizontal components of the upper unit. This analysis focused on the nonradioactive contaminant, nitrate, and was not useful in this compliance evaluation except for demonstrating that the analysts had a reasonable understanding of the limitations of the PORFLOW model for their groundwater flow regime.

Table 1 summarizes the results of the performance analysis for the performance measures listed. For the all-pathways and drinking water measures, the reported results correspond to the cases in which the upper moisture barrier has failed. It is noted that the reported results are maxima that occur beyond the 1000 year time of compliance. Therefore, compliance with the performance objective during the 1000 years time of compliance is readily projected.

4.2 *Dose via the air pathway; radon flux to be less than 20 pCi/m²/s*

There is a reasonable expectation that the doses to an offsite member of the public via the air pathway will be far below the limits of 40 CFR 61, that is, 10 mrem/yr exclusive of doses from radon. For the air pathway, performance is evaluated against 10 mrem/yr for H-3 and C-14, two radionuclides which can become available through vapor diffusion to the ground surface. Section 4.3 of this evaluation addresses the dose to a hypothetical intruder who lives 24 hours a day, 365 days a year in a basement 15 cm above the saltstone. The estimated doses from this bounding analysis are 10 mrem/yr from H-3 and 4×10^{-7} mrem/yr from C-14. This analysis is adequate to provide a reasonable expectation that the 10 mrem/yr dose limit to an offsite receptor will be met due to the extreme conservatism of the analysis in Section 4.3, the attenuation that would occur between the saltstone and the ground surface, and dispersion that would occur between the vaults and the 100 m point of compliance.

The performance of radon in the disposal system was evaluated against a flux rate of 20 pCi/m^2/s. Appendix A of the performance assessment presents a conservative estimate of the flux rate from saltstone. Some of the conservatisms used include calculating the flux at the surface of the saltstone (i.e., taking no credit for attenuation through the overlying barriers); an assumption that U-234 is in secular equilibrium with Ra-226 which will not occur until well after the 1000 year time of compliance; not accounting for depletion of the source inventory through leaching; and use of an effective diffusion coefficient for dry material when the saltstone is expected to be 80-90% saturated. The resulting flux rate is estimated to be 0.1 pCi/m^2/s.

A summary of the evaluation of compliance with the above performance measures is presented in Table 1.

Table 1: Results of All-Pathways and Air-Pathway Compliance Evaluation

Performance Measure (1)	Results Intact Vaults	Results Degraded Vaults
All-pathways (25 mrem in a year)	~0.001 mrem/yr	~0.6 mrem/yr
Drinking water (4 mrem in a year)	0.001mrem/yr	0.6 mrem/yr
Air pathway (10 mrem in a year)	<10 mrem/yr (3)	<10 mrem/yr (3)
Radon emission (20 pCi/m^2/s)	0.1 pCi/m^2/s (4)	0.1 pCi/m^2/s (4)

1 The first and third performance measures are performance objectives directly from DOE Order 5820.2A. The second performance measure was imposed by the site to evaluate compliance with State groundwater limits. The fourth performance measure is used in this review for radon emission.

2 Results of analyses relative to the all pathways dose limit are inferred based on the calculated drinking water dose and the relative significance of other pathways.

3 A conservative, bounding analysis of the dose to an intruder residing 15 cm above saltstone resulted in a maximum dose of 10 mrem/yr. The air pathway does to an member of the public would be significantly attenuated by the 2.9m of cover over the vaults and diluted in traveling the 100m distance to the offsite point of assessment. Consequently, the dose would be much less that one calculated just 15cm above the vaults.

4 A single analysis for radon flux at the surface of saltstone was performed. The condition of the saltstone is inconsequential to the analysis.

4.3 ***Dose to intruder to be less than 100 mrem in a year for chronic exposure. Dose to intruder to be less than 500 mrem for an acute exposure.***

Based on the analyses in the performance assessment and supplemental material, there is a reasonable expectation that the dose limits of 100 mrem in a year from chronic exposure of a hypothetical intruder and 500 mrem from an acute exposure of an intruder will not be exceeded.

The performance assessment included consideration of a number of chronic and acute intruder exposure scenarios. The scenarios that would result in chronic exposure of intruders are an excavation-agricultural scenario, a drilling-agricultural scenario, and an excavation-resident scenario. Scenarios resulting in acute exposure of a hypothetical intruder were construction, discovery, and drilling. The performance assessment concludes that showing compliance with the chronic exposure performance objective will assure that the acute exposure performance objective will be met. A number of factors are considered in drawing this conclusion. First, in comparing the drilling and the post-drilling agriculture scenarios, there are not any significant exposure modes that occur during drilling that do not occur during the post-drilling period. The amount of material exhumed does not constitute a large source for direct exposure, and there is not expected to be a significant airborne concentration because of the moisture content of the drilling waste, the small size of the waste pile, and the lack of mechanical disturbance of the pile. Second, a comparison of the construction and discovery scenarios shows that the construction scenario has a potential for higher impact to an intruder than the discovery. The greater impact is due to the assumption that in the discovery scenario the activity would cease shortly after discovery, but in the construction scenario it is assume that action continues towards constructing a residence resulting in a longer exposure time. Third, even though there is greater potential for direct exposure and higher levels of airborne activity in the construction scenario when compared to the post-construction agriculture scenario, these are partially offset by the longer exposure time. Comparison of intruder scenarios by Kennedy and Peloquin (1988) showed that for most radionuclides, the dose from the agriculture scenario is greater than for the construction scenario. The last factor which helps account for the few radionuclides which cause a greater does in the construction scenario is that the dose limit for the chronic exposure scenarios if one fifth of the limit for acute exposure (100 mrem compared to 500 mrem).

The performance assessment identified two variations of the excavation-agricultural scenario that were considered. The first is the traditional case whereby excavation for a basement results in bringing waste to the surface. Subsequently, this waste material, which is assumed to be indistinguishable from soil, is mixed with garden soil. Chronic exposures result from direct exposure in the house and the garden, consumption of contaminated vegetables, ingestion of contaminated soil on the vegetables, and inhalation of contaminated dust while working in the garden. Due to the characteristics of the Saltstone Disposal Facility and the time that would be required for the vaults and saltstone to lose sufficient structural integrity so as to be excavated, this compliance evaluation considers this scenario to not be credible during the 1000 year time of compliance. The alternate excavation-agricultural scenario involves excavation of, and incorporation into a garden, soil from above an intact vault that becomes slightly contaminated from the upward migration of radionuclides from the vaults. This scenario results in a dose to the hypothetical intruder of 10^{-5} mrem/yr.

A residential scenario is hypothesized in which the intruder excavates until finding the vault or saltstone. The performance assessment argues that in times shortly following the assumed 100 year active institutional control period, the intruder would encounter the vault roof. Therefore, the intruder would benefit from the shielding provided by the clean grout cap on top of the saltstone and the concrete of the vault roof. It is then assumed that the intruder builds a house on the vault and receives a dose of 0.6 mrem/yr from direct exposure. An additional, conservative analysis is included in the performance assessment in which the clean grout and concrete roof have degraded such that they are excavated as soil and the intruder is stopped by direct contact with saltstone. This second scenario requires a time that is well beyond the 1000 years time of compliance for degradation of the concrete and grout so is not considered credible in this compliance evaluation.

Although the second residential scenario is not relevant to the findings of this compliance evaluation it does provide the scenario for considering exposure via inhalation of the volatile radionuclides, H-3 and C-14. Exposure through inhalation is hypothesized for a person living year-round in a basement room 15 cm above saltstone. This bounding analysis results in a dose of 10 mrem/yr, well below the intruder chronic exposure performance objective of 100 mrem/yr.

As with the excavation-agricultural scenario, two variations of the drilling-agricultural scenario were considered in the performance assessment. And as with the excavation-agricultural scenario, the variation that assumes intrusion directly into the waste is not considered in this compliance evaluation because it is not credible during the 1000 year time of compliance. The alternative drilling scenario assumes that contaminated soil is brought to the surface in the process of drilling a well adjacent to a vault. The soil is assumed to have been contaminated by lateral migration from the vault. The exposure pathways are the same as discussed above for the other agricultural scenario and the resulting dose is 10^{-4} mrem/yr.

Since DOE will continue to control the land where the Saltstone Disposal Facility is located, an inadvertent intruder is an unlikely event that would be expected to occur for only a short period of time, possibly due to lapses in institutional controls, but would be discovered and rectified. The scenarios and parameters selected are considered adequate for concluding that there is a reasonable expectation of meeting the performance objectives. The performance assessment presents additional analyses of intrusion at times well beyond 1000 years. However, these analyses were not needed in making a determination of compliance. These additional analyses show that even more conservative scenarios involving complete degradation of the concrete and saltstone result in calculated doses of only 16 to 76 mrem/yr (Cook, 1993b).

The maximum annual doses to a hypothetical intruder relative to the performance objectives are summarized in Table 2.

Table 2: Results of Intruder Compliance Evaluation

Performance Objective	Estimated dose
100 mrem/yr chronic exposure	0.6 mrem/yr
500 mrem/yr acute exposure	less than the chronic exposure (see p 3-2)

4.4 ***Protect groundwater.***

The performance assessment and supplemental information indicate that the groundwater which flows under the Saltstone Disposal Facility is and will be protected. There is a reasonable expectation that groundwater at the Savannah River Site will not be adversely impacted by the Saltstone Disposal Facility based on the projected dose to an offsite member of the public being well below 4 mrem in a year as discussed in Section 4.1 above. In addition, the State of South Carolina has indicate it is their intent to monitor protection of the groundwater beneath saltstone through review of sampling and anlaysis data collected in accordance with a state-issued Industrial Solid Waste Permit.

The Department has established a tiered protocol for complying with the groundwater protection performance objective (DOE, 1996a). The first tier is that sites comply with applicable Federal, state, or local laws and regulations for groundwater protection. There are currently no Federal, state, or local regulations applicable to groundwater on the Savannah River Site.

The second tier of the groundwater protection protocol is that sites are to comply with agreements. Through a memorandum of agreement dated April 8, 1985, the Savannah River Site committed to complying with certain state laws and regulations as required by law or as a matter of comity. Included in these laws is the Pollution Control Act which addresses protection of state surface water and groundwater. Protection of these waters is accomplished by invoking the Safe Drinking Water Act maximum contaminant levels. The State has issued an Industrial Solid Waste Permit which requires the site to sample and monitor the groundwater for radioactive constituents. The site position that complying with the State-issued permit meets the commitment made under the agreement is considered acceptable.

As indicated in Section 4.1 of this compliance evaluation, it is expected that the Saltstone Disposal Facility will not unacceptably impact the groundwater over the long term. The analysis indicates that projected doses to an offsite individual who is assumed to consume 2 liters of water per day would be well less than 4 mrem in a year.

4.5 *Reasonable effort to maintain doses as low as reasonably achievable.*

An ALARA analysis has not been discussed in the performance assessment. Earlier work on saltstone formulation which constitutes part of an ALARA analysis has already been performed and performance assessment results imply that extension of the analysis would have minor effects. It is necessary, however, for the site to document and report the conclusion of a more complete analysis.

5.0 Conditions for Acceptance

The following conditions on the operation of the Saltstone Disposal Facility are imposed by Headquarters based on the review of the radiological performance assessment.

1. The site is to address the requirement for an ALARA analysis in accordance with the latter part of DOE Order 5820.2A, Chapter III, 3.a.(2). The detail of this analysis should be commensurate with the calculated doses.

2. An addendum to the performance assessment, or a revised performance assessment, is to be issued by June 30, 1998. The addendum is to include the additional information developed by the site in response to number 1 above and the supplemental information provided subsequent to submittal of the performance assessment (e.g., in response to requests from Headquarters and the PRP). The addendum or revision must be distributed to all known holders of the performance assessment. The purpose of this condition is to ensure that the documentation that was the basis for Headquarters' acceptance is readily available to any party interested in the performance assessment.

3. By December 31, 1998, the site is to develop a plan that commits to a schedule and budget for conducting studies to address the uncertainties surrounding the critical factors affecting performance of a degraded system. The performance assessment analyses showed that, with the assumptions made about flow through cracks , the migration of nuclides from degraded vault and saltstone was very dependent on the performance of the lower clay and gravel layer. For example, the plan could address closure studies that support the hydraulic conductivity of the cover over the vault, improved modeling of the degraded vault, or both.

4. Any contemplated changes in the design of the Saltstone Disposal Facility that were not analyzed in this performance assessment are to be analyzed, and the analysis submitted to and accepted by Headquarters prior to construction. This is consistent with the philosophy in the "Revised Interim Policy on Regulatory Structure for Low-Level Radioactive Waste Management and Disposal" (Guimond, 1996) as it applies to maintenance of performance assessments and to constructing new facilities.

5. The site is responsible for maintaining this performance assessment in accordance with the 1996 guidance, *Maintenance of U.S. Department of Energy Low-Level Waste Performance Assessments.* This includes the acquisition of field data needed to improve confidence in the analyses and reduce critical uncertainties.

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Confirmed:______________________________

Date:__________________________________