August 25, 2009

MEMORANDUM TO: Gregory Suber, Chief
Low-Level Waste Branch
Environmental Protection and
Performance Assessment Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

THRU: Christepher McKenney, Chief **/RA/ by D. Esh for**
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FROM: David Esh, Sr. Systems Performance Analyst **/RA/**
Performance Assessment Branch
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SUBJECT: TECHNICAL REVIEW: "HYDRAULIC AND PHYSICAL PROPERTIES OF SALTSTONE GROUTS AND VAULT CONCRETES"

On January 9, 2009, the U.S. Department of Energy, Savannah River Operations Office, provided the subject report for review by NRC staff pursuant to Section 3116(b) of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (ML090150297). The subject report is available on NRC's Agencywide Documents Access and Management System (ADAMS) at accession number ML090150298. This report was reviewed in accordance with

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monitoring activities described in “U.S. Nuclear Regulatory Commission Plan for Monitoring the U.S. Department of Energy Salt Waste Disposal at the Savannah River Site in Accordance with the National Defense Authorization Act for Fiscal Year 2005.” The staff’s technical review summary is enclosed for your use.

Docket No.: PROJ0734

Enclosure:
Technical Review Summary

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Technical Review Summary

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Technical Review Summary: *TECHNICAL REVIEW: "HYDRAULIC AND PHYSICAL PROPERTIES OF SALTSTONE GROUTS AND VAULT CONCRETES"*

Review Completed: March 20, 2009

Reviewer(s): D. Esh

Document(s): Dixon, K., J Harbour, M. Phifer, *Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*, SRNS-STI-2008-00421, Revision 0, Savannah River National Laboratory, WSRC. November 2008, ADAMS accession no. ML090150298

Evaluation

The primary focus of the report is to provide a summary of work performed to estimate the hydraulic and physical properties of three types of saltstone and two vault concretes. Wet properties measured on the saltstone formulations included yield stress, plastic viscosity, wet unit weight, bleed water volume, gel time, set time, and heat of hydration. Hydraulic and physical properties measured on cured saltstone and concrete samples included saturated hydraulic conductivity, moisture retention, compressive strength, porosity, particle density, and dry bulk density. Water retention data are presented for each material along with van Genuchten transport parameters determined with the RETC code.

The report provides a summary of previous initial testing of saltstone grout that provided the basis for hydraulic conductivity values used in the performance assessment and subsequent special analysis. The report provides an adequate summary of the sample preparation and analysis methods for the various measurements. In appendicies, the report provides strength reports and materials characterization test reports provided by the contractors that performed the measurements.

Note: All citations to previous work noted below are those cited in SRNS-STI-2008-00421.

Yu et al. (1993) measured a saturated hydraulic conductivity of 5.19E-12 cm/s, whereas Langton (1986) reported the results of previous testing that ranged from 3E-9 to <1E-11 cm/s. More recent measurements by Harbour et al. (2007a) estimated the hydraulic conductivity of saltstone as ranging between 1.4 to 3.4E-9 cm/s. Dixon and Phifer (2007) estimated the hydraulic conductivity of saltstone relative to the saltstone pore fluid of 5.3E-9 cm/s. The more recent measurements by Harbour, Dixon and Phifer did not corroborate the previous measurements by Yu and Langton. The saltstone performance assessment (2005) used an initial saturated hydraulic conductivity for the base case of 1E-11 cm/s for saltstone and 1E-12 cm/s for the vault concrete. In addition, the porosity measured in the most recent experiments described in this report was on the order of 0.6 to 0.7, much higher than used in the previous performance assessment of 0.42.

The differences in the results between the older and more recent measurements highlight a challenge in relying on limited measurements for parameters that are difficult to measure. Higher than expected hydraulic conductivity for the saltstone and vault concrete and porosity for the saltstone would be expected to lead to higher water flow rates, faster degradation, and higher release rates of radionuclides than previously anticipated (DOE, 2005). Anticipated degradation mechanisms that may proceed more quickly would include but not be limited to sulfate attack, reinforcement corrosion (when applicable), and leaching of calcium hydroxide. In addition, it is likely that higher hydraulic conductivity and porosity would correlate with higher than anticipated diffusivity which would impact the rate at which deleterious species can be transported to the grout or concrete and the rate at which radionuclides would be transported from the grout. DOE is in the process of revising the previous performance assessment. NRC staff plan to evaluate the revised performance assessment to ensure that the values for hydraulic conductivity, porosity, and diffusivity used in the performance assessment reflect the recent measurements and additional uncertainties. Additional uncertainties that could impact the physical property data and that may not be reflected in the more recent measurements were discussed with DOE during the March 2008 monitoring visit (ML081290367). DOE stated that, as a result of that monitoring visit, they were initiating a saltstone product quality assurance strategy to address the additional uncertainties. NRC staff will evaluate information that is generated as it becomes available. In addition to impacting the performance assessment calculation, changes to key variables may impact the assessment of the impact of other processes or uncertainties. For example, the extent of sulfate attack is strongly influenced by the diffusivity of the material. The research process to address uncertainties in performance of the saltstone disposal facility should properly integrate the results of individual studies, many of which may be completed in parallel. NRC staff plan to evaluate future reports and information generated by DOE to assess whether the reports are consistent and appropriately integrated.

This report summarizes and recommends logarithmic averages of hydraulic conductivity for use in future performance assessments, but does not explain why the logarithmic average is appropriate given the limited number of measurements and understanding about the underlying parameter distribution. In this case, the logarithmic average is lower than the arithmetic mean, and should only be used if it can be shown that the data are logarithmically distributed.

Hydraulic conductivity measurements were performed on test cylinders that were 2.8 x 6.0 inches that were filled, capped, and sealed. Page 4 of the report states that bleed liquid leaked from the hydraulic test cylinders during the cure period. It is not clear what is meant by the text, if the cylinders were sealed. NRC asked for additional information at the March 2009 monitoring visit. Adequate seals of the samples can be important in these types of measurements because leakage between the sample and sample holder can influence the measurements and result in inaccurate data for the fundamental hydraulic properties of the material.

The hydraulic conductivity measurements discussed in the report were conducted with a simulated groundwater permeant for vault concrete and a permeant of similar composition as salt waste for saltstone grout. Due to the small volume of permeant used in these tests relative to the volume of simulant used to prepare the samples (i.e., a stimulant to permeant volume ratio of 1:150), the measured hydraulic conductivity values are considered to be representative of the simulant used to prepare the test materials. The report states that geochemical modeling was performed to assess the potential for chemical reactions between the simulants and grout that could impact the property testing. As the material ages, it would be expected that the grout would be less reactive and therefore the permeants contacting the material would be less concentrated because the permeants would contain less salts and other soluble components from reaction with the grout itself. In order for the data generated in the report to apply for degraded conditions, it would be necessary to derive intrinsic permeabilities that are specific to anticipated future groundwater compositions. However, the staff believes that this source of uncertainty may not be significant relative to the other sources of uncertainty.

The report summarizes measurements of moisture characteristic curves for saltstone and vault concrete and also provides data from similar measurements completed by the Idaho National Laboratory (INL). Page 18 of the report discusses a fitting procedure to develop the parameterization of the moisture characteristic curves. The fitting procedure appears to be loosely constrained, which could result in non-unique solutions. The moisture characteristic curve measurements are difficult to perform and can be subject to considerable uncertainty. For example, page 32 of the report provides the characteristic curves for MCU saltstone samples as determined by INL. Figure 15 on page 31 of the report provides the characteristic curve measured for ARP/MCU saltstone in the current study. The moisture characteristic curves are markedly different. In simulations of facility performance, differences in the assigned moisture characteristic curves of dissimilar materials can sometimes have a profound effect on estimated release rates due to the strong non-linear relationship between saturation and relative permeability. NRC staff will evaluate the revised performance assessment to see if the results of the performance assessment are sensitive to the assigned moisture characteristic curves and how uncertainty in the moisture characteristic curves was evaluated in the revised performance assessment.

Teleconferences or Meetings

The subject report was discussed with representatives of the Department of Energy and its contractors on March 25-26, 2009 at an onsite observation at the Savannah River Site (SRS). A summary of the discussion is provided in the onsite observation report (ADAMS accession no. ML091320439). The follow-up actions as a result of the discussion are:

1) Clarify whether bleedwater was leaking from sealed containers during the hydraulic properties study, when the report indicated the samples were sealed;
2) Clarify the impact of changing pore solution concentration on measured hydraulic properties on p. 8 of the report;
3) Explain how uncertainty will be addressed for moisture characteristic curves that are fit to data reported on p. 18 of the report;
4) Justify the use of logarithmic averages for recommended hydraulic property values on p. 19 of the report; and
5) Provide an up to date copy of the PA maintenance plan.

A follow-up action identifies an information need or request that will help NRC staff determine whether a technical issue is risk significant and can warrant tracking as an open issue.

Open Issues

No open issues are identified as a result of this technical review at this time. However, as stated above, DOE has a number of follow-up actions resulting from the staff's questions on the report.

Conclusion

The NRC staff has not identified open issues associated with the methods and data reported in this report (SRNS-STI-2008-00421) at this time. However, DOE has several follow-up actions in response to staff questions. The staff plans to review any new information developed by DOE as part of these follow-up actions.

This report contains data that may be relied upon in future performance assessment (PA) updates in support of the 2005 DOE waste determination for the Saltstone Disposal Facility. However, until such time as a PA update is completed and reviewed by NRC staff, the staff cannot fully assess the risk significance of the data. For this reason, all monitoring activities identified under Factors 1-3 of the NRC monitoring plan remain open at this time.