April 14, 2004

Mr. Joseph Ziegler, Director
Office of License Application and Strategy
U.S. Department of Energy
Office of Repository Development
1551 Hillshire Drive
North Las Vegas, NV 89134-6321

SUBJECT: STAFF REVIEW OF INFORMATION ADDRESSING, "UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS" KEY TECHNICAL ISSUE AGREEMENTS 5.01, 5.06, 5.08, 5.10, AND 5.11 AND "TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION" KEY TECHNICAL ISSUE AGREEMENT 4.02; STATUS COMPLETE

Dear Mr. Ziegler:

In a letter dated October 2, 2003, the U.S. Department of Energy (DOE) submitted information to address Key Technical Issue (KTI) Agreements related to Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC), Radionuclide Transport (RT), and Total System Performance and Integration (TSPAI). In addition, DOE provided responses to various comments from KTI Agreement General 1.01. The agreements between DOE and the U.S. Nuclear Regulatory Commission (NRC) were reached during the USFIC Technical Exchange and Management Meeting held August 16-17, 2000; Radionuclide Technical Exchange and Management Meeting held December 5-7, 2000; and the TSPAI Technical Exchange and Management Meeting held August 6-10, 2001. The DOE submittal addressed a total of 24 agreements within Technical Basis Document No. 11, "Saturated Zone Flow and Transport," Revision 2. DOE's transmittal letter stated that it considered all agreements to be fully addressed and that they should be considered complete. The NRC review of the technical basis document, as it pertains to 6 agreements, USFIC 5.01, 5.06, 5.08, 5.10, and 5.11; and TSPAI 4.02, is discussed in the enclosure to this letter. Disposition and discussion of the remaining 18 agreements will be sent under a separate cover.

The NRC, in a letter dated December 23, 2003 (Adams Accession No. ML033520395) requested DOE to provide additional supporting references to allow NRC staff to complete its review of the technical basis document. In addition, the NRC stated that the supporting references needed to be publicly available in order for NRC staff to complete a detailed review. However, Technical Basis Document No. 11 provided sufficient information for NRC staff to complete its review of six agreement responses. The NRC reviewed DOE's response with respect to these six agreements to determine whether any aspect of the agreements were excluded from the response. No omissions were found. In addition, the NRC performed an independent assessment to determine whether the information provided would support submission of a potential license application for a geologic repository. Notwithstanding new information that could raise new questions or comments concerning the above agreements, the information provided satisfies the intent of the agreements. On the basis of this review, the NRC agrees with DOE that the information assembled in response to the agreements subject of this review is acceptable to support the submission of a license application for the potential repository at Yucca Mountain, Nevada.

Based upon the enclosed review, the NRC staff agrees with DOE, that the information provided is adequate to support the submission of a potential license application. Therefore, the NRC staff considers agreements USFIC 5.01, USFIC 5.06, USFIC 5.08, USFIC 5.10, and USFIC 5.11; and TSPAI 4.02 complete. If you have any questions regarding this matter, please contact Daniel Rom, of my staff at 301-415-6704 or by e-mail to dsr@nrc.gov.

Sincerely,

/RA/

C. William Reamer, Director
Division of High Level Waste Repository Safety
Office of Nuclear Material Safety
and Safeguards

Enclosure:
NRC Review

cc: See attached list

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cc: See attached list

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OFC	HLWRS	HLWRS	HLWRS	HLWRS
NAME	LHamden*:cyj	DRom*	GHatchett*	LCampbell*
DATE	03/15 /04	03/15/04	04/09/04	04/12/04
OFC	HLWRS	OGC	HLWRS	
NAME	TMcCartin*	JMoore* NLO	CWReamer	
DATE	04/09/04	04/08/04	03/14/04	

Letter or Memorandum to J. Ziegler from C.W. Reamer, dated: April 14, 2004

cc:

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cc: (Continued)

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D. Duncan, USGS
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W. Booth, Engineering Svcs, LTD
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C. Bradley, Kaibab Band of Southern Paiutes
R. Joseph, Lone Pine Paiute-Shoshone Tribe
L. Tom, Paiute Indian Tribes of Utah
E. Smith, Chemehuevi Indian Tribe
D. Buckner, Ely Shoshone Tribe
V. Guzman, Walker River Paiute
D. Eddy, Jr., Colorado River Indian Tribes
H. Jackson, Public Citizen
J. Wells, Western Shoshone National Council
D. Crawford, Inter-Tribal Council of NV
I. Zabarte, Western Shoshone National Council
S. Devlin
G. Hudlow
D. Irwin, Hunton & Williams

REVIEW BY THE OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS OF THE U.S. DEPARTMENT OF ENERGY'S KEY TECHNICAL ISSUE AGREEMENT RESPONSES RELATED TO UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS (USFIC), TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION (TSPAI), AND RADIONUCLIDE TRANSPORT(RT) FOR THE POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NEVADA,
[PROJECT NO. WM–00011]

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) issue resolution goal during this interim prelicensing period is to ensure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a license application for review. Resolution by the NRC staff during prelicensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Further, resolution of an issue by NRC during prelicensing does not prejudge the NRC staff evaluation of the issue during the licensing review. Issues are considered resolved by the NRC staff during prelicensing when the staff have no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

By a letter dated October 2, 2003, DOE submitted a report titled Technical Basis Document No. 11: "Saturated Zone Flow and Transport" (Bechtel SAIC Company, LLC, 2003a) to satisfy the informational needs of 24 Key Technical Issue (KTI) Agreements related to Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC), Total System Performance Assessment and Integration (TSPAI), and Radionuclide Transport (RT). The DOE report included referenced technical documents that included detailed technical information, sensitivity results, and references for supporting data. In addition, the report stated that the NRC's information needs regarding the agreements are satisfied and their status should be considered closed. The report provided responses to the following agreements:

USFIC	RT	TSPAI	General (GEN) Comment
USFIC 5.01, USFIC 5.02, USFIC 5.04, USFIC 5.05, USFIC, 5.06, USFIC 5.08, USFIC 5.10, USFIC 5.11, and USFIC 5.12	RT 1.04, RT 1.05, RT 2.01, RT 2.02, RT 2.03, RT 2.06, RT 2.07, RT 2.08, RT 2.09, RT 2.10, and RT 3.08	TSPAI 4.02, TSPAI 3.31, and TSPAI 3.32	GEN 1.01 (28), (34), (41), (43), (45), and (102)

This report provides the NRC staff evaluation of DOE responses to 6 of the 24 agreements included in Technical Basis Document No. 11. Section 4.0 provides the NRC evaluation of the extent to which the DOE submittal satisfies the requirements of agreements USFIC 5.01, USFIC 5.06, USFIC 5.08, USFIC 5.10, USFIC 5.11, and TSPAI 4.02. The NRC evaluation of the extent to which DOE submittal satisfies the requirements of the remaining agreements will be provided in a separate NRC response to DOE.

ENCLOSURE

2.0 WORDING OF THE AGREEMENTS

The NRC found that DOE in Appendices A, C - F, and I of its Saturated Zone Flow and Transport technical basis document (TBDoc) identified various KTI agreements as being satisfied by the information within the TBDoc. The NRC review of DOE response to the agreements within the TBDoc is based upon DOE providing the requested information identified in NRC letters, dated September 8, 2000 (Adams Accession No. ML003751891) for the USFIC agreements, and dated August 23, 2001 (Adams Accession No. ML012390350) for the TSPAI agreement. The wording of the agreements include the following:

USFIC.5.01: "The NRC believes that the incorporation of horizontal anisotropy in the site-scale model should be reevaluated to ensure that a reasonable range for uncertainty is captured. The data from the C-wells testing should provide a technical basis for an improved range. As part of the C-wells report, DOE should include an analysis of horizontal anisotropy for wells that responded to the long-term tests. Results should be included for the tuffs in the calibrated site-scale model. The DOE will provide the results of the requested analyses in C-wells report(s) in October 2001, and will carry the results forward to the site-scale model, as appropriate."

USFIC.5.06: "Provide a technical basis for residence time (for example, using C-14 dating on organic carbon in groundwater from both the tuffs and alluvium). The DOE will provide technical basis for residence time in an update to the Geochemical and Isotopic Constraints on Groundwater Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada, AMR during FY 2002."

USFIC.5.08: "Taking into account the Nye County information, provide the updated potentiometric data and map for the regional aquifer and an analysis of vertical hydraulic gradients within the site-scale model. The DOE will provide an updated potentiometric map and supporting data for the uppermost aquifer in an update to the Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available in October 2001, subject to receipt of data from the Nye County program. Analysis of vertical hydraulic gradients will be addressed in the site-scale model and will be provided in the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002."

USFIC.5.10: "Provide in updated documentation of the HFM that the noted discontinuity at the interface between the GFM and the HFM does not impact the evaluation of repository performance. The DOE will evaluate the impact of the discontinuity between the Geologic Framework Model and the Hydrogeologic Framework Model on the assessment of repository performance and will provide the results in an update to the Hydrogeologic Framework Model for the Saturated-Zone Site-Scale Flow and Transport Model AMR during FY 2002."

USFIC.5.11: "In order to test an alternative conceptual flow model for Yucca Mountain, run the SZ flow and transport code assuming a north-south barrier along the Solitario Canyon fault whose effect diminishes with depth or provide justification not to. The DOE will run the saturated zone flow and transport model assuming the specified barrier and will provide the results in an update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002."

TSPAI.4.02: "The DOE will provide the documentation that supports the representation of distribution coefficients (K_ds) in the performance assessment as uncorrelated is consistent with the physical processes and does not result in an underestimation of risk. This will be documented in the TSPA for any potential license application in FY 2003."

3.0 TECHNICAL INFORMATION PROVIDED IN DOE AGREEMENT RESPONSES

3.1 Agreement USFIC.5.01

The DOE response to Agreement USFIC.5.01 is provided in Appendix E (Bechtel SAIC Company, LLC, 2003a).

The DOE response discusses the heterogenous nature of the fractured volcanic tuff aquifers in the Yucca Mountain area and makes it clear that horizontal anisotropy is difficult to evaluate in such a complex and heterogenous flow system. Nevertheless, it is noted by DOE that, over a large enough representative volume, there likely exists fractures and faults that impart a preferential flow direction that is consistent with anisotropic conditions. Anisotropic hydraulic conductivity refers to the situation in which the permeability of a water-bearing formation is directionally dependent, which can result in deflecting flow paths from the normal flow direction expected for isotropic conditions (i.e., in the direction of the potentiometric gradient). Therefore, it should be possible to use an anisotropy ratio to indirectly include directional effects of subgrid-scale heterogeneities in the fractured volcanic tuff portion of the saturated zone flow model.

The analysis of horizontal anisotropy in DOE response contains a combination of previously published analytical anisotropy estimates and estimates based on new data and analyses. The previously published estimates considered by DOE are based on analysis of data obtained from testing at the C-Holes Complex. These estimates include an anisotropy ratio of 17.0 oriented 30° east of north (Ferrill, et al., 1999) and a ratio of 5.0 oriented 33° east of north (Winterle and La Femina, 1999). The DOE response also provides an analysis that leads to a new set of four different estimates for horizontal anisotropy ratios obtained using two different analytical methods and three different assumptions about bulk aquifer transmissivity. These four anisotropy ratio estimates also are based on data from the C-Holes Complex, and their values range from 3.3 to 11.3, with a range of azimuth orientations from 79° west of north to 35° east of north.

The DOE response indicates a range of anisotropy ratios from 0.05 to 20 will be used for stochastic saturated zone flow model analyses in support of a license application. Because DOE site-scale saturated zone flow model uses a Cartesian grid system, with grid lines oriented in the north-south and east-west directions, the model can include only horizontal anisotropy oriented in those two directions. Accordingly, a horizontal anisotropy ratio with a value greater than 1.0 indicates preferential permeability oriented in the north-south direction, and a ratio less than 1.0 indicates preferential permeability in the east-west direction. Thus, the upper bound value of 20 represents a case with hydraulic conductivity in the north-south direction that is 20 times as great as it is in the east-west direction. Similarly, the lower bound value of 0.05 represents a case with hydraulic conductivity in the east-west direction that is 20 times as great as it is in the north-south direction. The upper bound value of 20 is consistent with the highest available analytical estimate of 17 and is conservatively set to a slightly higher value.

Greater anisotropy in the north-south direction is generally considered conservative because it results in deflection of flow paths to more southerly routes with less travel distance in alluvium. The lower values (less than 1.0) are intended to represent a conceptual model in which preferential flow can occur through northwest-trending features such as the Antler Wash fault zone.

The probability weighting distribution assigned to this range of values is as follows. Because preferential east-west flow represents an alternate conceptual model with little supporting data, the assigned probability of the anisotropy ratio being less than 1.0 is only 10 percent. This portion of the probability weighting is assumed to have a triangular distribution that decreases to a probability of zero at an anisotropy ratio of 0.05. The analytical estimate with a ratio of 3.5, oriented at 79° west of north, falls within this portion of the probability distribution. Because three of six analyses yielded anisotropy ratios between 1.0 and 5.0, a 50-percent probability is assigned to that range of values. This portion of the probability weighting is assumed to be uniformly distributed such that any value between 1.0 and 5.0 is equally likely. The remaining 40 percent of the probability distribution was assigned to the range of anisotropy ratios between 5.0 and 20. This portion of the probability weighting is assumed to have a triangular distribution that decreases to a probability of zero at an anisotropy ratio of 20.

The DOE response provides a figure showing the effects of varying the horizontal anisotropy ratio on flow paths. The results shown represent flow paths originating from the center of the potential repository area for model realizations with anisotropy ratios of 0.05, 0.20, 1.0, 5.0, and 20.0.

The DOE response also contains an analysis of the sensitivity of the site-scale saturated zone flow model calibration to the assigned anisotropy ratio. This sensitivity study was not used in determining the probability distribution for the horizontal anisotropy ratio, but is provided as supporting evidence that the range of uncertainty being considered by DOE is appropriate. This sensitivity analysis revealed that residual calibration error for DOE site-scale saturated zone flow model is slightly sensitive to the anisotropy ratio. This analysis considered a range of anisotropy ratios from 0.01 to 100, which is broader than the range of values considered in the performance assessment abstraction. The weighted root-mean-square model calibration error varied only between 6.9 and 7.6 m [1 m = 3.2808 ft] for the entire range of anisotropy ratios considered. A graph presented by DOE shows the residual calibration error was greatest for anisotropy ratios less than 1.0, representing the preferential east-west hydraulic conductivity. The same graph shows that error decreases slightly for anisotropy ratios greater than 1.0, reaches a relatively flat minimum for values between approximately 10 and 50, and then increases slightly for a value of 100.

3.2 Agreement USFIC.5.06

The DOE response to Agreement USFIC.5.06 is provided in Appendix F (Bechtel SAIC Company, LLC, 2003a).

The DOE response proposes that the combined C-13 and C-14 data suggest groundwater sampled beneath Yucca Mountain has a large local recharge component and is not simply regional groundwater that flows from north to south.

The DOE response also contains information pertaining to analyses of C-13 and C-14 isotopes as a means to estimate groundwater residence times and flow velocities along potential transport pathways from Yucca Mountain.

The $\delta^{13}C$ value can be a useful indicator of the source of carbon in water samples because this value is generally less for carbon derived from organic materials than for carbon derived from carbonate rocks. The analysis presented in DOE response showed that, although patterns of $\delta^{13}C$ values are complex on a borehole by borehole basis, groundwater in the northernmost part of Yucca Mountain is generally lighter in C-13 than groundwater in the central and southern parts of Yucca Mountain. Farther north of Yucca Mountain, however, $\delta^{13}C$ values are considerably higher. The lower $\delta^{13}C$ values for the groundwater directly beneath Yucca Mountain, compared with the hydraulically upgradient areas west and north, suggest a significant amount of local recharge at Yucca Mountain and areas immediately to the north rather than water that simply flowed under the mountain. South of Yucca Mountain, $\delta^{13}C$ values from the Nye County Early Warning Drilling Program wells at the southern edge of Crater Flat are similar to those in groundwater in the southern part of Yucca Mountain. Near Fortymile Wash, along likely flow pathways from Yucca Mountain, the $\delta^{13}C$ values of groundwater generally increase from north to south, although there are some local reversals to this trend. This observation is consistent with a major component of groundwater from the Yucca Mountain area.

The activity of C-14 was evaluated as a potentially useful indicator of groundwater age. In a closed system, C-14 activity will diminish with time as this isotope, with a half life of 5,730 years, undergoes radioactive decay. Water-rock interactions can cause the bicarbonate and carbonate composition of groundwater to increase by orders of magnitude as precipitation percolates below the surface to become groundwater. Such groundwater-rock interactions affect the apparent age calculated from C-14 activity. Some of the lowest C-14 activities in the site area were observed on the eastern edge of Crater Flat, just west of Yucca Mountain and the Solitario Canyon fault. There is a relatively rapid decrease in C-14 activity for groundwater between the northern and central areas of Yucca Mountain. Relatively high C-14 activities were measured in groundwater from Wells NC–EWDP–2D, NC–EWDP–19P, and some zones in NC–EWDP–19D, which are along the southern end of likely flow paths from Yucca Mountain to the compliance boundary. The C-14 data, therefore, do not indicate a clear decrease in activity from north to south along likely flow paths. Accordingly, DOE proposes that the combined C-13 and C-14 data suggest groundwater sampled beneath Yucca Mountain has a large local recharge component.

Appendix F provides results of the analyses of C-14 activity for three sample groups collected in the vicinity of Yucca Mountain: (i) dissolved organic carbon from saturated zone waters, (ii) dissolved inorganic carbon from saturated zone waters, and (iii) dissolved inorganic carbon from perched waters. Thirteen samples analyzed for C-14 activity in dissolved organic carbon yielded a range of age estimates from 8,000 to 16,000 years. Groundwater age estimates based on dissolved inorganic carbon showed a similar age range and distribution (Figure F–4). Ages calculated for perched waters ranged from 7,000 to 11,000 years and were consistent with ages calculated from Cl-36/Cl ratios. A separate analysis was conducted for dissolved inorganic carbon samples collected from locations where, based on U-234/U-238 ratios, the groundwater at the sample locations was interpreted to originate mostly from local recharge. After applying correction factors for the geochemical exchange of dissolved carbon and the potential introduction of radiometrically dead carbon, these analyses yielded groundwater age estimates ranging from 11,430 to 16,390 years. Results of these analyses are summarized in tables provided in DOE response.

The DOE response also provides an analysis of C-14 activities used to estimate groundwater transit times between pairs of wells along a postulated flow path segment. Transit times were calculated using the dissolved inorganic carbon age estimates for the upgradient wells. The PHREEQC code was used to estimate the amount of carbon dissolved as groundwater moves along the flow path segment. The first flow path segment to be analyzed was between upgradient Well UE–25 WT#3 and downgradient Well NC–EWDP–19D. The composite transit time estimate for Well NC–EWDP–19D was 1,000 to 2,000 years to travel a 15-km [9.3-mi] flow distance between the well pair. Groundwater from the deeper alluvial portion (Zones 3 and 4) of Well NC–EWDP–19D was estimated to have transit times of 1,500–3,000 years. Transit times calculated for groundwater in the shallow portion (Zones 1 and 2) of the well ranged from 0–350 years. Using the same approach, groundwater transit times estimated for the 10-km [6.2-mi] distance between well pair USW WT–24 and UE–25 WT#3 ranged from 0 to slightly more than 1,000 years. A transit time of 216 years also was estimated for this well pair based solely on the difference in dissolved inorganic carbon age estimates. Results of the groundwater transit-time analyses are summarized in tables provided in DOE response.

The final analysis presented in DOE response is for residence time of groundwater that originates at the potential repository level and subsequently moves to the accessible environment. Based on C-14 activities, residence times in perched-water zones beneath Yucca Mountain are estimated to range from 3,000 to 10,000 years. Perched-zone residence times of nearly zero were estimated for one sample at Well NRG–7 and one at Well UZ–14; however, these samples were obtained using a bailer and are believed to be influenced by mixing with atmospheric gasses. When combined with the estimates of travel time between Well USW WT–24 and the accessible environment (near Well NC–EWDP–19D), a range of 0–10,000 years is obtained for the estimates of total groundwater residence time. The DOE response notes the low end of this range is highly model dependent and likely an underestimate.

3.3 Agreement USFIC.5.08

The DOE response to Agreement USFIC.5.08 and the request for additional information is provided in Appendix C (Bechtel SAIC Company, LLC, 2003a).

The DOE response contains information pertaining to all requested additional information for Agreement USFIC.5.08. The DOE had previously responded to Agreement USFIC.5.08 by providing a revised analysis and model report for saturated zone water-level data (CRWMS M&O, 2001), which included a potentiometric map of the water table in the Yucca Mountain area that takes into account data from several recently completed Nye County wells. The NRC staff review of this previous response resulted in a request for the following additional information (Schlueter, 2002).

- Incorporation of data from Well USW SD–6 into the analysis of water levels near Yucca Mountain

- A hydrogeologic interpretation for the high potentiometric heads observed in Wells USW UZ–14 and USW H–5

- An updated hydrogeologic interpretation for groundwater elevations in Wells USW G–2 and UE–25 WT#6 based on newly available data from Well USW WT–24

- A basis for assuming the water level in Well NC–EWDP–7S represents perched water

- An analysis of vertical hydraulic gradients within the site-scale model

The DOE current response explains the observed water level for Well USW SD–6 was used for model validation rather than incorporation into the interpretation of the potentiometric surface. The observed water-level elevation in Well USW SD–6 is 731.2 m [2,398.9 ft], which can be compared with a calculated hydraulic head value of 734.8 m [2,410.7 ft] from the calibrated site-scale saturated zone flow model (Bechtel SAIC Company, LLC, 2001a). The response states that the observed water level could be plotted on the existing interpretation of the potentiometric surface (CRWMS M&O, 2001) and would not require any changes to the interpreted potentiometric contours.

The DOE response also provides an explanation of the possible causes for the high potentiometric heads observed in Wells USW H–5 and USW UZ–14. The high head in Well USW H–5 is attributed to the penetration of a splay of the Solitario Canyon fault believed to be an extension of the hydrologic barrier to east-west groundwater flow across the main fault zone. Thus, the high hydraulic heads in Well USW H–5 are believed to be related to the high heads observed in the Crater Flat area, and this well defines part of the moderate hydraulic gradient along the western edge of Yucca Mountain. Borehole USW UZ–14 is said to be in a transition zone between the large hydraulic gradient north of Yucca Mountain and the moderate hydraulic gradient to the west; the high potentiometric head at this well may be related to either of these areas. Two possible explanations for the high heads in Well USW UZ–14 are that this well is in a perched zone caused by a growth fault that impedes percolation of water from the surface or there are low-permeability rocks in the upper part of the saturated zone in that area.

The DOE response indicates there are insufficient data to unequivocally determine whether the high groundwater elevations in Wells USW G–2 and UE–25 WT#6 represent perched water bodies or a large hydraulic gradient area of the regional water table, north of Yucca Mountain. Borehole USW WT–24 was drilled to better understand the cause of this apparent large hydraulic gradient. It is stated the drilling and monitoring of Borehole USW WT–24 found a water table elevation of 840 m [2,755.8 ft] that remained relatively constant as the well was deepened an additional 100 m [328.1ft]. This observation suggests the 840-m [2,755.8-ft] water elevation reflects the regional water table, but, because the well is completed in a low-permeability formation, the possibility this water level reflects perched conditions above a thick aquitard cannot be ruled out. The DOE response indicates both conceptual models for the high groundwater elevations north of Yucca Mountain have been tested with the site-scale flow model, and the two models yielded nearly identical results.

The DOE response explains the original interpretation of perched water at Well NC–EWDP–7S was based on the anomalously high 830-m [2,723.1-ft] potentiometric hydraulic head observed at that location. Recent data from nearby Well NC–EWDP–1DX and also from a new well, NC–EWDP–7SC, provide evidence for a large downward hydraulic gradient between the deep and shallow monitored intervals in that area. The high water levels in the upper zones may represent localized perched water above clay layers. Another possible explanation raised by Nye County consultants is that Well NC–EWDP–7S was not sufficiently developed to allow water flow into the lower monitored intervals and, hence, data from this borehole may be questionable. The DOE also notes the location of Well NC–EWDP–7S is distant from predicted flow paths and outside the compliance boundary, and, therefore, the effect of the uncertainty in this data is minor relative to potential radionuclide transport from the potential repository location.

The DOE response also provides information pertaining to vertical hydraulic gradients within the site-scale flow model domain. Potentiometric head data are provided for the 18 wells within the model domain that monitors water levels in more than one vertical interval. Upward hydraulic gradients between deepest to shallowest intervals are observed in 12 of these wells, and downward gradients are observed in 6 wells.

3.4 Agreement USFIC.5.10

The DOE response to Agreement USFIC.5.10 is provided in Appendix A (Bechtel SAIC Company, LLC, 2003a).

Agreement USFIC.5.10 pertains to the integration of DOE Geologic Framework Model (GFM) (Bechtel SAIC Company, LLC, 2001b) into the larger-scale Hydrogeologic Framework Model (HFM) (U.S. Geological Survey, 2001). Documentation of the HFM (U.S. Geological Survey, 2001) mentions discontinuities in hydrogeologic layer thicknesses were noted in certain HFM layers near the boundary of the GFM domain. Agreement USFIC.5.10 requests information that would allow the NRC staff to evaluate whether these noted discontinuities might bias performance evaluations of the potential Yucca Mountain repository.

The DOE response explains the GFM was developed to provide a geologic basis for various process models of the immediate Yucca Mountain area, including the unsaturated zone flow and transport model. The HFM provides the basis for assigning hydrologic properties to the saturated zone flow and transport model, which covers a larger model area than is represented in the GFM. The HFM is thus based on stratigraphic data interpretations from both the smaller-scale GFM and the regional-scale Death Valley Regional Flow System Model (D'Agnese, et al., 1997). Adjacent stratigraphic layers with similar hydrologic properties from the GFM were grouped together to correspond to hydrogeologic layers in the HFM.

The DOE response presents two types of analyses to address Agreement USFIC.5.10 (Bechtel SAIC Company, LLC, 2003a, Appendix A). The first analysis is a set of four illustrations (Figures A–2 through A–5) of vertical layer thickness extracted from the same version of the HFM (U.S. Geological Survey, 2001) as was used to develop the saturated zone flow and transport model. The illustrations represent the Upper Volcanic, Prow Pass, Bullfrog, and Tram hydrogeologic units and allow visual identification of locations and magnitudes of abrupt changes in layer thicknesses that occur at the interface of the GFM and HFM models. These illustrations show that, for the Upper Volcanic, Prow Pass, and Bullfrog hydrogeologic units, no significant layer discontinuities occur at the interface of the GFM and HFM models. For the Tram unit, however, a large north-south-trending discontinuity was identified near the northwest corner of the GFM boundary. In this area, the Tram unit thins westwardly to approximately 350 m [1,148.3 ft] and abruptly increases in thickness to nearly 1,000 m [3,280.8 ft] near the western boundary of the GFM area. The DOE notes in the response the discontinuity in the Tram unit thickness has been addressed in the latest version of the HFM, referred to as HFM–2002 (has not been publicly released).

The second analysis presents a comparison of north-south and east-west cross sections representing the same cross-sectional areas of the GFM and HFM models. This comparison showed that, when the same grid system is overlaid on cross sections of the two models, mismatches in hydrostratigraphic units occurred in 33 percent of the node locations within the GFM model domain. Information on the grid resolution used in the analysis is not provided. This analysis includes a table that provides permeability values from grid cells in the saturated zone flow model that correspond to each of the identified mismatches between the GFM and HFM. The same table also includes the range of permeability values assigned in the flow model to each HFM hydrogeologic unit that corresponds to a mismatched GFM hydrogeologic unit. In most cases, the range of permeability values assigned to the various HFM units in the saturated zone flow model spans six to eight orders of magnitude. The DOE response states that the effect of the mismatches should be negligible because the permeability assigned in the flow model to each mismatch location cell falls within the total range of permeability values assigned to the corresponding HFM unit throughout the entire model domain.

3.5 Agreement USFIC.5.11

The DOE response to Agreement USFIC.5.11 and the request for additional information are provided in Appendix D (Bechtel SAIC Company, LLC, 2003a).

The DOE had previously responded to this agreement in a letter report dated July 5, 2002, (Ziegler, 2002). Staff review of that report resulted in a request for specific additional information (Schlueter, 2003). Specifically, NRC requested DOE to provide the following two additional items.

- To examine flow and potential radionuclide transport in the deeper aquifer system, a vertical cross-sectional figure showing the flow paths is needed. Two such particle tracking figures showing distance versus depth are needed: one for the calibrated model and another for the shallow Solitario Canyon fault alternative model.

- To test the hypothesis that potential contaminant releases on the west side of a shallow Solitario Canyon fault might enter the lower carbonate aquifer, DOE should provide an analysis of flow paths from the west side of a shallow Solitario Canyon fault. Alternatively, DOE could provide an explanation of potential repository design and site characteristics that would preclude contaminant releases to the west side of the Solitario Canyon fault.

The DOE current response describes the analysis of an alternative conceptual flow model (i.e., “shallow fault alternative model”) in which the Solitario Canyon fault extends vertically from the water table to no deeper than the top of the carbonate aquifer. It is stated that this alternative model is identical to the original site-scale saturated zone flow model in all respects except for changes to the computation grid to implement the alternate formulation of the Solitario Canyon fault. It is further indicated that the alternative model was calibrated in a manner identical to the original model and was run to delineate flow and transport paths on the west and east sides of the Solitario Canyon fault.

The DOE response indicates simulations using the two conceptualizations of the Solitario Canyon fault (original and alternative models) produced essentially the same results. The alternative conceptualization resulted in no major changes to the flow system and hence, has no consequences for radionuclide transport. The simulated water levels, hydraulic gradients, and transport pathways were little affected by the alternative conceptualization. Both conceptualizations yielded essentially the same flow paths from the water table under the potential repository to the accessible environment, and transport times were not affected by the presumed depth of the Solitario Canyon fault.

The DOE response also provides the specific additional information needs requested by NRC. For comparison, figures included in the response depict areal and cross-sectional views of the flow and transport paths obtained from the alternative model and the original model (see, Figures D–15 through D–18 of DOE response). Results of the simulation from the alternative conceptual model formulation indicate the bulk of the radionuclide contamination reaches the saturated zone beneath the potential repository on the east side of the Solitario Canyon fault and is subsequently transported in the tuff aquifer units along flow paths that travel east-southeast of the potential repository, ultimately in a southerly direction, to the accessible environment. The DOE response also shows that a study of potential radionuclide flow paths in the unsaturated zone indicates a negligible number of particles would reach the water table west of the Solitario Canyon fault within the 10,000-year regulatory period. The simulations indicate a small amount of radionuclide contamination could reach the deep carbonate aquifer system along and on the west side of the Solitario Canyon fault, but would then move eastward and upward into the alluvial aquifer to follow a southward path to the compliance boundary.

The DOE response concludes that the alternative conceptualizations resulting in some flow paths occurring west of the Solitario Canyon fault have little effect on radionuclide transport from the potential repository into the saturated zone; therefore, the influence of reducing the depth of the Solitario Canyon fault on total system performance is expected to be minor.

3.6 Agreement TSPAI.4.02

The DOE response to Agreement TSPAI.4.02 is provided in Appendix I (Bechtel SAIC Company, LLC, 2003a).

The DOE response indicates that correlations have been derived for sampling sorption-coefficient probability distributions for both sorbing (americium, neptunium, protactinium, plutonium, thorium, and uranium) and nonsorbing (carbon, iodine, and technetium) elements.

For the strongly sorbing radionuclides americium, protactinium, and thorium, the same probability distribution (K_d = 1,000 to 10,000 mL/g) is used, and DOE indicates a 100-percent correlation. Similarly, all nonsorbing radionuclides are assigned a constant K_d of 0 mL/g and no correlation is required.

Sorption behavior of uranium and neptunium are assumed to exhibit similar geochemical controls from alkalinity and pH, and the sampling correlation between these two radionuclides is assigned a value of 50 percent. Further, separate probability distributions are assumed for neptunium and uranium sorption coefficients in tuff and alluvium. Because of mineralogical differences, the neptunium and uranium sorption coefficients for the two segments of the saturated zone flow path are assumed to be less than perfectly correlated. A correlation is assumed of 75 percent between tuff and alluvium parameter values.

4.0 NRC EVALUATION AND COMMENTS

4.1 Agreement USFIC.5.01

Agreement USFIC.5.01 pertains to the treatment of uncertainty for horizontal anisotropy of hydraulic conductivity in the Yucca Mountain site-scale saturated zone flow model. Anisotropic hydraulic conductivity refers to the situation in which the permeability of a water-bearing formation is directionally dependent. Anisotropic hydraulic conductivity can result in deflecting flow paths from the normal flow direction expected for isotropic conditions (i.e., in the direction of the potentiometric gradient).

The DOE response to Agreement USFIC.5.01 (Bechtel SAIC Company, LLC, 2003a, Appendix E) directly addresses the original NRC concern that the degree of horizontal anisotropy in the volcanic tuff aquifer system at Yucca Mountain was poorly constrained and that analyses from long-term pumping at the C-Holes Complex could provide an improved technical basis for estimating horizontal anisotropy. The DOE approach used to develop a stochastic uncertainty distribution is reasonably based on available data from long-term testing at the C-Holes Complex, and appropriately includes a variety of analytical and data reduction methods to establish a range and probability distribution for parameter uncertainty.

A limitation of DOE site-scale saturated zone flow model is that the Cartesian grid system allows for inclusion of anisotropy in only the north-south or east-west directions. Although anisotropy in hydraulic conductivity can occur in any orientation, consideration of a range of anisotropy values in two orthogonal directions allows consideration of the range of potential effects for modeled flow paths. Further, the uncertainty distribution developed for the horizontal anisotropy parameter assigns 90 percent of the probability weighting to anisotropy ratios oriented in the north-south direction, which is consistent with the predominant orientation of fractures and faults in the region.

The flow path modeling results provided by DOE suggest the range of uncertainty considered for horizontal anisotropy produces significant variability in the location where flow paths transition from volcanic tuff to alluvial aquifer systems. The propagation of the stochastic distribution of flow paths into the flow and transport abstraction for performance assessment will ensure this parameter's uncertainty is appropriately considered in any performance assessment analysis used to support a license application.

The NRC staff conclude that information provided by DOE is responsive to the requirements of Agreement USFIC.5.01, and staff conclude that this agreement is complete. Staff has determined that DOE response provides sufficient detail, and contains sufficient descriptions of, and references to, the analytical methods, data sources, and input parameter values, to conclude its review and complete this agreement.

4.2 Agreement USFIC.5.06

Appendix F (Bechtel SAIC Company, LLC, 2003) provides a summary of results from the analyses of groundwater residence time based on C-14 and C-13 isotope studies. This information is consistent with the type of analysis requested in Agreement USFIC.5.06. An important result of these analyses is they provide evidence that groundwater sampled from wells at Yucca Mountain contains a substantial component of local recharge and is not simply groundwater that flowed southward from recharge areas to the north. Additionally, the fact that C-14 data do not show a clear decrease in activity from north to south along likely flow pathways suggests groundwater may be affected by recharge and groundwater mixing along the entire flow path. The mixing of groundwater of various ages, combined with significant uncertainty in the locations and compositions of recharge source areas, and the degree of calcite dissolution during water-rock interactions make it difficult to obtain reliable estimates of groundwater residence times. This difficulty is reflected in the broad range, from 0 to 10,000 years, estimated for groundwater residence time from below the potential repository area to the accessible environment at the compliance boundary. Although groundwater travel times predicted by DOE models fall within this range, this fact provides little additional confidence in the models because the range is so broad. The DOE site-scale saturated zone flow model for Yucca Mountain does include spatially variable rates of recharge at Yucca Mountain, the higher-elevation areas to the north, and in Fortymile Wash, which is broadly consistent with the interpretation of recharge and mixing along flow paths.

The NRC staff conclude that the information provided by DOE is responsive to the requirements of Agreement USFIC.5.06, and conclude that this agreement is complete.

4.3 Agreement USFIC.5.08

As requested in Agreement USFIC.5.08, Appendix C (Bechtel SAIC Company, LLC, 2003) provides information on vertical hydraulic gradients in the Yucca Mountain area. The DOE response to Agreement USFIC.5.08 also contains information to address the NRC additional information requests that followed review of a previous DOE response to this agreement.

DOE includes recent hydraulic head observations from Well NC–EWDP–2DB, which is the second well in the area to penetrate the deep carbonate aquifer system. Observations at Well NC–EWDP–2DB suggest the upward hydraulic gradient between the deep carbonate and shallow volcanic tuff aquifer systems, which is also observed in Well UE–25 p#1, extends southward beyond the regulatory compliance boundary.

Staff agree with DOE assessment that the water level of 731.2 m [2,398.9 ft] observed in Well USW SD–6 generally is consistent with the previously interpreted potentiometric head contour map for the area (CRWMS M&O, 2001). Additionally, the difference between the potentiometric head observed in Well USW SD–6 and that calculated by the site-scale flow model for that location is 3.6 m [11.8 ft]. This error is small relative to the moderate hydraulic gradient in this area where observed heads in the volcanic tuff aquifer change by several tens of meters moving west to east under Yucca Mountain.

Staff also agree DOE explanations of the possible causes for the potentiometric heads observed in Wells USW H–5, USW UZ–14, USW G–2, UE–25 WT#6, USW WT–24, and NC–EWDP–7S, while not conclusive, are reasonably consistent with available site data.

The DOE analysis of vertical hydraulic gradients revealed upward hydraulic gradients between deepest to shallowest intervals in 12 wells and downward gradients in 6 wells. The NRC staff agree that, in the area of potential flow paths from Yucca Mountain, upward hydraulic gradients are prevalent between the shallow volcanic aquifer and the deeper, confined regional aquifer. Areas of downward hydraulic gradients variably are interpreted as attributable to localized perched zones or areas of local recharge. These interpretations are consistent with the available site data, which are being used by DOE to calibrate the site-scale saturated zone flow model.

Based on the information provided by DOE and the foregoing considerations, the NRC staff conclude that the information contained in Appendix C (Bechtel SAIC Company, LLC, 2003) is sufficient to complete Agreement USFIC.5.08.

4.4 Agreement USFIC.5.10

Agreement USFIC.5.10 is addressed by DOE analysis of how layer thicknesses change at the GFM model boundary within the HFM model. This information illustrates the locations and magnitudes of hydrogeologic layer discontinuities at the GFM model boundary. The analysis shows significant layer anomalies at the GFM–HFM interface are limited to the Tram tuff unit in a north-south line along the northwest portion of the GFM boundary. Staff have determined that this layer discontinuity could not significantly affect the predicted flow paths or groundwater fluxes that are important to the performance assessment, in view of the following considerations:

- The Tram unit discontinuity at the GFM–HFM interface occurs several kilometers upgradient from the potential repository location.

- Modeled groundwater fluxes in the saturated zone in the potential repository area are controlled by low-permeability structural features included in the model, such as the Solitario Canyon fault barrier west of Yucca Mountain and the Claim Canyon caldera and the Calico Hills formations north of Yucca Mountain. Thus, any upstream effects of the Tram discontinuity on groundwater fluxes would be mitigated by these structural barriers.

- The DOE saturated zone flow model is well calibrated in the area beneath and downstream from the potential repository area, so predicted groundwater fluxes and flow paths are consistent with available data. That is, the noted layer discontinuity is not in a location critical to model calibration in the area of flow paths from Yucca Mountain.

- The Tram unit is several hundred meters below the water table beneath and downstream from the potential repository and is observed to be much less permeable than the overlying Bullfrog and Prow Pass units where flow paths from beneath Yucca Mountain are likely to occur. Therefore, uncertainty in the assumed thickness of the Tram unit is unlikely to have a significant effect on modeled flow paths.

- Saturated zone flow paths predicted in DOE model generally flow eastward toward Fortymile Wash before turning southward for the remainder of the distance to the compliance boundary. These flow paths are consistent with those predicted independently using the Center for Nuclear Waste Regulatory Analyses (CNWRA) independent groundwater flow model (e.g., Winterle, 2003).

The DOE response also provides analyses taken from two new versions of the GFM and HFM models, including GFM-2000 (Bechtel SAIC Company, LLC, 2002) and HFM-2002 (which has not been publicly issued). The staff has determined that these analyses are not particularly useful for resolution of Agreement USFIC. 5.10 because the saturated zone flow and transport model for the license application and the staff evaluation of DOE response are based on the original HFM (U.S. Geologic Survey, 2001), and Version 3.1 of the GFM model (Bechtel SAIC Company, LLC, 2001b).

The NRC staff considers the information in DOE response that is based on the original HFM (U.S. Geological Survey, 2001) to be responsive to the requirements of agreement USFIC.5.10. Staff, therefore, consider Agreement USFIC.5.10 complete based on DOE explanations of the nature and extent of discontinuities at the GFM–HFM model interface in the earlier model version, as well as the five additional considerations listed previously.

4.5 Agreement USFIC.5.11

The basis for Agreement USFIC 5.11 is the uncertainty about the conceptual model used by DOE to develop the site-scale saturated zone flow model for Yucca Mountain. At issue is whether saturated zone flow paths from Yucca Mountain could occur within two different aquifer systems (i.e., the shallow volcanic aquifer system and the deep carbonate rock aquifer system), depending on the source area of potential contaminants from the unsaturated zone.

Available potentiometric head data indicate the presence of a barrier to horizontal flow across the Solitario Canyon fault. These data also indicate that, on the east side of the Solitario Canyon fault, there is a significant upward potentiometric-head gradient across the thick confining unit that separates the deep carbonate aquifer system from the shallow volcanic tuff aquifer system. This upward gradient precludes the downward transport of radionuclides from the tuff aquifer into the underlying carbonate aquifer on the east side of the Solitario Canyon fault. On the west side of the Solitario Canyon fault, however, no data are available to indicate upward potentiometric head gradients, and the higher potentiometric head values measured in the volcanic tuff aquifer are similar to those measured in the deep carbonate aquifer east of the fault. Additionally, available structural geology data indicate the potential repository footprint may be crossed by one or more splays of the Solitario Canyon fault, and, if the fault splay beneath the potential repository area also acts as a barrier to horizontal flow, radionuclides released from the potential repository area east of the main fault, but west of the fault splay, could conceivably migrate into the carbonate aquifer. Thus, it was considered a plausible alternative conceptual model that the barrier effect of the Solitario Canyon fault to horizontal flow may diminish with depth, and potential contaminant releases reaching the west side of the Solitario Canyon fault could end up on flow paths within the deep carbonate aquifer system. Based on these concerns, DOE was requested to examine the extent to which radionuclides reaching the saturated zone beneath the potential repository could be transported into and within the deep carbonate aquifer on the west side of the Solitario Canyon fault.

The DOE provided information indicating it had formulated, calibrated, and tested an alternative conceptual flow model consistent with the concerns of Agreement USFIC.5.11. Results of DOE modeling indicate the original flow model and the alternative flow model show radionuclide contamination reaching the west side of the Solitario Canyon fault would be transported southward in the tuff and carbonate aquifer, but eventually will be transported eastward across the Solitario Canyon fault, then move in an east-southeast direction, ultimately converging at nearly the same location along the 18-km [11.2-mi] compliance boundary.
The DOE also provided maps and cross sections to clearly describe the modeling results, consistent with the additional information requested by Schlueter (2003). This modeling analysis provides a reasonable basis for DOE conclusion that the effects on total system performance of both reducing the depth of the Solitario Canyon fault and of initiating some flow paths west of the fault zone are expected to be minor. Staff, therefore, agree the information provided by DOE to address Agreement USFIC 5.11 (Bechtel SAIC Company, LLC, 2003a, Appendix D) satisfies the intent of the agreement and the additional information requested by Schlueter (2003).

The NRC staff conclude that the information provided by DOE is responsive to the requirements of Agreement USFIC.5.11, and conclude that this agreement is complete.

4.6 Agreement TSPAI.4.02

Agreement TSPAI.4.02 requested DOE to provide justification for using distribution coefficients that were uncorrelated. Appendix I (Bechtel SAIC Company, LLC, 2003a) provides information on correlations among sorption coefficients for different radionuclides and indicates a change in DOE's approach to modeling sorption.

In its total system performance assessment model, DOE has included correlated sampling of probability distributions for sorption coefficients (K_d values) for six sorbing and three nonsorbing radionuclides. The DOE also correlates the tuff and alluvium K_d values for neptunium and uranium. Correlations among K_d values are provided for these nine radionuclides, with the exception of plutonium, which is not explicitly discussed. The radionuclides most significant to dose estimates at 10,000 years (neptunium, technetium, and iodine) are addressed.

With regard to risk significance, the NRC and DOE performance assessments indicate dose estimates at 10,000 years are dominated by two nonsorbing radionuclides (technetium and iodine) and the weakly sorbing neptunium. This dominance by two non-sorbing radionuclides would suggest correlation among transport parameters for sorbing radionuclides would minimally contribute to variation in the calculated dose, and would have low overall risk significance with regard to performance.

The NRC staff conclude that the information provided by DOE is responsive to the requirements of Agreement TSPAI.4.02, and conclude that this agreement is complete.

5.0 SUMMARY

The NRC reviewed DOE KTI Agreement responses within the report to determine whether any important aspect of the agreements were excluded from the response. No such omissions were found. In addition, the NRC performed an independent assessment to determine whether the information provided would support submission of a potential license application for a geologic repository. Notwithstanding new information that could raise new questions or comments concerning the above agreements, the information provided satisfies the intent of the agreements. On the basis of this review, the NRC agrees with DOE that the information assembled in response to the agreements is adequate to support the submission of a license application for the potential repository at Yucca Mountain, Nevada.

6.0 STATUS OF THE AGREEMENTS

Based upon the above review, NRC agrees with DOE that the information provided is adequate to support the submission of a potential license application. Therefore, NRC considers agreements TSPAI 4.02, USFIC 5.01, USFIC 5.06, USFIC 5.08, USFIC 5.10, USFIC 5.11 to be complete.

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