RAI: Volume 3, Chapter 2.2.1.3.8, Number 1:

Justify the validity of Bayesian updating of the groundwater specific discharge multiplier using Alluvial Testing Complex data.

Basis: The applicant uses a groundwater specific discharge multiplier (i.e., the GWSPD parameter in Total System Performance Assessment) to propagate uncertainty related to the site-scale specific discharge (SAR Section 2.3.9.2.3.6). The probability distribution of GWSPD was originally provided by an Expert Elicitation Panel (CRWMS M&O, 1998). Based on tracer testing at the Alluvial Testing Complex, 12 specific discharge values (SAR Table 2.3.9-2) were estimated using four interpretation methods. In light of this new information, the applicant applied a Bayesian updating formula to reduce uncertainty in GWSPD, where the probability distribution provided by the Expert Elicitation Panel was treated as a log-normal prior. The applicant then uses the 12 specific discharge data to estimate a log-normal likelihood function, although the applicant states that "some significant uncertainties are associated with each of the estimation methods" (Sandia National Laboratories, 2007b, Appendix G4.4). The applicant needs to justify the validity of assuming the 12 specific discharge estimates as independent and identically distributed random samples from a log-normal distribution, which is an underlying assumption of Bayesian updating (Gelman et al., 2004, Section 2.6).

The information is needed to determine whether uncertainty in GWSPD is appropriately reduced using *in-situ* data and to verify compliance with 10 CFR § 63.114(b), (g).

References:

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1998. Saturated Zone Flow and Transport Expert Elicitation Project. Deliverable SL5X4AM3. Las Vegas, Nevada: CRWMS M&O.

Sandia National Laboratories. "Saturated Zone In-Situ Testing." ANL–NBS–HS–000039. Rev. 02. Las Vegas, Nevada: Sandia National Laboratories. 2007b.

Gelman, A., Carlin, J.B., Stern, H.S., and Rubin, D.B. Bayesian Data Analysis. Texts in Statistical Science. 2nd Edition. New York, New York: Chapman & Hall. 2004.

1. RESPONSE

This response shows that the 12 specific discharge estimates discussed in the RAI basis are independent and identically distributed random samples from an approximately log-normal distribution. As such, these data are consistent with the assumptions of the Bayesian updating method for their use as new information. Consequently, application of the Bayesian updating method, as implemented for the GWSPD parameter, is appropriate for reevaluating the uncertainty in this parameter.

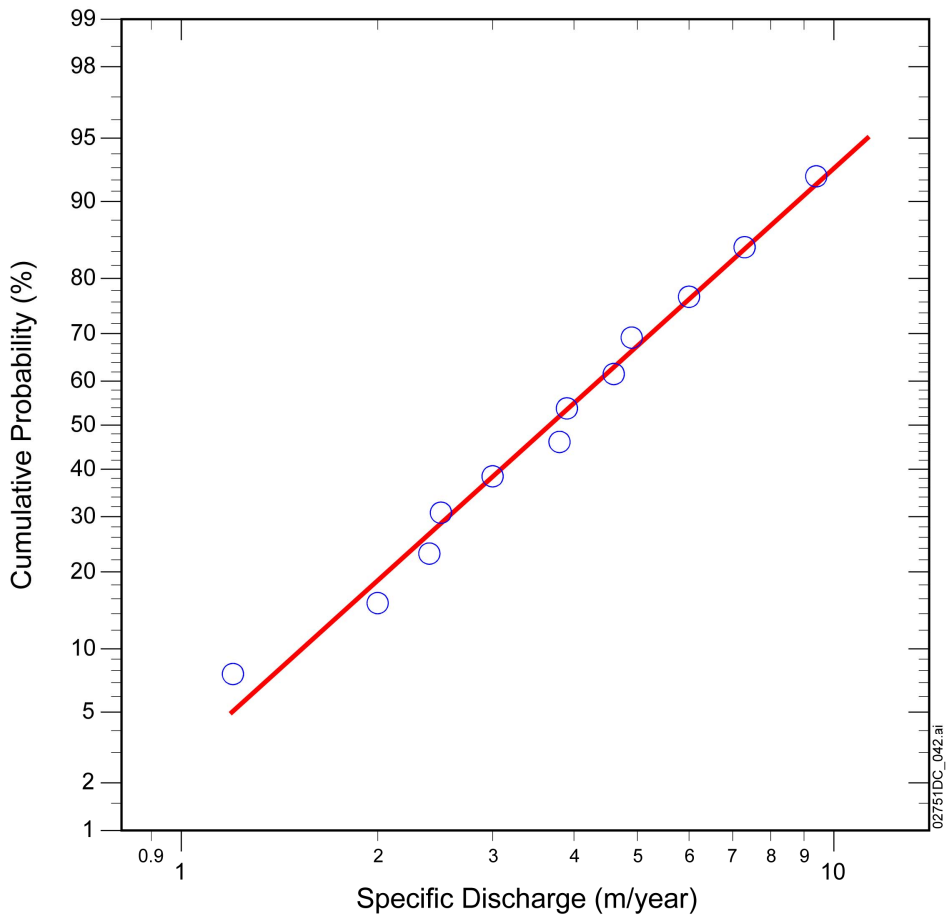
The uncertainty in the groundwater specific discharge multiplier (GWSPD parameter) was modified to incorporate new information from the tracer testing at the Alluvial Testing Complex (ATC) using the Bayesian updating method, as described in *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008, Section 6.5.2.1[a]). Bayesian updating assumes that the new data used in developing the posterior predictive distribution be independent and identically distributed random samples. In addition, Bayesian updating assumes that the new data be from a distribution of the same type as the prior information distribution (log-normal in this case).

The new data used in the Bayesian updating of the GWSPD parameter consist of 12 estimates of groundwater specific discharge, based on single-well injection-withdrawal tracer testing in well NC-EWDP-19D at the ATC. Details of the testing methods and interpretations of testing results are documented in *Saturated Zone In-Situ Testing* (SNL 2007, Sections 6.5.2, 6.5.3, 6.5.5, and Appendix G). Four alternative interpretation methods and three different assumed values of alluvium porosity were applied to analyzing the tracer testing results in order to quantitatively evaluate the uncertainty in the estimated values of specific discharge (SAR Table 2.3.9-2). The four interpretation methods used in the analyses were: 1) peak tracer concentration arrival time, 2) late tracer arrival times, 3) mean arrival time of tracer mass, and 4) mean arrival time using extrapolated tracer response curves (SNL 2007, Section 6.5.5). Estimates of specific discharge were made for three assumed values of porosity, corresponding to minimum, expected, and maximum values for this parameter in the alluvium. Combinations of the four interpretation methods and the three assumed values of porosity resulted in 12 estimated values of groundwater specific discharge in the alluvium.

The interpretation methods and the assumed values of porosity used to estimate values of specific discharge are not mutually dependent. Each combination of interpretation method and porosity value is a unique, independent, and equally likely analytical outcome. The four interpretation methods are considered to be equally likely alternative models of the tracer testing results because each interpretative method uses a different, but equally valid, analytical approach. There is no reason to expect that one of the interpretation methods is more valid than any other because they are each based on the physical principles of solute transport, so they are assigned equal weights in the distribution. Similarly, the three values of porosity are considered to be representative and equally likely values in the alluvial aquifer because they span the range of estimated values of effective porosity. The minimum and maximum values of porosity were used because they are clearly possible values and needed to be included in order not to underestimate the uncertainty in specific discharge. The 12 estimated values of specific discharge are approximately identically distributed because they are equally likely outcomes. Although all of the estimated values of specific discharge are derived from the same tracer-

testing data set, each analytical estimate constitutes an independent assessment of those underlying data. Because there are significant uncertainties associated with each of the estimation methods (SNL 2007, Section G4.4), applying these estimation methods in aggregate is an appropriate approach to quantifying epistemic uncertainty in specific discharge in the alluvium.

The distribution of the 12 estimated values of specific discharge used as new information in the Bayesian updating is shown graphically in Figure 1-1. Values of specific discharge are plotted on a log scale along the x axis and cumulative probability is plotted on a normal probability scale along the y axis. A linear plot of the empirical cumulative distribution function on a graph with these axis types indicates a log-normal statistical distribution of the data. The close comparison between the 12 estimated values of specific discharge shown with the open circles and the fitted log-normal distribution shown with the solid line demonstrates that these data are approximately log-normally (and identically) distributed. The conclusion that the estimates of specific discharge are identically distributed is supported by the fact that they conform closely to a single log-normal distribution.



Source: SNL 2007, Table 6.5-5; DTN: LA0303PR831231.002, *ATC_SW_Flow_Velocity.xls*.

Figure 1-1 Cumulative Normal Probability Plot of Estimated Specific Discharge at the Alluvial Testing Complex

In summary, the 12 specific discharge estimates are independent and identically distributed random samples from an approximately log-normal distribution. As such, these data are consistent with the assumptions of the Bayesian updating method for their use as new information. Consequently, application of the Bayesian updating method, as implemented for the GWSPD parameter, is appropriate for reevaluating the uncertainty in this parameter.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

LA0303PR831231.002. Estimation of Groundwater Drift Velocity from Tracer Responses in Single-Well Tracer Tests at Alluvium Testing Complex. Submittal date: 03/18/2003.

SNL (Sandia National Laboratories) 2007. *Saturated Zone In-Situ Testing.* ANL-NBS-HS-000039 REV 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070608.0004; DOC.20070911.0001; DOC.20071018.0020; LLR.20080324.0012.

SNL 2008. *Saturated Zone Flow and Transport Model Abstraction.* MDL-NBS-HS-000021 REV 03 AD 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080107.0006; LLR.20080408.0256.

RAI: Volume 3, Chapter 2.2.1.3.8, Number 2:

Demonstrate that the GWSPD values used in the applicant's Total System Performance Assessment analysis are representative of new information derived from the Alluvial Testing Complex as well as those derived from the Expert Elicitation.

Basis: The applicant uses specific discharge estimates obtained from Alluvial Testing Complex to reduce uncertainty in the variance of a groundwater specific discharge multiplier (GWSPD). The applicant states the mean of GWSPD need not be updated because it is only a multiplier (Bechtel SAIC Company, LLC, 2008, Section 6.5.2.1[a]). However, updating the multiplier ignores the shift in the posterior mean (or median) of the specific discharge values. The median of the expert-elicited specific discharge distribution is 0.6 m/yr, whereas the median of the Alluvial Testing Complex data is 3.85 m/yr (Sandia National Laboratories, 2007a, Section 7.2.3). The applicant should demonstrate that the Total System Performance Assessment analysis adequately captures and propagates uncertainty in the specific discharge.

This information is needed to verify compliance with 10 CFR § 63.114(b), (g).

References:

Bechtel SAIC Company, LLC. "Saturated Zone Flow and Transport Model Abstraction." MDL–NBS–HS–000021. Rev. 03 AD 02. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2008.

Sandia National Laboratories. "Saturated Zone Site-Scale Flow Model." MDL–NBS–HS–000011. Rev. 03. Las Vegas, Nevada: Sandia National Laboratories. 2007a.

1. RESPONSE

This response demonstrates that the groundwater specific discharge values used in the TSPA analysis are representative of new information derived from the Alluvial Testing Complex (ATC) as well as those derived from the saturated zone expert elicitation. The uncertainty distributions in specific discharge from the saturated zone expert elicitation and from the analyses of tracer testing at the ATC represent quantitative evaluations of uncertainty at two separate and distinct locations along the flow path from beneath the repository. The saturated zone expert elicitation focused on the volcanic units beneath the repository site, while the ATC estimated groundwater specific discharge in the alluvium which is located approximately 18 km down gradient of the repository (i.e., at the approximate location of the boundary of the accessible environment). As discussed herein, specific discharge increases along the saturated zone flow path and information from the ATC cannot be used to update the mean specific discharge from the expert elicitation because of the substantial differences in flow characteristics at the two specific locations; the information is complementary and taken into account when assessing the flow path in its entirety. The approach used to update uncertainty in the GWSPD

parameter adequately captures and propagates uncertainty in the specific discharge in the TSPA analysis.

Groundwater flow rates, uncertainty in those flow rates, and their impacts on radionuclide transport in the saturated zone are implemented in the Total System Performance Assessment analysis using results from the calibrated site-scale flow model (SNL 2007b) and the GWSPD parameter (SNL 2008, Sections 6.5.2.1 and 6.5.2.1[a]). The calibrated site-scale flow model provides the spatially variable, expected values of specific discharge along the flow path from beneath the repository. The GWSPD parameter provides a normalized quantification of uncertainty in specific discharge along that flow path that is applied in the saturated zone flow and transport abstraction model and the saturated zone one-dimensional transport model (SNL 2008, Section 6.5).

The groundwater specific discharge in the saturated zone varies significantly along the flow path from beneath the repository to the boundary of the accessible environment. The configuration of the potentiometric surface (SNL 2007b, Figure 6-4) shows a flow pattern down gradient of the repository that converges toward the Fortymile Wash area shown as the blue line in Figure 6-4, suggesting that groundwater specific discharge increases along the inferred flow path from beneath Yucca Mountain. The median value of the aggregate uncertainty distribution for specific discharge in the volcanic units beneath the repository site from the saturated zone expert elicitation is 0.6 m/yr (CRWMS M&O 1998, Figure 3-2e). The median of the distribution based on the 12 estimated values of groundwater specific discharge in the alluvium at the Alluvial Testing Complex (ATC) is 3.85 m/yr (SNL 2007a, Table 6.5-5). Because the ATC is located about 18 km down gradient of the repository approximately at the boundary of the accessible environment, the difference of 0.6 to 3.85 m/yr is indicative of increasing specific discharge along the saturated zone flow path from beneath the repository. In addition, the calibrated site-scale saturated zone flow model has an expected simulated specific discharge of 0.36 m/yr in the area five kilometers down gradient of the repository and a simulated value of 11.7 m/yr at the ATC (SNL 2007b, Section 7.2.3), also indicating increasing specific discharge along the saturated zone flow path.

Uncertainty in the groundwater specific discharge in the saturated zone is quantified using the GWSPD parameter as a multiplier to specific discharge. To do this, the uncertainty distributions for the prior information from the saturated zone expert elicitation and the new information from the estimated values of specific discharge at the ATC were normalized or scaled to the median value from each of the two distributions (SNL 2008, Section 6.5.2.1[a]). The distribution of specific discharge from the saturated zone expert elicitation was normalized by dividing values in the distribution by 0.6 m/yr. The distribution of specific discharge from the tracer testing at the ATC was normalized by dividing values in the distribution by 3.85 m/yr. This approach acknowledges the expected difference in the groundwater specific discharge at the different locations along the flow path from beneath the repository and allows the application of the Bayesian updating method using the normalized uncertainty distributions from the saturated zone expert elicitation and the tracer testing at the ATC.

The expected value of specific discharge at different locations along the flow path from beneath the repository is determined by the calibration of the site-scale saturated zone flow model, which

is constrained, in part, by water-level observations in wells and simulated boundary volumetric flow rates from the Death Valley regional flow model (SNL 2007b, Section 6.5.1.2). Uncertainty in the groundwater specific discharge along that flow path is evaluated by applying the GWSPD parameter as a multiplier to all values of specific discharge (including along the flow path from beneath the repository) in the saturated zone flow and transport abstraction model (SNL 2008, Sections 6.5.2.1 and 6.5.2.1[a]). The uncertainty distributions in specific discharge for the volcanic units from the saturated zone expert elicitation and from the analyses of tracer testing at the ATC represent quantitative evaluations of uncertainty at two different locations along the flow path at which the expected values are significantly different. As such, both sources provide complementary information on the uncertainty in specific discharge along the entire flow path. However, neither of these sources supplies useful information on the expected value of specific discharge at the other location. Consequently, it would be inappropriate to use the uncertainty distribution in specific discharge from the ATC to update the mean specific discharge from the saturated zone expert elicitation. Using the expected (but spatially variable) values of specific discharge along the flow path from the calibrated site-scale saturated zone flow model and the assessments of uncertainty in specific discharge from the saturated zone expert elicitation and the ATC adequately captures and propagates uncertainty in the specific discharge to the Total System Performance Assessment analysis and demonstrates that the GWSPD value used in the TSPA represents both the median value obtained via the expert elicitation and the new median value obtained from the ATC.

It should be noted that the reference cited as “Bechtel SAIC Company, LLC, 2008” in the RAI basis text is the same document as the reference cited as “SNL 2008” in the response text.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

CRWMS M&O 1998. *Saturated Zone Flow and Transport Expert Elicitation Project*. Deliverable SL5X4AM3. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980825.0008.

SNL (Sandia National Laboratories) 2007a. *Saturated Zone In-Situ Testing.* ANL-NBS-HS-000039 REV 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070608.0004; DOC.20070911.0001; DOC.20071018.0020; LLR.20080324.0012.

SNL 2007b. *Saturated Zone Site-Scale Flow Model.* MDL-NBS-HS-000011 REV 03. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070626.0004; DOC.20071001.0013; LLR.20080408.0261; LLR.20080512.0162; DOC.20080623.0001.

SNL 2008. *Saturated Zone Flow and Transport Model Abstraction.* MDL-NBS-HS-000021 REV 03 AD 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080107.0006; LLR.20080408.0256.

RAI: Volume 3, Chapter 2.2.1.3.8, Number 3:

Demonstrate quantitatively that the calibrated site-scale flow model reproduces the upward vertical hydraulic gradient and shows the lateral continuity of the model-simulated upward hydraulic gradient.

Basis: The applicant considers the upward vertical hydraulic gradient from the Paleozoic carbonate aquifer to overlying volcanic aquifers an important barrier to radionuclide transport. The applicant states that "wells showing an upward gradient are assigned a weight of 10 because it is important to reproduce this phenomenon" (SAR Section 2.3.9.2.3.2). Only two boreholes (UE-25 p#1) and NC-EWDP-2DB penetrate the carbonate aquifers. However, neither UE-25 p#1 nor NC-EWDP-2DB is assigned a weight factor of 10 during the calibration process (Sandia National Laboratories, 2007a, Table 6-8).

1. RESPONSE

This response corrects an inconsistency in documentation in SAR Section 2.3.9.2.3.2 and a supporting document, *Saturated Zone Site-Scale Flow Model* (SNL 2007), and the site-scale saturated zone flow model (DTN: SN0612T0510106.004) concerning the weights used for several target wells in the calibration of the model. In addition, through a quantitative analysis of the model-generated hydraulic heads, the response then demonstrates that the calibrated model reproduces the upward hydraulic gradient from the carbonate aquifer to the overlying volcanic aquifer in the vicinity of the two boreholes that penetrate the carbonate aquifer (i.e., UE-25 p#1 and NC-EWDP-2DB) and over much of the flow path from underneath the repository to the accessible environment. Furthermore, a clarification is made that although the upward hydraulic gradient is a potentially important characteristic of the site-scale flow regime, it is not designated a barrier to radionuclide transport and is not relied upon for performance of the lower natural barrier. This clarification reduces the significance of uncertainty in quantification of this characteristic to the TSPA calculations.

The values for "Weight" in Table 6-8 in *Saturated Zone Site-Scale Flow Model* (SNL 2007) for UE-25 p #1 (Lwr Intrvl) and NC-EWDP-2D and NC-EWDP-2DB are not those used in the actual model calibration (DTN: SN0612T0510106.004). For UE-25 p #1 (Lwr Intrvl) the correct weight is 10, not 20, as stated in Table 6-8 of *Saturated Zone Site-Scale Flow Model* (SNL 2007). For NC-EWDP-2D and NC-EWDP-2DB the correct weights are 5 (for a total of 10), not 1. Note that NC-EWDP-2D is in the same well complex as NC-EWDP-2DB and was used to measure the upper head for the vertical hydraulic gradient. The DOE will correct *Saturated Zone Site-Scale Flow Model* (SNL 2007) to change the errors associated with Table 6-8 in that document. An explanation of the weighting is provided in Section 2.3.9.2.3.2 of SAR Rev 00 (p. 2.3.9-32) and *Saturated Zone Site-Scale Flow Model* (SNL 2007) as included in the following paragraphs.

Section 2.3.9.2.3.2 of SAR Rev 00 (p. 2.3.9-32) and *Saturated Zone Site-Scale Flow Model* (SNL 2007, p. 6-59) state:

> Wells showing an upward gradient are assigned a weight of 10 because it is important to reproduce this phenomenon (SNL 2007a, Section 6.5.1.2). If multiple calibration targets (head measurements) are available from a single well, the sum of weights from each well sum to the specified value (i.e., four measurements from USW H-1 each have weights of 7, 1, 1, and 1).

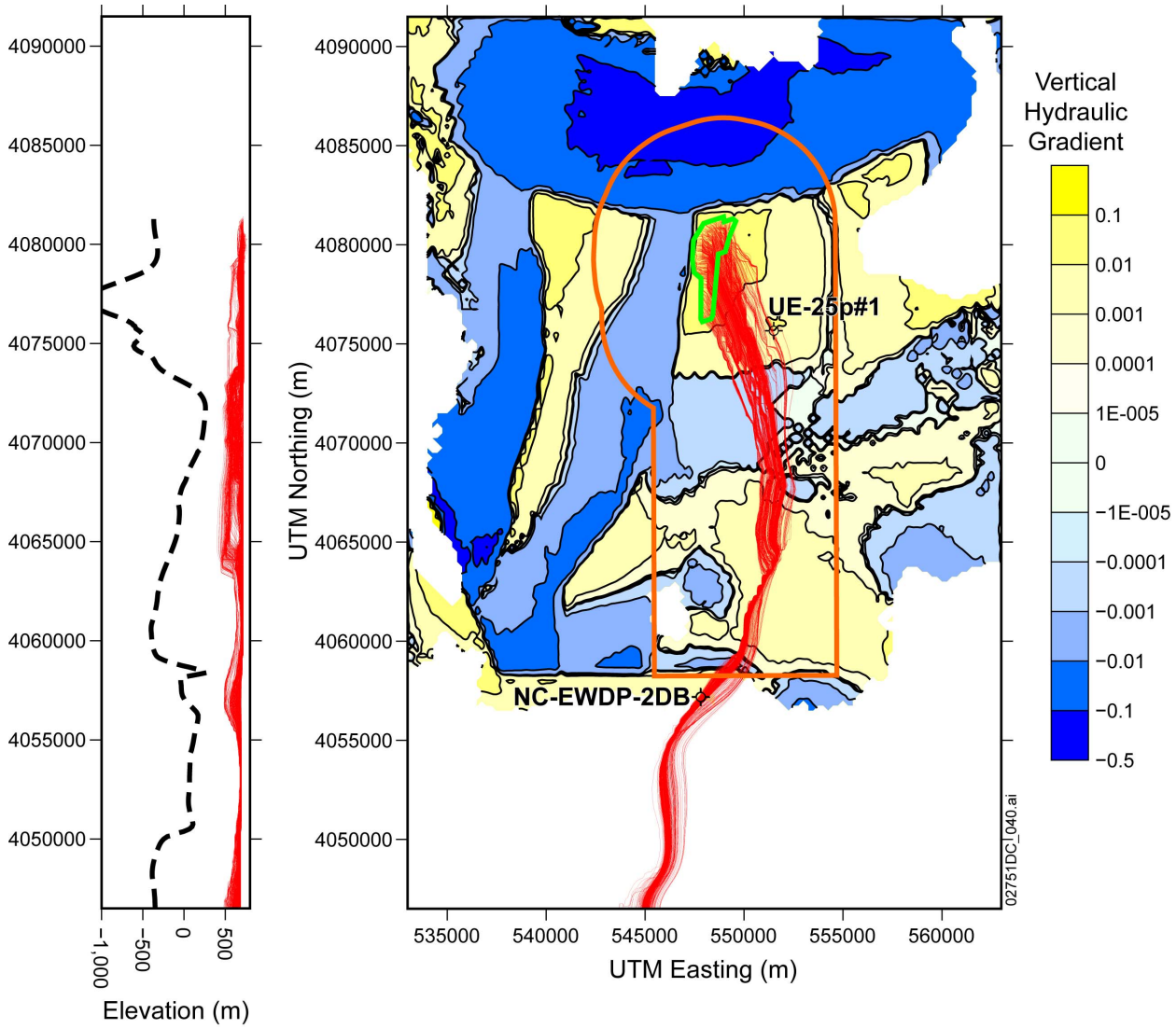
This text will be changed in both documents to:

> Well locations showing an upward gradient (e.g., UE-25 p#1) are assigned an ensemble weight of 10 to help ensure that these data points are appropriately considered in the calibrated model. If multiple calibration targets (head measurements) are available from a single well location, the weights for the individual measurements should sum to the specified value (i.e., four measurements from USW H-1 each have weights of 2.5, the two measurements for USW H-3 each have a weight of 5, NC-EWDP-2D and -2DB each have a weight of 5, and NC-EWDP-4PA and -4PB each have a weight of 5).

Thus, the weight values used in the calibration of the site-scale saturated zone flow model are consistent with license application text.

The NRC states in the basis for this RAI that, "The applicant considers the upward vertical hydraulic gradient from the Paleozoic carbonate aquifer to overlying volcanic aquifers an important barrier to radionuclide transport." While the upward vertical gradient is a potentially important characteristic of the site-scale saturated zone flow system that should be reproduced in the flow model, it is not designated as a barrier to radionuclide transport in Section 2.1 of SAR Rev 00, "System Description And Demonstration Of Multiple Barrier" and is not relied upon for performance of the lower natural barrier.

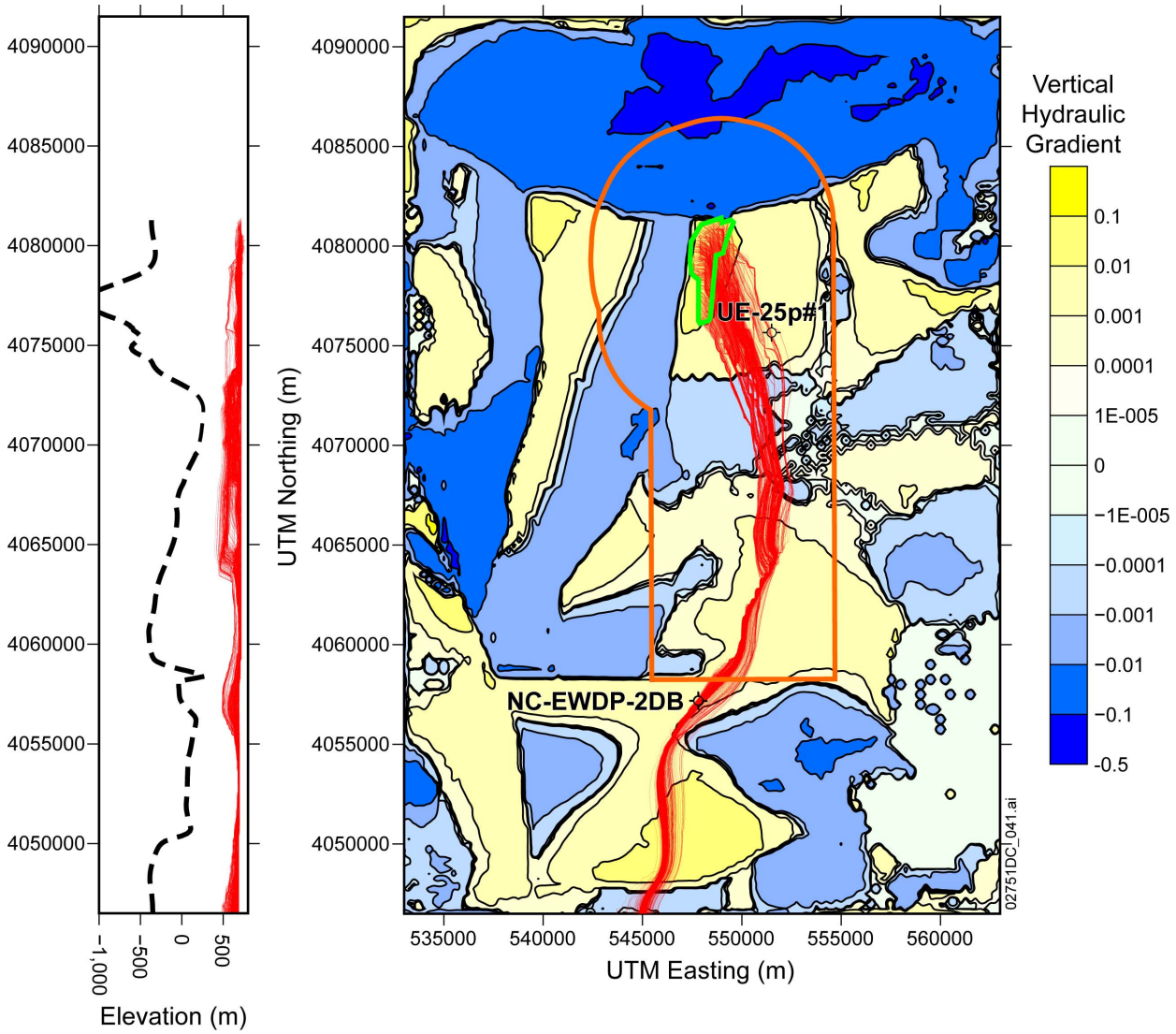
To further address this RAI, information was extracted from the site-scale saturated zone flow model to determine whether an upward vertical gradient is being reproduced in the vicinity of the wells that penetrate the carbonate aquifer. The vertical hydraulic gradient was calculated using two methods, with results illustrated in Figures 1.1 and 1.2. In Figure 1.1, the vertical hydraulic gradient was calculated using the simulated head values at the lowermost volcanic unit in the Crater Flat Group and the uppermost part of the lower carbonate-rock aquifer (LCA) or the lower carbonate-rock aquifer (thrusted) (LCA_T1). In Figure 1.2, the vertical hydraulic gradient was calculated using the simulated head values at the water table and the uppermost node in the LCA or the LCA_T1. The upper carbonate-rock aquifer (UCA) was not used to define the Paleozoic contact because it comprises only 0.12% by volume of the site-scale saturated zone flow model (SNL 2007, Table 6-5). The upper clastic-rock confining unit (UCCU) and lower clastic-rock confining unit (thrusted) (LCCU_T1) were also not included because they are confining units. In both analyses, if neither the LCA nor LCA_T1 were present in a specific location, the upper boundary of the next lower unit below the LCA was used in the hydraulic gradient calculation (i.e., the uppermost node of either the lower clastic confining unit (LCCU), the crystalline confining unit (XCU) or the intrusive confining unit (ICU)).



Source: DTNs: SN0612T0510106.004 (hydraulic heads); SN0704T0510106.008 (particle tracks).

NOTE: Positive values of vertical hydraulic gradient are for upward gradient and negative values are for downward gradient. The simulated particle paths are shown with the red lines on the map and cross section. White areas on the map correspond to locations at which the Crater Flat volcanic units have zero thickness. The dashed black line on the cross section shows the approximate upper surface of the Paleozoic units along the simulated particle paths. Green outline shows the repository footprint. The wells mentioned in the RAI are shown in black. The orange line shows the postclosure controlled area.

Figure 1.1 Map of Vertical Hydraulic Gradient between the Volcanic Units and the Top of the Paleozoic Aquifer and Cross Section of Simulated Particle Paths



Source : DTNs: SN0612T0510106.004 (hydraulic heads); SN0704T0510106.008 (particle tracks).

NOTE: Positive values of vertical hydraulic gradient are for upward gradient and negative values are for downward gradient. The simulated particle paths are shown with the red lines on the map and cross section. The dashed black line on the cross section shows the approximate upper surface of the Paleozoic units along the simulated particle paths. Green outline shows the repository footprint. The wells mentioned in the RAI are shown in black. The orange line shows the postclosure controlled area.

Figure 1.2 Map of Vertical Hydraulic Gradient between the Water Table and the Top of the Paleozoic Aquifer and Cross Section of Simulated Particle Paths

Contour maps of the vertical hydraulic gradient from the site-scale saturated zone flow model, generated as defined above, along with a cross section of simulated particle paths are shown in Figures 1.1 and 1.2. A positive value indicates an upward gradient and a negative value indicates a downward gradient. Similar patterns of upward and downward vertical gradients are shown for the two methods of calculating the vertical gradient described earlier.

The upward gradient is simulated at the locations of the wells that penetrated the carbonate aquifer, UE-25 p #1 and NC-EWDP-2DB and much of the model domain. Upward vertical hydraulic gradients are simulated to occur for several kilometers to the east and south of the repository. After crossing one area in which the vertical gradient is downward, the simulated flow paths are generally located in areas of upward vertical gradient to the boundary of the accessible environment and to the boundary of the site-scale model domain. Downward simulated gradients are noted in the area to the north of the steep hydraulic gradient in the northern part of the domain and to the west of the Solitario Canyon fault, which are located away from the predominant flow paths originating beneath the repository.

The patterns of upward and downward vertical hydraulic gradients shown in Figures 1.1 and 1.2 are consistent with the principles of regional groundwater flow, the boundary conditions for the site-scale saturated zone flow model, and the hydrogeologic framework model. Strong downward vertical gradients are simulated to occur in areas of lower permeability and greater recharge (SNL 2007, Figures 6-12 and 6-14) in the area to the north of the repository, as expected. Upward vertical gradients are simulated over much of the area to the south of Yucca Mountain, particularly along most of the inferred flow paths from beneath the repository to the south southeast and then to the south. This pattern of downward hydraulic gradients in areas of regional recharge and upward gradients further along regional flow paths is typical of large-scale regional flow systems (Freeze and Cherry 1979, Section 6.1). Several areas of simulated downward vertical gradient shown in Figures 1.1 and 1.2, such as to the west of the Solitario Canyon fault, to the east of the Bare Mountain fault, and to the north of the Highway 95 fault, occur on the upstream side of the associated low-permeability faults (SNL 2007, Figure 6-12), which act to impede horizontal groundwater flow.

The east-west zone of simulated downward hydraulic gradient along the flow path from beneath the repository (approximately at 4069000 to 4074000 m UTM northing) is associated with a relatively high upper surface of the Paleozoic units, as shown on the cross sections in Figures 1.1 and 1.2. This higher area on the Paleozoic surface consists of the thrusted LCA_T1 hydrogeologic unit (SNL 2007, Figure 6-8), which has a high calibrated value of permeability relative to the overlying volcanic hydrogeologic units (SNL 2007, Table 6-9). The higher permeability of the LCA_T1 unit provides a pathway for flow and lateral continuity with the deeper and thicker LCA unit to the south (SNL 2007, Figure 6-8), creating the moderate downward vertical hydraulic gradient in this area of the site-scale saturated zone flow model. Although there is some downward movement of simulated particle flow paths evident in this area and further to the south in the cross sections in Figures 1.1 and 1.2, this downward vertical gradient does not cause flow paths from beneath Yucca Mountain to enter the LCA_T1 or LCA units. The values of vertical hydraulic gradient plotted in the maps of Figures 1.1 and 1.2 are average values that are calculated over varying thicknesses, whereas simulated flow paths are a function of the local vertical gradients along the flow path. There are several areas of downward vertical gradients and mixed gradients in the southeastern part of the model domain shown in Figure 1.2 that are related to complexity of the hydrogeologic framework model in this area of the site-scale saturated zone flow model and the presence of the higher-permeability LCA_T1 unit.

In summary, the directions of vertical hydraulic gradient simulated by the site-scale saturated zone flow model are consistent with the observations in the wells penetrating the lower carbonate aquifer at the Yucca Mountain site, UE-25 p #1 and NC-EWDP-2DB. Although patterns of simulated vertical gradient are complex, they exhibit lateral continuity that is consistent with hydrogeologic principles, boundary conditions, and the hydrogeologic framework.

2. COMMITMENTS TO NRC

DOE commits to update the license application as described in Section 3. The change to be made to the license application will be included in a future license application update.

3. DESCRIPTION OF PROPOSED LA CHANGE

- In SAR REV 00 Section 2.3.9.2.3.2, p. 2.3.9-32, the text:

  > Wells showing an upward gradient are assigned a weight of 10 because it is important to reproduce this phenomenon (SNL 2007a, Section 6.5.1.2). If multiple calibration targets (head measurements) are available from a single well, the sum of weights from each well sum to the specified value (i.e., four measurements from USW H-1 each have weights of 7, 1, 1, and 1).

  will be replaced with:

  > Well locations showing an upward gradient (e.g., UE-25 p#1) are assigned an ensemble weight of 10 to help ensure that these data points are appropriately considered in the calibrated model. If multiple calibration targets (head measurements) are available from a single well location, the weights for the individual measurements should sum to the specified value (i.e., four measurements from USW H-1 each have weights of 2.5, the two measurements for USW H-3 each have a weight of 5, NC-EWDP-2D and -2DB each have a weight of 5, and NC-EWDP-4PA and -4PB each have a weight of 5).

4. REFERENCES

Freeze, R.A. and Cherry, J.A. 1979. *Groundwater.* Englewood Cliffs, New Jersey: Prentice-Hall. TIC: 217571.

SNL (Sandia National Laboratories) 2007. *Saturated Zone Site-Scale Flow Model.* MDL-NBS-HS-000011 REV 03. Las Vegas, Nevada: Sandia National Laboratories.
ACC: DOC.20070626.0004; DOC.20071001.0013; LLR.20080408.0261; LLR.20080512.0162; DOC.20080623.0001.

SN0612T0510106.004. Saturated Zone (SZ) Site-Scale Flow Model PEST and FEHM Files Using HFM2006. Submittal date: 01/17/2007.

SN0704T0510106.008. Flux, Head and Particle Track Output from the Qualified, Calibrated Saturated Zone (SZ) Site-Scale Flow Model. Submittal date: 05/01/2007.