ENERGY*SOLUTIONS*

March 31, 2014 CD14-0084

Mr. Helge Gabert
Project Manager, DU Contract
Utah Division of Solid and Hazardous Waste
P.O. Box 144880
Salt Lake City, UT, 84114-4880

Subject: License No: UT2300249; RML #UT 2300249 –Condition 35 Compliance Report, Revision 1; **Responses to February 2014 Round 1 Interrogatories**

Dear Mr. Gabert:

On 1 June 2011, (in compliance with Condition 35.B of its Radioactive Material License UT2300249), Energy*Solutions* submitted to the Utah Division of Radiation Control the Report, "*Utah Low-Level Radioactive Waste Disposal License (RML UT2300249) – Condition 35 Compliance Report.*" Following a reply to the Utah Department of Environmental Quality SC&A's "*Task 1: Preliminary Completeness Review*" Energy*Solutions* received Round 1 Interrogatories from the Division (dated On 28 February 2014).

In preparation of responses to the Round 1 Interrogatories, Energy*Solutions* has chosen to revise the initial design of the Federal Cell to include an evapotranspirative cover equivalent to that currently under review by the Division for construction on the Class A West Embankment. As a result, Energy*Solutions* is revising its depleted uranium Performance Assessment GoldSim model, accordingly. In parallel to reconstructing the revised GoldSim model to address the performance of the evapotranspirative cover, Energy*Solutions* has prepared the enclosed responses to the Round 1 Interrogatories of 28 February 2014. Results generated from the revised GoldSim model will be transmitted under separate cover, when completed.

In order to facilitate public access during the public review and comment period, Energy*Solutions* will provide the Division with a complete, self-contained Report with the final revised GoldSim model, responses to Preliminary Completeness Review, and responses to the Division's other rounds of Interrogatories.

It is the understanding of Energy*Solutions* that we should expect to receive any requests for further clarification in the form of limited Round 2 Interrogatories by 16 April 2014. Please contact me or Sean McCandless at 801-649-2000 if there are any comments or questions regarding this submittal.

Sincerely,

Vern C. Rogers
Environmental Manager

cc Rusty Lundberg, DRC
Don Verbica, DSHW

Enclosures

RESPONSES TO 28 FEBRUARY 2014 – ROUND 1 INTERROGATORIES
UTAH LLRW DISPOSAL LICENSE RML UT 2300249
CONDITION 35 COMPLIANCE REPORT

March 31, 2014

For
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1. INTRODUCTION

Energy*Solutions*, headquartered in Salt Lake City, Utah is a worldwide leader in the safe recycling, processing and disposal of nuclear material, providing innovations and technologies to the U.S. Department of Energy (DOE), commercial utilities, and medical and research facilities. At its Clive Facility, located 75 highway miles west of Salt Lake City, Energy*Solutions* operates a commercial treatment, storage and disposal facility for Class A low-level radioactive waste and Class A low-level mixed waste.

Historically, Energy*Solutions'* authorization for disposal of depleted uranium (DU) was approved by the Utah Division of Radiation Control at a concentration of 110,000 pCi/g beginning with License amendment 2 of Utah Radioactive Material License UT2300249, (approved December 3, 1990). This concentration was later increased to the specific activity of depleted uranium; i.e., pure form; with approval of the Performance Assessment submitted in support of the October *22,* 1998 License renewal (limiting the depleted uranium within a container to no greater than 370,000 pCi/g, upon receipt). Under this License authorization, approximately 18,400 Ci of depleted uranium were safely disposed at Clive between 1990 and 2010.

In 2010, the Utah Radiation Control Board initiated rulemaking to require a site-specific analysis before authorizing the disposal of additional large quantities of depleted uranium. This rulemaking also applies to 3,577 metric tons (5,408 drums) of uranium trioxide (DUO_3) waste received by Energy*Solutions* from the Savannah River Site (SRS) in December 2009. In compliance with the depleted uranium Performance Assessment prerequisite, Energy*Solutions* is temporarily holding these drums in storage (awaiting Director approval of this depleted uranium Performance Assessment). In the future, Energy*Solutions* is also considering disposal of significant quantities of depleted uranium from the gaseous diffusion plants at Portsmouth, Ohio and Paducah, Kentucky.

As is illustrated in Figure 1-1, Energy*Solutions* is evaluating a new Federal Cell, using an evapotranspirative cover design equivalent to that under consideration by the Division for the Class A West Embankment, as the ultimate destination for significant quantities of depleted uranium. As initially submitted in 2009, the Federal Cell was named the “Class A South” cell, with a revised application and completeness review response package dated June 9, 2009 (Energy*Solutions*, 2009). Energy*Solutions*’ records show that the Division indicated interrogatories on this design were under preparation, but not received prior to its withdrawal on May 2, 2011. The former Class A South cell included a clay isolation barrier as well as a proposed system for monitoring groundwater beneath this barrier; in order to differentiate the source of any potential groundwater contamination as being from Class A or 11e.(2) wastes. The former Class A South cell design was subjected to these additional buffer zone and monitoring requirements due to long-term stewardship being split between the State of Utah and DOE. The Federal Cell will be entirely within DOE stewardship; therefore, the additional requirements will not apply.

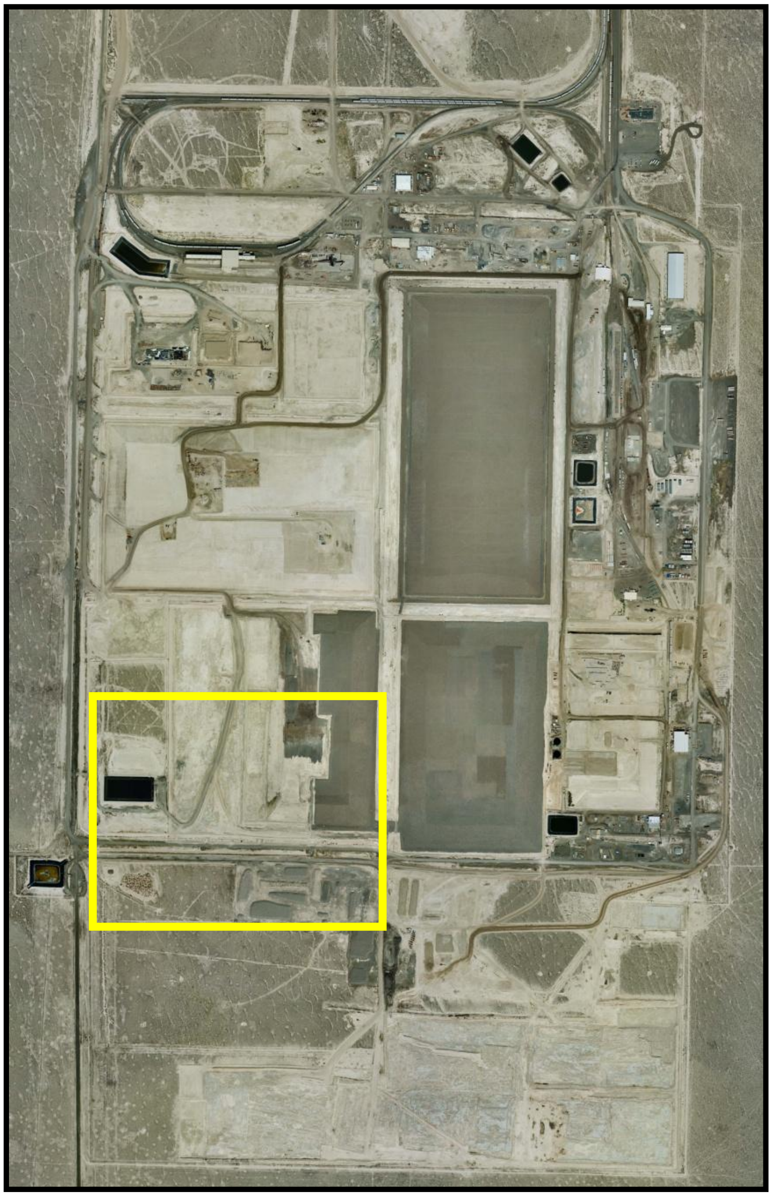

Figure 1-1, Energy*Solutions*' Proposed Federal Cell Location

On June 1, 2011, (in compliance with Condition 35.B of its Radioactive Material License UT2300249), Energy*Solutions* submitted to the Division the Report, "*Utah Low-Level Radioactive Waste Disposal License (RML UT2300249) – Condition 35 Compliance Report*," documenting the depleted uranium Performance Assessment. In response, Energy*Solutions* received on October 25, 2013 from the Utah Department of Environmental Quality "*Task 1: Preliminary Completeness Review.*" Following examination of the Preliminary Completeness Review, Energy*Solutions* submitted revision 1 of its depleted uranium Performance Assessment Report titled, "*Utah Low-Level Radioactive Waste Disposal License (RML UT2300249) – Condition 35 Compliance Report*," (Energy*Solutions*, 2013a).

On February 28, 2014, Energy*Solutions* received Round 1 Interrogatories from the Division, requesting clarification and additional information to support the Division's continued review of Energy*Solutions'* depleted uranium Performance Assessment. As a result of ongoing research Energy*Solutions* has conducted regarding cover design and in review of the Round 1 Interrogatories, Energy*Solutions* has chosen to revise the initial design of the Federal Cell to include an evapotranspirative cover equivalent to that currently under review by the Division for construction on the Class A West Embankment. As a result, Energy*Solutions* is revising its depleted uranium Performance Assessment GoldSim model, accordingly. In parallel to constructing the revised GoldSim model to address the performance of the evapotranspirative cover, Energy*Solutions* has prepared responses contained herein to the Round 1 Interrogatories of February 28, 2014.

In order to facilitate public access during the public review and comment period, Energy*Solutions* will provide the Division with a complete, self-contained Report with the final revised GoldSim model, responses to Preliminary Completeness Review, and responses to the Division's other rounds of Interrogatories.

2. RESPONSES TO 28 FEBRUARY 2014 - ROUND 1 INTERROGATORIES

Responses to the Division's Round 1 Interrogatories, requesting clarification and additional information to support the Division's continued review of Energy*Solutions'* depleted uranium Performance Assessment, are presented herein. As part of the review and response preparation for the Round 1 Interrogatories, Energy*Solutions* has revised the initial design of the Federal Cell to include an evapotranspirative cover equivalent to that currently under review by the Division for construction on the Class A West Embankment. Refer to drawing series 14004, attached. In parallel to revising GoldSim model to address the performance of the evapotranspirative cover, Energy*Solutions* responds herein to the Round 1 Interrogatories of February 28, 2014.

1. INTERROGATORY CR R313-25-19-01/1: INTERGENERATIONAL CONSEQUENCES

Please follow the policy of the U.S. Nuclear Regulatory Commission (NRC) in determining dollar values per person-rem and discount rates, or explain why that policy would not apply.

EnergySolutions' Response*:* Revised ALARA modeling is being performed that will include the NRC dollar per-person/rem value (NRC, 1995; NRC, 2004). Additionally, sensitivity to a range of reasonable discount rates is being explored as suggested in NRC (2004). The NRC (2004) guidance is being referenced in the Final Report and the text is being revised to discuss NRC policy on the subjects of dollar per-person/rem value and intergenerational consequences. A discussion of the intergenerational impacts will also be included.

2. INTERROGATORY CR R313-25-8(5)(A)-02/1: DEEP TIME

Provide further information on how the length of the deep time assessment (2.1 million years (My)) was determined.

EnergySolutions' Response*:* Radioactive decay and ingrowth in a given decay chain is calculated using the Bateman equation,

$$N_i = \lambda_1 \lambda_2 \cdots \lambda_{i-1} N_{1(0)} \sum_{j=1}^{i} \frac{e^{-\lambda_j t}}{\prod_{k \neq j} (\lambda_k - \lambda_j)},$$

Where:

- λ_i is the decay coefficient for each member *i* in the chain (where $\lambda = \ln(2)/T_{½}$, $T_{½}$ being the half-life) [T^{-1}],
- t is time [T],
- N_i is the abundance of each member *i* at time *t*, and
- $N_{1(0)}$ is the abundance of the initial parent at $t = 0$.

The starting amount of the initial parent, U-238, is arbitrary for the purposes of determining secular equilibrium, since the time at which the abundance of progeny (decay products) stops increasing is being sought. This is the time at which all progeny are at maximum abundance, which is the time of interest for deep time modeling.

The information required to perform the Bateman equation calculations is simply the identification of members of the decay chain and the half-lives for each. These data are inputs to the GoldSim Clive DU PA Model, as documented in the \Materials container. The decay chains are illustrated in the container \Materials\DecayChains, with the uranium series shown here:

Short-lived members of the chain are not modeled for contaminant transport,

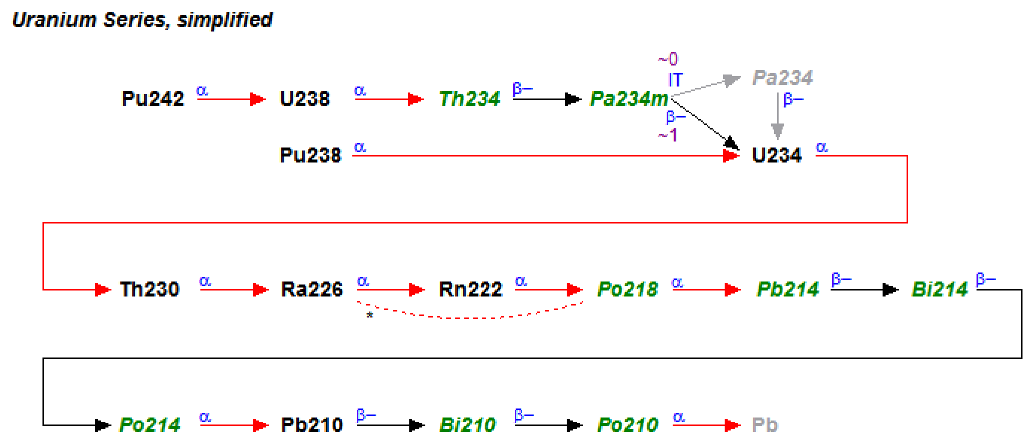

Figure 2-02/1, Uranium-238 Decay Series

however this matters not for the determination of the time of secular equilibrium. The half-lives and direct progeny for each member of the chain are implemented in the Species element, in the \Materials container, a screen shot of which is shown.

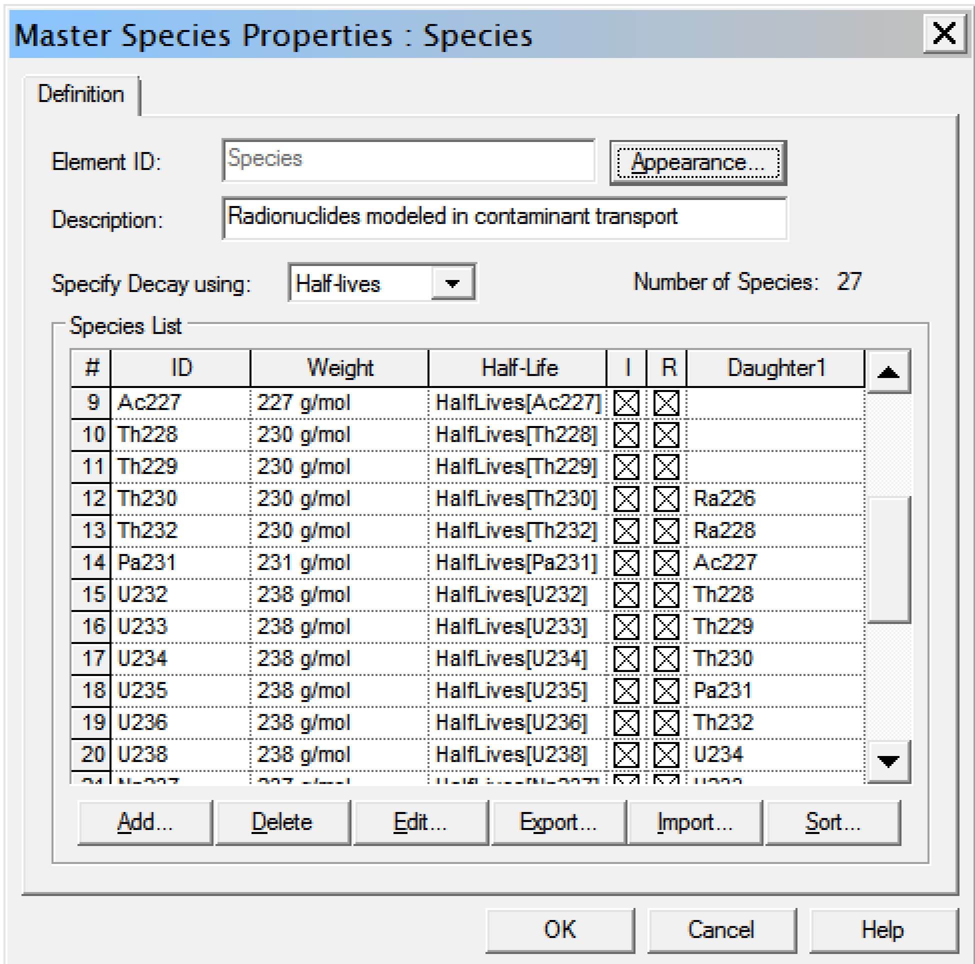

Figure 2-02/2, GoldSim \Material Screen Shot

The GoldSim software uses this information to solve the Bateman equation internally, thereby producing values for abundance of all members of the chain at any time. In order to illustrate this, a special calculation is executed in the Clive DU PA Model in the \DeepTimeScenarios container (see box on upper right part of the page in that container, labeled "A study of the decay and ingrowth from U-238"). Two result elements in that box show the abundance of all modeled radionuclides, having started with 1 g of U-238 in the "UnitInventoryU238" cell. One result element shows abundance in units of mass (g), and the other in units of activity (Ci). The latter is shown here and illustrates how all members of the chain gradually come into equilibrium with the U-238 parent. Therefore, they all achieve the same activity. Radon is the exception, due to how its E/P ratio is implemented in this model, but this has no implications for the determination of secular equilibrium.

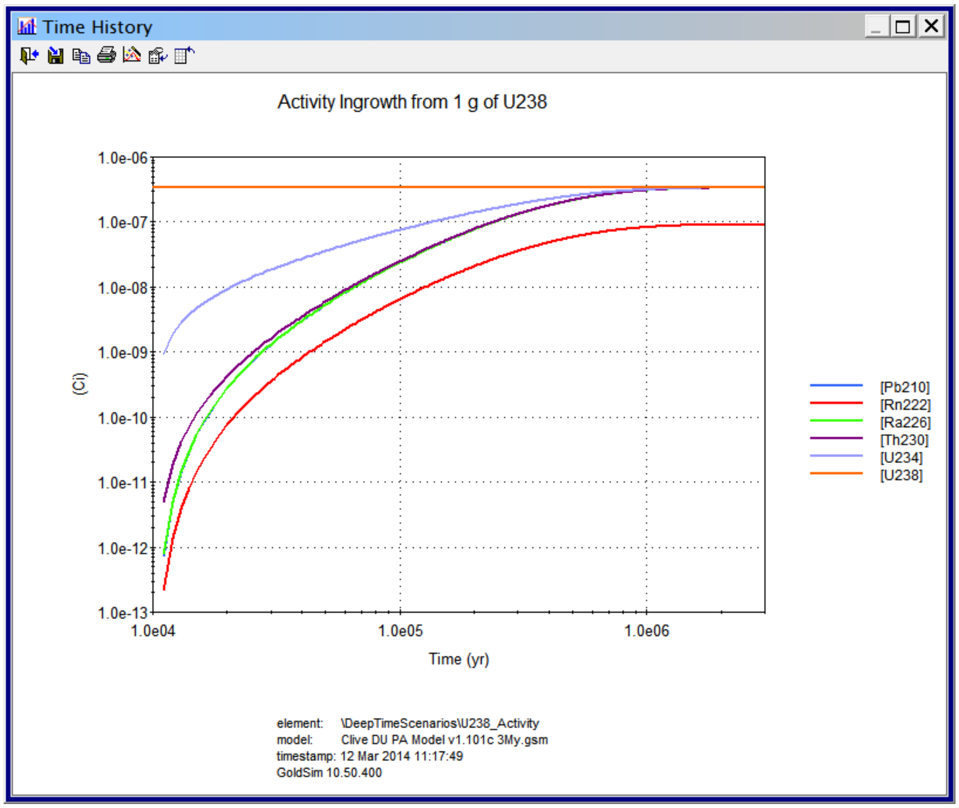

Figure 2-02/3, GoldSim \DeepTimeScenarios Screenshot

As can be seen in this graph of activity over time, secular equilibrium is reached at just over 2 My. At 2.1 My, the abundance of the last modeled member of the chain, Pb-210, is equal to that of ^{238}U, within less than one half of one percent.

While one could carry the calculation out further to achieve a greater degree of accuracy, there is no benefit in doing so for decision-making purposes. Note that for the purposes of illustration here, the model time has been extended to 3 My, as reflected in the Time axis.

The text in the FRV1 Executive Summary, page 5 is being changed as follows to reflect that the decay products reach secular equilibrium with the major parent, U-238, and further explanation is being provided along the lines presented above.

[FRV1, Executive Summary, page 5, third sentence:]

> "*Peak activity of the waste occurs when the progeny of the principal parent, ^{238}U (with a half-life that is approximately the age of the earth—over 4 billion years), reach secular equilibrium. This occurs at roughly 2.1 My from the time of isotopic separation, and the model evaluates the*

potential future of the site in this context. At 2.1 My the abundance of the last modeled member of the chain, ^{210}Pb, is equal to that of ^{238}U, within less than one half of one percent. While one could carry the calculation out further to achieve a greater degree of accuracy, there is no benefit in doing so for decision-making purposes."

3. INTERROGATORY CR R313-25-8(5)(A)-03/1: DEEP TIME – SEDIMENT AND LAKE CONCENTRATIONS

1. Explain why FRV1 does not provide any health and environmental concentration limits for future lake water or sediments for comparison.
2. Resolve discrepancies between the concentration values given in Table 14 and the concentrations shown in FRV1 Figure 13.
3. Provide the basis for presenting only the U-238 sediment concentrations (rather than the full U-238 decay series), as well as the basis for concluding that these concentrations are "small."
4. Indicate why the soil criteria in 40 CFR Part 192 should not apply to the deep time assessment.

***EnergySolutions*' *Response*:**

1. The purpose of the deep time analysis is to provide a "*qualitative analysis with simulations*". Although the intent of this requirement could be debated, calculating doses in deep time is neither required nor informative. ICRP states that "*doses and risks, as measures of health detriment, cannot be forecast with any certainty for periods beyond around several hundreds of years into the future*" (ICRP, 1998). Also, DOE (DOE 1997) has stated: ". . .*DOE recommends that quantitative assessments of collective dose to support ALARA efforts be limited to a few hundred years.*" And, the National Academy of Public Administration (NAPA), in a report for DOE (NAPA 1997), considered the "*near future*" to be 2 to 4 generations, and the "*distant future*" to be 500 to 1,000 years. Deep time analysis is interesting for gaining a sense of what might happen, but is not considered very useful for quantitative results, and based on clear guidance in the regulatory language. As noted in the interrogatory, health limits are not provided for future lake water or sediments, and this is because they are not considered useful. Environmental concentration limits are also health-based, so the same applies.

2. Discrepancies between the concentration values given in Table 14 and the concentrations shown in FRV1 Figure 13 are being resolved. The full resolution involves generation of revised Figures 12 and 13 that include the QA notes in the Figures' footers, a clarification that both these figures show the 3-m waste burial option, and a modification of values in Tables 13 and 14 to coincide with the values in the Figures. This is being addressed with the results of the next version of the GoldSim PA model.

3. The Clive DU PA Model provides concentrations for sediments and water for all modeled radionuclides, including those in the uranium decay chains. These can all be accessed from the Control Panel dashboard, by choosing the button for “Deep Time Scenarios” results. The time history graphs of concentrations show all radionuclides, not just uranium. The next version of the report includes results for these other radionuclides. Also, clarification is being provided for why the uranium concentrations are considered “small” – statements about the concentrations is being clarified with comparison to current background concentrations.

4. It is not clear why 40 CFR 192 is applicable to this Performance Assessment. However, there are at least 2 related sections of 40 CFR 192 that are considered in this response.

   § 192.00 Applicability. *This subpart applies to the control of residual radioactive material at designated processing or depository sites under section 108 of the Uranium Mill Tailings Radiation Control Act of 1978 (henceforth designated ‘‘the Act’’), and to restoration of such sites following any use of subsurface minerals under section 104(h) of the Act.*

   § 192.02 Standards. *Control of residual radioactive materials and their listed constituents shall be designed 1 to: (a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and, (b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not: (1) Exceed an average 2 release rate of 20 picocuries per square meter per second, or (2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter. (c) Provide reasonable assurance of conformance with the following groundwater protection provisions:*

   Section 192.02 indicates the applicability of 40 CFR 192, which seems to suggest it is not applicable to the DU waste, and Section 192.02 indicates that effectiveness is limited to 1,000 years. In which case, the soil criteria of 40 CRF 192 do not seem to be applicable to deep time assessment, or to the DU PA more generally.

4. INTERROGATORY CR R313-25-8(4)-04/1: REFERENCES

Ensure that links to references online are working at the time of submittal and that they do not bring users to sites that require entry of a username and passcode.

EnergySolutions' Response*:* As the current documents are now nearly three years old and numerous comments have been made that will require document revision, all online reference links in the Final Report and its appendices will be checked again before submission of the next revised draft. Please note that many of the references in the documents are copyrighted journal articles or books. It is illegal to provide these documents to those who have not paid a fee, thus links were provided to abstracts or publishers of the copyrighted works.

5. INTERROGATORY CR R313-25-7(2)-05/1: RADON BARRIER

Explain why the model does not consider the effects of a compromised radon barrier.

EnergySolutions' Response: SCWA has conducted detailed analysis demonstrating negligible degradation of the Evapotranspirative Cover's radon barrier from animal borrow and root penetration (Energy*Solutions*, 2013d). As a result of their analysis, SWCA concluded,

> "*The proposed biointrusion barrier and capillary breaks in the [Evapotranspirative] cover have been demonstrated to effectively deter or limit penetration by deep rooting plants [native to Clive] into protective [clay] layers"* (pg 45).

Similarly, SWCA's analysis concluded that the

> "*preferred [Evapotranspirative] cover design includes multiple layers of in-filled gravel and cobbles that have been demonstrated elsewhere to effectively minimize or eliminate biointrusion by small mammals [native to Clive]*," (pg. 30).

The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two orders of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

A compromised radon barrier need not be modeled at this time because the ET Cover design will limit infiltration down to the radon barrier. With no infiltration down to that level, the naturalization of the radon barrier will have no effect on performance.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of the radon barrier and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility.

Confidence in the assessment of radon barrier performance can be enhanced through sensitivity and uncertainty analyses of the models. Modeling the uncertainty in cover performance involves alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty). Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling.

There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. To provide a more comprehensive sensitivity analysis for infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

6. INTERROGATORY CR R313-25-7(2)-06/1: GULLY MODEL ASSUMPTIONS

Add a cross-reference in the Executive Summary to the discussion on gully model assumptions in the Erosion Modeling report.

EnergySolutions' Response: The editorial suggestion is noted and the Executive Summary is being revised.

7. INTERROGATORY CR R313-25-8(4)(B)-07/1: APPLICABILITY OF NRC HUMAN INTRUSION SCENARIOS

Identify the intrusion barriers in the disposal cell design and explain why typical NRC intrusion scenarios usually underestimate the performance of the disposal system and under what unusual circumstances the performance of the facility/site will not be underestimated. Evaluate other suggested scenarios in addition to the usual NRC intrusion scenarios.

<u>EnergySolutions' Response</u>: The intruder barriers of Energy*Solutions* Federal Cell are the same as its licensed Low Level Radioactive Waste Disposal Facility, which are those defined in UAC R313-25-2 as,

> "*a sufficient depth of cover over the waste that inhibits contact with waste and helps to ensure that radiation exposures to an inadvertent intruder will meet the performance objectives set forth in R313-25, or engineered structures that provide equivalent protection to the inadvertent intruder.*"

UAC R313-25-20 requires assurance of protecting individuals from the consequences of inadvertent intrusion into disposed waste. An inadvertent intruder is someone who is exposed to waste unintentionally and without realizing it is there (after loss of institutional control). This is distinct from an intentional intruder, who might be interested in deliberately disturbing the site, or extracting materials from it, or who might be driven by curiosity or scientific interest.

> "*Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.*" [UAC R313-25-20]

While an unlimited number of hypothetical inadvertent intruder scenarios could be developed, Division requirements limit such development to include, "*Identification of the known natural resources at the disposal site whose exploitation could result in inadvertent intrusion into the wastes after removal of active institutional control.*" UAC R313-25-7(8). Of similarly sentiment, NRC's Performance Assessment Working Group (PAWG) notes that,

> "*the overall intent [of exposure scenario development guidance] is to discourage excessive speculation about future events and the PAWG does not intend for analysts to model long-term transient or dynamic site conditions, or to assign probabilities to natural occurrences. . . The parameter ranges and model assumptions selected for the LLW performance assessment should be sufficient to capture the variability in natural conditions, processes, and events. . . Therefore, PAWG*

> *recommends that new site conditions that may arise directly from significant changes to existing natural conditions, processes, and events do not need to be quantified in LLW performance assessment modeling . . . With respect to human behavior, it may be assumed that current local land-use practices and other human behaviors continue unchanged throughout the duration of the analysis. For instance, it is reasonable to assume that current local well-drilling techniques and/or water use practices will be followed at all times in the future.*" (NUREG-1573).

NRC further supports the importance of selecting appropriate inadvertent intruder scenarios that reflect current practices and site environments in its guidance to Regulators reviewing performance assessments to,

> "*[1] verify that conceptual models for the biosphere include consistent and defensible assumptions based on regional practices and characteristics (i.e., conditions known to exist or expected to exist at the site or surrounding region); [2] verify that intermediate results (e.g., fluxes, travel times) are physically reasonable;. . . [3] evaluate the types of scenarios . . . considered in the intruder analysis and confirm that the scenarios considered are appropriate for the site; [4]verify that assumptions and parameters used in defining the exposed intruder, including location and behavior of the intruder, timing of the intrusion, and exposure pathways, are consistent with the current regional practices [emphasis added]; and [5] if a garden is assumed in the scenario [implying it is not always required], verify that the garden size is appropriate and consistent with regional practices*" NRC (2007).

Traditional generic exposure scenarios evaluating potential inadvertent intruder doses (in compliance with UAC R313-25-20) are described in NRC's draft Environmental Impact Statement supporting 10 CFR 61 (NRC 1981) and the Update of Part 61 Impacts Analysis Methodology (NRC 1986). The methodology described therein includes evaluation of exposure pathways within a group of four inadvertent intruder scenarios including intruder discovery, intruder drilling, intruder construction, and intruder agriculture. These inadvertent intrusion scenarios represent a potential series of events that are initiated by the successful completion of a water supply well. However, NRC further notes that,

> "*it would be unreasonable to expect the inadvertent intruder to initiate housing construction at a comparatively isolated location before assuring that water for home and garden use will be available. Thus, this scenario (intruder-driller) is assumed to precede the following three scenarios*" (NRC, 1986).

The intruder-drilling scenario is assumed to be an initiating event for the intruder-construction and intruder-agriculture scenarios (NRC 1986, Section 4.1.1.1). This scenario assumes that waste is brought to the ground surface in a mixture with cover material, unsaturated zone material, and drilling mud and is then contained in a mud pit used by the driller. The driller (a separate individual from that in any subsequent exposure scenario) may be exposed by direct gamma radiation from the waste mixture in the mud pit (NRC, 1986). Attributes of this scenario such as the dimensions of the mud pit and depth of water above the cuttings are described in Section 4.2.1 of NRC (1986).

The intruder-discovery scenario described in Section 4.2.3 of NRC (1981) involves external exposure to discoverable wastes that are clearly distinguishable from natural materials. The dose assessment methodology described in NRC (1981) was updated in NUREG/CR-4370 (NRC, 1986). Exposure to the intruder-discoverer is assumed to be limited to the topmost waste layer, since the intruder "*would likely stop excavating before digging too deep into the rest of the waste*" (NRC 1986, Section 4.2.3). The intruder-discovery scenario for stable waste streams in the first 500 years after closure is assumed to preempt the intruder-agriculture scenario (and, presumably, the intruder-construction scenario) because construction and inhabitation of a home will not occur once the waste has been discovered and recognized (NRC 1986, Section 4.2.3).

The intruder-construction scenario involves direct intrusion into disposed wastes for activities associated with the construction of a house {(e.g., installing utilities, excavating basements, and similar activities [as described in Section 4.2.2 of NRC (1986)]}. However, because there is no historic evidence of prior residential construction at the Clive site, the extreme salinity of Clive's soils, the non-potable groundwater, the severe lack of irrigation sources, and the inadequacy of precipitation to support agriculture, the inadvertent intruder-construction scenario is not considered "*reasonable*" for the Clive site nor included in this updated site-specific Performance Assessment.

The intruder-agriculture scenario assumes an individual is living in the home built under the intruder-construction scenario, and is also exposed from gardening activities involving the waste/soil mixture excavated during construction (NRC 1986, Section 4.2.4). As with the inadvertent intruder-construction scenario, the lack of historic evidence of prior residential agriculture at the Clive site, the extreme salinity of Clive's soils, the non-potable groundwater, the severe lack of irrigation sources, and the inadequacy of precipitation to support agriculture, the inadvertent intruder-agriculture scenario is not considered "*reasonable*" for the Clive site nor included in this Report's site-specific Performance Assessment.

As part of an unrelated investigation, NRC staff specifically asked the Division to "*provide further information on its position that the onsite residential and* *agricultural intruder pathways for the [EnergySolutions] site are unrealistic.*" In response, Division staff:

> "*stated that onsite residential and/or farming scenarios at the [EnergySolutions] facility are unrealistic for several reasons. First, the site conditions of low precipitation (i.e., approximately 5-6 inches/year) and high evapotranspiration rates (i.e., approximately 40 - 50 inches/year). Also, there is a lack of suitable irrigation water . . . and the soil is extremely saline. Secondly, Tooele County has designated this part of the county as Heavy Industry and Hazardous Waste Zones which bars any such residential and/or farming uses*" (NRC, 2005).

The Division's judgment of the unrealistic nature of farming or residential intruder scenarios is consistent with the requirements of UAC R313-25-7(8).

As a groundwater quality standard, non-degradation has been demonstrated using groundwater protection levels based on a potential dose of 4 mrem/year. In establishing this standard, certain assumptions were made regarding human consumption. For highly saline sources of groundwater, the consideration of untreated consumption in evaluating health protection determinations can be particularly critical and is consistent with the discretion described in NUREG-1573. Consequently, for performance assessment purposes, considering site-specific data regarding groundwater quality, uses, and reasonable receptor pathways is an appropriate approach and is consistent with prior and current performance assessment approvals for the facility.

A similar memorandum to Staff by the U.S. Nuclear Regulatory Commission encourages that "*the proposed rule should clearly indicate that the intruder assessment should be based on intrusion scenarios that are realistic and consistent with expected activities in and around the disposal site at the time of site closure.*" (SECY-13-075).

The Division's clarifications are also consistent with NUREG-1573,

> "*Consideration given to the issue of evaluating site conditions that may arise from changes in climate or the influences of human behavior [beyond what is currently evident at the site] should be limited so as to avoid unnecessary speculation.*" (NUREG-1573, October 2000, p. 3-10).

Archeological surveys of the Clive area performed in 1981 support this determination, (Energy*Solutions*, 2013c). This survey found no evidence of long-term residential or agricultural resource sites. A similar cultural and archaeological resource survey was conducted in 2001 on a land adjacent south to Section 32 (Energy*Solutions*, 2013c). In addition to the new survey, Sagebrush's

(2001) report also summarized five additional cultural resource inventories performed within a mile of the subject area, between the original 1981 and 2001 studies. In all surveys, Sagebrush reported no paleontological, prehistoric, or historic resources were discovered in the survey area. In fact, no evidence has been discovered that suggests the Clive facility has ever been inhabited or developed for agriculture by permanent residents in the past (probably due to unfavorable conditions for human habitation).

In compliance with UAC R313-25-20 and Division directive, Energy*Solutions* has included credible inadvertent intrusion scenarios in this Performance Assessment. However, since (1) Clive's groundwater is not potable and will not support a residence or agriculture, (2) the expense of treating Clive's groundwater with conventional technologies as well as low aquifer yield is preventing current industrial occupants from using such treatment; (3) Clive's geology holds no mineral resources of value, and (4) Clive's current practices and county-zoning limit use of the area to only ranching and periodic recreational uses, the Depleted Uranium Performance Assessment includes scenarios of inadvertent intrusion reflecting current conditions surrounding the site (as documented in Appendices 1 and 2). Therefore, incorporation of additional inadvertent intruder scenarios is unsupported.

8. INTERROGATORY CR R313-25-8(4)(A)-08/1: GROUNDWATER CONCENTRATION ENDPOINTS

Explain why six different models are considered for the dose and groundwater concentration endpoints rather than three.

EnergySolutions' Response: The six different dose and concentration endpoints referenced in the Executive Summary are:

1) depleted uranium waste below 3m of other material and no gullies modeled,
2) depleted uranium waste below 3m of other material and gullies modeled,
3) depleted uranium waste below 5m of other material and no gullies modeled,
4) depleted uranium waste below 5m of other material and gullies modeled,
5) depleted uranium waste below 10m of other material and no gullies modeled, and
6) depleted uranium waste below 10m of other material and gullies modeled.

These six variations of the model were run to capture the differences between the disposal depths (top of waste at 3, 5, and 10 m bgs), as well as the presence or absence of gullies, again for the three disposal depths. This results in a matrix of disposal depths (3) times gully state (2), making 6 cases.

The text is being modified as follows to clarify this distinction:

[end of paragraph following numbered bullets on page 6 of the FRV1]

> *"Consequently, six different models are considered for the dose endpoints. Dose results for ranch workers are presented in Tables ES-1 (without gullies) and ES-2 (with gullies). Doses to ranch workers are more than an order of magnitude greater than doses to hunters and OHV enthusiasts. Groundwater results for 99Tc in Table ES-3, and are not affected by the presence or absence of gullies in the Clive DU PA Model v1.0.*"

9. INTERROGATORY CR R313-25-19-09/1: DEFINITION OF ALARA

Change the citation for the definition of ALARA from 10 CFR 61.42 to 10 CFR 20.1003.

***EnergySolutions' Response*:** Section 1.3 of FRV1 is being revised as indicated. This change is being made in the final version of the report. The reference to 10 CFR 61.42 is being maintained for traceability from Utah code through 10 CFR 61 to the original NRC definition, and the text is being changed to reflect that the original ALARA definition is contained in 10 CFR 20.1003.

10. INTERROGATORY CR R313-22-32(2)-10/1: EFFECT OF BIOLOGICALS ON RADIONUCLIDE TRANSPORT

Provide support for the statement that the severity of the *"…effect* [of plants, ants, and burrowing mammals] *on radionuclides transport might be small."*

EnergySolutions' Response*:* The intent of this statement is to point out that the effects of biologically-induced transport would be expected to be less for deeply-buried waste than for shallower waste. This occurs because plant roots and animal burrows are most concentrated at the ground surface, and gradually lessen as a function of depth, therefore their influence in the realm of contaminant transport also decreases with depth. In the Clive DU PA Model v1.0 biotic effects are not linked to gully formation.

The text in FRV1 Section 4.1.2.8 is being modified as follows to clarify the concept that more deeply-buried waste is being subject to less biotically-induced contaminant transport than wastes that are buried closer to the surface.

[modified text for Section 4.1.2.8, p. 32 in FRV1]

> **4.1.2.8 Biologically-Induced Contaminant Transport**
>
> "*Biological organisms play an important role in soil mixing processes, and therefore are potentially important mediators of transport of buried wastes from deeper layers to shallower layers or the soil surface. Three*

broad categories are evaluated for their potential effect on the redistribution of radionuclides at the Clive facility: plants, ants, and burrowing mammals. The impact of these flora and fauna will be limited largely to the top several meters, as their potential influence as contaminant transport mechanisms is greater in the cover layers than in the underlying waste, although contaminant concentrations are lower in the cover layers. Details for all three categories can be found in the Biological Modeling white paper (Appendix 9)."

11. INTERROGATORY CR R313-25-20-11/1: INADVERTENT HUMAN INTRUDER

Ensure that the text correctly reflects the language of UAC R313-25-20.

EnergySolutions' Response: Section 4.1.2.10.1 of FRV1 is being revised as requested and Section 5.1.7 is being referenced to clarify the interpretation of the UAC R313-25-20 definition.

Please refer to Section 5.1.7 of the Final Report where the definition of IHI as specifically applied in the PA is described:

> *"Inadvertent intrusion is often used in terms of direct but inadvertent access to the waste (e.g. through well drilling or basement construction), for which the initiator is exposed. However, such direct activities are unlikely at this site. The types of activities here do not result in direct exposure to the waste by the initiator, but potentially to future receptors."*

12. INTERROGATORY CR R313-25-20-12/1: SELECTION OF INTRUSION SCENARIOS

Address inadvertent human intruder exposure scenarios that are likely to result in the greatest doses to members of the public.

EnergySolutions' Response: As explained in the response to Interrogatory CR R313-25-8(4)(B)-07/1, likelihood of maximum dose is not a criterion for inadvertent intruder scenario selection within the Depleted Uranium Performance Assessment.

13. INTERROGATORY CR R313-25-7-13/1: REFERENCE FOR LONG-TERM CLIMATIC CYCLES

Provide a reference for the statement about the likelihood of long-term climatic cycles of 100 thousand years (ky).

***EnergySolutions*' *Response**: The following references are being included in the text to support the statement, "*Given that long-term climatic cycles of 100 ky are considered very likely….*"

Hays, J.D., J. Imbrie, and N.J. Shackleton, 1976, Variations in the Earth's orbit; Pacemaker of the Ice Ages, Science, Vol. 194, No. 4270, pp. 1121-1132. (see p. 1126.)

Shackleton, N.J., 2000, The 100,000-year Ice-Age cycle identified and found to lag temperature, carbon dioxide, and orbital eccentricity, Science, Vol. 289(5486), pp. 1897-1902.

14. INTERROGATORY CR R313-25-8(4)(D)-14/1: SEDIMENT MIXING

Clarify the statement *"probably leads to conservative results"* to indicate those cases in which conservative results would not be obtained.

***EnergySolutions*' *Response**: As described in *Deep Time Assessment for the Clive DU PA*, May 30, 2011, the sources of sediment from the formation and presence of lakes are sediments resulting from precipitation/biological processes and sediment that is mechanically and chemically eroded and transported; the majority of the lake sediment will originate from erosional processes during transgressive and regressive lake fluctuations near the elevation of the Clive site.

In the conceptual model for future lakes, the return of a large lake disperses the contents of the waste embankment through wave action. The model assumes that the waste is fully mixed with the accumulated sediment during each lake cycle (intermediate and deep lakes). This assumption is considered conservative because it leads to the highest concentrations of waste in the near-surface sediments in the first new lake with continual remixing of waste/sediment in successive lake cycles. Assuming burial of some fraction of the waste by future lake sediment would be a less conservative assumption.

The extent of mixing of previous sediment with new sediment is not understood, hence an assumption that the sediments completely mix is conservative, since it retains some of the waste near the surface rather than burying all of it under the successive cycles of lake sedimentation.

In addition, sediment mixing was associated here with lake cycles. However, the system is aggrading from windblown deposition. No credit was taken for covering the waste site with windblown deposition. Instead, an assumption was made that all forms of sedimentation would be fully mixed with the DU waste. This seems quite conservative considering the site will be covered by rounds of windblown deposition during non-lake periods, which is expected to be quite long for this current 100k-yr cycle. Recent literature indicates that the conditions are not conducive for development of a lake at Clive in this cycle, in which case the site will be under windblown sediment before a lake comes back.

15. INTERROGATORY CR R317-6-6.3(Q)-15/1: URANIUM CHEMICAL TOXICITY

Provide the spatial compliance points for uranium chemical toxicity.

EnergySolutions*' *Response: Ingestion of groundwater at the Clive site is not identified as a potential exposure pathway, so dose and risk from uranium toxicity are not evaluated for this pathway, and there are no GW compliance points for uranium toxicity. In addition, naturally occurring uranium concentration in shallow groundwater exceed EPA MCLs with or without the disposal of DU.

16. INTERROGATORY CR R313-25-8(4)(A)-16/1: RADON PRODUCTION AND BURROWING ANIMALS

Discuss the relationship between burrowing animals in the cover system and the radon escape/production ratio, if any. Provide the values used in the Conceptual Site Model with regard to the waste form, porosity, and surface area and escape/production ratios for both the Savannah River Site (SRS) and gaseous diffusion plant (GDP) waste sources of DU.

EnergySolutions*' *Response: There is no relationship between the radon E/P ratio and animal burrowing. The E/P ratio defines the fraction of radon (Rn-222) produced by alpha decay of Ra-226 that "escapes" from a solid form (e.g. a crystalline matrix) into a location where the radon can freely migrate away. This would be into interstitial air or water adjacent to the solid in which the ^{226}Ra was present. This has no relationship to the distance from waste to the ground surface, as it represents phenomena on the scale of millimeters.

The input distribution used for the E/P ratio is defined in the Clive DU PA Model v1.0 element \Processes\AirTransport\EPRatio_Radon, and is tabulated in the Model Parameters document (Clive PA Model Parameters.pdf), Table 5.1, p. 18. This E/P ratio distribution is used for all materials in the model.

17. INTERROGATORY CR R317-6-6.3(Q)-17/1: URANIUM PARENTS

Clarify the reference to "*uranium parents.*"

EnergySolutions' Response: Uranium hazard quotient is tied directly to uranium, and no other radionuclides except parent nuclides which decay to uranium will influence this endpoint.

Only parents of uranium could affect the concentrations of uranium. The presence of uranium progeny and other radionuclides not related to uranium is irrelevant. The text is being modified as follows to clarify this.

[Section 6.3.2, page 71, second paragraph, first sentence:]

> "*The uranium hazard quotient is tied directly to uranium, and no other radionuclides except parents of U, including Am, Pu, and Np, which occur only in relatively insignificant quantities, could influence this endpoint.*"

18. INTERROGATORY CR R313-25-8(5)(A)-18/1: SEDIMENT ACCUMULATION

Resolve the discrepancy between the values for sediment accumulation cited in FRV1 and the Deep Time Assessment report.

EnergySolutions' Response*:* There is no discrepancy, but further clarification is being made.

The sedimentation rate of 17 meters per 100 ky discussed in FRV1, Section 6.5, page 78 refers to the rate of total sediment accumulation which includes both aerial deposition and lake sedimentation. The sedimentation rate of 120 millimeters/ky (12 meters per 100 ky) discussed in Section 6.3, page 24 of the Deep Time Assessment report refers to the sedimentation rate for deep lakes only. The text is being revised to provide clarification.

Note that the sedimentation rates for aerial deposition were not used in the model prior to the formation of the first intermediate or deep lake; instead an assumption was made that the next lake would destroy the disposal mound. See the responses to Interrogatories 129 and 131 for a discussion of uncertainty in lake erosion and the use of analog studies in the Lake Bonneville basin to constrain the depth of lake erosion.

However, recent research suggests that it is unlikely that a lake will inundate Clive in the current 100ky glacial cycle. The higher levels of CO_2 in the atmosphere coupled with the expected insolation levels make it very unlikely that a large lake can form (see response to Interrogatory # 123). Aeolian sedimentation rates at Clive are expected to be between 0.1 and 3 mm/yr during the current inter-pluvial period based on analogue measurements at dry pluvial lake sites throughout the world and in the arid SW United States. Based on these data, the total thickness of aeolian deposits could be 5 m or greater if the current inter-glacial lasts for 50 ky; the embankment could be completely covered if the first lake does not occur for 150 ka, which would be the case if there is no large lake in the next glacial cycle. The conservative assumption of complete erosion of the embankment with mixing of DU inventory becomes unlikely given the combination of partial to complete burial of the Clive site by aeolian deposition and more realistic assumptions of lake erosion.

Note that the historical record provided in the subject report (FRV1) indicates that not all glacial cycles produce large lakes. Given current conditions, it seems reasonable that a large lake will not occur in this glacial cycle.

The deep time model is being updated to address sediment mixing, and further research is being performed to quantify aeolian deposition rates to better support the deep time modeling.

19. INTERROGATORY CR R313-25-8(5)(A)-19/1: REFERENCE FOR SEDIMENT CORE RECORDS

Provide a reference from technical peer-reviewed literature for the sediment core records.

<u>EnergySolutions' Response</u>*:* As is addressed in detail in Sections 3.1 through 3.3 of Appendix 13, Deep Time Assessment – references to the evaluation of sediment cores can be found in:

- Oviatt, C. G., Thompson, R. S., Kauffman, D. S., Bright, J., and R. M. Forester, 1999. Reinterpretation of the Burmester core, Bonneville Basin, Utah. Quaternary Research, 52: 180-184.

Evidence of significant mixing of sediment is seen in sediment core records and an analysis of a pit wall at the Clive site. Sediment core evidence can be found in an analysis of the Burmester core (Eardley et al., 1973, and, Oviatt et al., 1999) and the Knolls core (Appendix B of the Deep Time Assessment Report; C.G. Oviatt, unpublished data). The pit wall analysis can be found in Appendix B of the Deep Time Assessment Report (C.G. Oviatt, unpublished data). Neither the pit wall nor the Knolls core data have been published previously.

20. INTERROGATORY CR R317-6-2.1-20/1: GROUNDWATER CONCENTRATIONS

Explain why groundwater concentrations are not identical with and without the formation of gullies in the cover system.

<u>EnergySolutions' Response:</u> As is noted in Section 7.1 of Appendix A of the Report, "*once gullies are involved, the doses increase (groundwater concentrations do not change noticeably).*" Since proximity to waste dominates projected doses, the thinning of the cover due to gullies and the possibility of bringing waste to the surface increases the resulting doses. Additionally, the addition of gullies also results in local changes to the cover system. However, when modeled across the entire Federal Cell cover, minor local changes in infiltration result in extremely minor variations in point-of-compliance groundwater concentrations.

The groundwater concentrations are not related to the presence/absence of gullies in the Clive DU PA Model v1.0. The text is being modified as follows for clarity.

[Section 7.1, p. 83, fourth paragraph of section, first sentence:]

> "*Once gullies are involved, the doses increase (groundwater concentrations do not change).*"

21. INTERROGATORY CR R313-25-8(4)(D)-21/1: INFILTRATION RATES

Explain why infiltration rates may be overestimated.

***EnergySolutions' Response**:* This discussion is already included in Section 4.1.2.4.1 where it states the following:

> "*Comparisons of HELP modeling results with results from mechanistic unsaturated zone modeling programs such as UNSAT-H and HYDRUS at arid and semi-arid sites suggest that the HELP model will generally overestimate the vertical flow rates through waste cell covers (Meyer et al. 1996, Khire et al. 1997, Albright et al. 2002). These model comparisons indicate that the vertical flow rates through the CAS cell calculated using the HELP model are likely to be overestimated in the PA Model*."

Text on page 85 is being changed. Original text: "*Infiltration rates might be overestimated, and 99Tc inventory concentrations might be overestimated*." New text: "*Infiltration rates might be overestimated (refer to Section 4.1.2.4.1), and 99Tc inventory concentrations might be overestimated.*"

22. INTERROGATORY CR R313-25-7-22/1: DEFINITION OF FEPS

Clarify the distinction between *"features, events, and processes"* (FEPs) and *"technical performance objectives."*

***EnergySolutions' Response**:* The list in Section 4.1.1 is intended to be a list of objectives, not FEPs. These objectives were erroneously referred to as FEPs in the text. The text "*The types of FEPs mentioned in 10 CFR 61 include*:" is being revised to "*The types of objectives mentioned in 10 CFR 61 include*:" Further, the bullet item "*releases of radionuclides via pathways in air, water, surface water, plant uptake, or exhumation by burrowing animals,*" is being revised to "*limitation of releases of radionuclides via pathways in air, water, surface water, plant uptake, or exhumation by burrowing animals*,".

The list in Section 4.1.2 was derived from Utah Administrative Code (UAC) Rules 313-25-8 and provides a summary of the performance objectives of R313-25. For clarification the text in Section 4.1.2, "*Notable technical performance objectives of near-surface disposal sites established of UAC Rule R313-25 include:*" is being revised to "*Notable performance objectives of near-surface disposal sites established of UAC Rule R313-25 include*:".

23. INTERROGATORY CR R313-25-7(2)-23/1: CANISTER DEGRADATION AND CORROSION

Provide a specific cross-reference to the evaluation of canister degradation and corrosion in the Conceptual Site Model.

EnergySolutions' Response*:* Although canister degradation and corrosion were identified as applicable FEPs, the Clive DU PA Model takes no credit for either. Instead, it is assumed that waste packages, including the 48 Y DU cylinders, provide no containment of the DU waste, and that it is all immediately available for environmental transport. This is discussed in Section 8.1 of the Conceptual Site Model Report. A cross-reference is being provided back to the FEP Analysis report in the final version.

24. INTERROGATORY CR R313-15-101(1)-24/1: UTAH REGULATIONS

Frame the discussion in the context of the governing Utah rule and correct errors in quoting Utah rules.

EnergySolutions' Response: Governing Utah rules (i.e., UAC R313-25-8(5)(a)) are being cited in addition to NRC rules in sections 1, 1.3, and 4.2.1 of the Conceptual Site Model and these corrections are also being made in Section 1.3 of FRV1.

25. INTERROGATORY CR R313-25-7(9)-25/1: DISPOSITION OF CONTAMINANTS IN UF6

Provide a reference for the discussion of the results occurring when contaminated uranium hexafluoride (UF_6) is introduced to the cascade.

EnergySolutions' Response*:* The text is being changed as follows to reflect that only some of the contaminants end up in the U-238 tails. This is clearly the case, as radiochemical analysis has identified their presence in the DUF_6 (Hightower et al. 2000). The cause of their presence in the DUF_6 is not particularly relevant. What is relevant is that it is found there.

[section 6, page 22, last sentence (before section 6.1):]

> "*If uranium hexafluoride derived from irradiated reactor returns is introduced to the cascade, some of the associated fission products and actinides migrate to the depleted end of the cascade, with the U-238. Some contaminants also remain fixed to the inside walls of the DU feed cylinders, which are reused for collecting tails. These "heels" will remain in the cylinders through the process of deconversion, since they are again reused for collecting the U_3O_8 product.*"

26. INTERROGATORY CR R313-25-8(4)(A)-26/1: RADON DIFFUSION IN THE UNSATURATED ZONE

Clarify whether diffusion of radon in the air phase in the unsaturated zone is included in the PA model. If it is not, justify why its omission is protective of human health and the environment. Also, describe and justify what site-specific investigation was performed at Clive to determine the applicable air phase tortuosity model.

EnergySolutions' Response*:* The text in Section 6.6, page 26, of the Conceptual Site Model white paper is being modified as shown below to clarify that the transport of radon in the saturated and in the unsaturated zone from the waste to the ground surface is included in the PA model, resolving the apparent inconsistency.

[section 6.6, second sentence, second paragraph:]

> "*The transport of radon in the saturated zone and in the unsaturated zone from the waste to the ground surface is included in the PA model."*

No site-specific investigation of air phase tortuosity was performed, since no laboratory is offering to conduct radon diffusion measurements since the shut-down of Kirk Nielson's lab (personal communication, Kirk Nielson to John Tauxe). The analysis is therefore dependent on models proposed in the literature.

27. INTERROGATORY CR R313-25-8(4)(A)-27/1: DIFFUSION PATHWAY MODELING

Clarify how the PA model accounts for the impact of diffusion pathways.

EnergySolutions' Response*:* Indeed the Clive DU PA Model v1.0 does not model the effects of cracks, fissures, animal burrows, and plant roots on diffusive contaminant transport. The text is being modified as follows to clarify this.

[Conceptual Site Model report , Section 7.1.3.1, page 28, first paragraph:]

> *"Contaminants released from the waste (or generated by decay of parents in any location) may be transported via the air pathway by migration of gaseous species through soil pore space. Over time, cracks, fissures, animal burrows, and plant roots can also provide preferential pathways that reduce the effectiveness of the engineered barrier. These effects are difficult to quantify and are not modeled in the Clive DU PA Model v1.0. Efforts at quantification could be included as part of future cover modeling as part of PA maintenance."*

28. INTERROGATORY CR R313-25-8(4)(A)-28/1: BIOTURBATION EFFECTS AND CONSEQUENCES

Provide references to support the statement that bioturbation and homogenization of the radon barriers will probably occur very slowly relative to the 10,000-year time frame for the PA, and address other effects and consequences of biointrusion and bioturbation.

Energy*Solutions'* Response: Detailed analysis conducted by SCWA demonstrating negligible degradation of the Evapotranspirative Cover's radon barrier from animal borrow and root penetration has previously been conducted (Appendix C of Energy*Solutions*, 2013d). As a result of their analysis, SWCA concluded,

> "*The proposed biointrusion barrier and capillary breaks in the [Evapotranspirative] cover have been demonstrated to effectively deter or limit penetration by deep rooting plants [native to Clive] into protective [clay] layers"* (pg 45).

Similarly, SWCA's analysis concluded that the

> "*preferred [Evapotranspirative] cover design includes multiple layers of in-filled gravel and cobbles that have been demonstrated elsewhere to effectively minimize or eliminate biointrusion by small mammals [native to Clive]*," (pg. 30).

The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

Text in the Compliance Report will be revised to remove reference to jackrabbits in the discussion of burrowing mammals. The current PA model evaluates mammals burrowing to a depth of 2 m based on the likely average vertical extent of multiple badger excavations (Kennedy et. al, 1985). The distribution of mammal burrow density used in the current PA model is based on actual burrow survey data collected by SWCA in each plot. The modeled distribution of excavated soil volumes is based on measurements of burrow mounds by SWCA in randomly selected ¼-hectare sections of each plot, and included 25 mouse/vole/rat burrows, 98 kangaroo rat burrows, and 1 badger burrow (Table 15 in the Biologically-Induced Transport Report).

Because of the scarcity of ground squirrel and badger burrows on site, all mammals were lumped into a single category for the purpose of developing distributions in the PA for mammal burrowing. As part of PA maintenance, the model will be updated with separate distributions for soil movement by small mammals (deer mice, kangaroo rats, and ground squirrels) which occur frequently on the site, and large mammals (badger, coyote, kit fox) which occur in much lower densities at Clive and the surrounding area. Because of the low frequency of large mammal burrows within the surveyed Clive plots, data collected by SWCA within the Clive plots is not sufficient to develop burrow volume and burrow density distributions for the larger mammal category. Therefore, these distributions will be based on review of literature for these species.

Hakonson (1986) found that rock armor layers are effective in preventing burrowing by mammals due to several factors, including the weight of the cobbles compared to the weight of the small mammals included in his evaluation, and the non-cohesiveness of the gravel which makes structural maintenance of the burrow problematic. Larger mammals such as badgers may be able to move the cobbles more easily than smaller mammals such as mice and kangaroo rats, but the structural instability of the burrows would remain, making the in-filled gravel and cobbles unsuitable for burrowing.

29. INTERROGATORY CR R313-25-8(5)(A)-29/1: LIMITATION TO CURRENT CONDITIONS OF SOCIETY AND THE ENVIRONMENT

Explain and justify why Bureau of Land Management (BLM) restrictions should be included in the inadvertent intruder analysis, given the likelihood that they will change over the compliance period of the PA (i.e., 10,000 years). Explain why other future land uses and FEPs were omitted.

EnergySolutions' Response*:* As is outlined in Appendix 1, "*Clive Du Pa FEP Analysis*" those features, events, and processes not representative of conditions currently observable at the site were eliminated from the Performance Assessment, as unnecessarily speculative. As is reflected in U.S. NRC guidance to staff,

> "*Given the significant uncertainties inherent in these long timeframes ["the period from the end of the compliance period through 10,000 years"], and to ensure a reasonable analysis, this performance assessment should reflect changes in features, events, and processes of the natural environment such as climatology, geology, and geomorphology only if scientific information compelling such changes from the compliance period is available*." (NRC, SRM- SECY-2013-075, February 2014).

This is further echoed by NRC's PAWG in NUREG-1573,

> "*The applicant should apply a current conditions philosophy to determine which pathways are to be evaluated. That is to say that current regional land use and other local conditions in place at the time of the analysis will strongly influence pathways that are considered to be significant.*" (NREUG-1573).

Therefore, inclusion of a recreational scenario based on current BLM land management in the Depleted Uranium Performance Assessment is appropriate.

As a general principle, Performance Assessment modeling into the distant future requires projection of current conditions or knowledge. This has been a commonly accepted practice for Performance Assessment modeling for many years, and is the only way to avoid unnecessary speculation on the future.

Application of this basic approach addresses the need to project into the future based on current conditions, and implies that BLM restrictions should be considered for the ranching scenario, that scenarios such as seawater aquaculture are not current in this area (partly because the groundwater is much more saline than seawater), resource mining does not occur in the close vicinity of Clive but does occur in some of the hills that are not too distant, and there is no water resource management in the general area.

30. INTERROGATORY CR R313-25-8(5)(A)-30/1: INCLUSION OF SRS-2002 DATA IN THE SENSITIVITY ANALYSIS

Provide a cross-reference in the text to the results of DU waste characterization, including the SRS-2002 data (Beals et al. 2002), in the sensitivity analysis.

EnergySolutions' Response*:* The wording in the Waste Inventory white paper is being changed. The intention of these white papers is to proved information on the development of input distributions, and not to comment on the results of the modeling. Consequently, the sentence is being changed to acknowledge that the "*effect of the inclusion of these data will be tested during model evaluation and will be reported as part of the sensitivity analysis*".

Note that no inventory distribution was identified as sensitive using the global sensitivity methods that were applied to the DU PA model. See response to Interrogatories #31, #32, #54 and #55 (and others).

31. INTERROGATORY CR R313-25-8(5)(A)-31/1: TC-99 CONTENT IN THE WASTE AND INCLUSION IN THE SENSITIVITY ANALYSIS

Indicate whether (and where) the expectation that the concentration of Tc-99 will be a sensitive parameter was tested. Alternatively, explain and justify what other evidence is available that led to this conclusion. Perform additional characterization of the SRS waste proposed for disposal in terms of Tc-99 content and provide the results for agency review, or explain and justify why additional sampling and laboratory analysis are not needed.

EnergySolutions' Response*:* The cited language is being removed from the Waste Inventory white paper.

However, the Tc-99 inventory was included in the global sensitivity analysis and was not identified as a sensitive parameter (variable) for any endpoint of interest. This implies that other variables that are included in the assessment of dose to various receptors contain uncertainty that swamps the uncertainty effect from the inventory distribution. Further explanation is being provided in an updated sensitivity analysis results section or appendix to the main report. And, since the issue of inventory of Tc-99 is considered important here, further analysis is being performed to show how the dose results change as a function of changes in only the Tc-99 concentrations. In addition, the sampling performed in 2002 is documented in other SRS reports as consisting of a random selection of drums, from which samples were collected from the top of the material in the drums because the process by which the material was produced was always the same. The representativeness of the sampling of the drums is clear given random mixing of material in the drums during shipping and the random selection of drums for sampling by Energy*Solutions*.

Overall, considering the lack of sensitivity of the model results to the Tc-99 inventory, and the representativeness of the samples for the entire waste stream, no further characterization of the SRS waste is considered necessary from a technical perspective. Also see response to Interrogatory #48.

32. INTERROGATORY CR R313-25-8(4)(A)-32/1: EFFECT OF OTHER POTENTIAL CONTAMINANTS ON PA

State how the PA confirmed that other potential contaminants in the DU did not contribute significantly to doses and indicate whether they were included in the sensitivity analysis.

EnergySolutions' Response: Justification for the suite of isotopes, including distributions of depleted uranium and fission product concentrations from the Savannah River site that are included in the Depleted Uranium Performance Assessment is presented in Section 3.0 of Appendix 4, "*Radioactive Waste Inventory for the Clive DU PA.*" Each radionuclide's contribution to dose is computed as:

$$\text{Dose Contribution}_{\text{nuclide}} = (\text{Concentration})_{\text{nuclide}} \times (\text{Media Volume Up-taken}) \times (\text{Dose Conversion Factor})_{\text{nuclide}}$$

The sensitivity of dose contribution is linear to changes in isotopic concentration at the point of uptake or external exposure.

The sensitivity analysis performed on this model, the results of which are presented in the Report, is a global sensitivity analysis. All input parameters (variables) are changed simultaneously to determine which are most important predictors (most sensitive inputs) for the model outputs. The inventory terms have not shown to be sensitive parameters (variables) for any of the dose or risk outputs. This implies that the greater uncertainties that are important to the model output are in other parts of the model. This also implies that reduction of inventory uncertainty through collection of more information will have only a small effect on the results. In many ways this should not be surprising considering the amount of data available for the inventory in this case, compared to the amount of information available for, for example, the radon emanation factor, K_ds, solubilities, or plant concentration ratios, etc. Further explanation of the approach taken to sensitivity analysis and model evaluation, and of the results is being presented in a new section or appendix to the Report.

33. INTERROGATORY CR R315-101-5.3(6)-33/1: CLARIFICATION OF THE PHRASE "PROOF-OF-PRINCIPLE EXERCISE" AND SENSITIVITY TO URANIUM ORAL REFERENCE DOSE FACTORS

Clarify the meaning of the phrase *"proof-of-principle exercise"* with regard to the uranium toxicity analysis and explain how the sensitivity of the PA to different uranium oral reference dose factors was determined.

EnergySolutions' Response*:* The term "*proof of principle*" was applied to assessment of the effect of uncertainty in the uranium oral reference dose (RfDo) on chemical hazard results because this assessment was limited to consideration of the differences in the two RfDo values published by EPA. To improve clarity, the first sentence of paragraph two of Section 3.4.5 of the Final Report is being revised:

> "*A limited evaluation of the effect of uncertainty in the value of the uranium oral RfD on chemical hazard results is included in this assessment.*"

Values for toxicity criteria such as the RfDo represent science policy decisions by EPA, and this assessment only evaluated the significance of selecting one or the other of these values. A broader assessment of the effect of uncertainty in the uranium RfDo would include uncertainties related to the policy assumptions, toxicological models, and dose-response data underlying both RfDo values.

The sensitivity of the mean uranium hazard quotient (HQ) for each scenario to the stochastic input distributions was evaluated in the same manner as sensitivity analyses for other PA endpoints. Methods applied for the sensitivity analyses are described in Appendix 15 (Sensitivity Analysis Methods) of the Final Report. In the case of the uranium RfDo, the input distribution was defined as an equal probability of either 0.0006 mg/kg-day or 0.003 mg/kg-day. As shown in Figures 10 and 11 of the Final Report, uncertainty in the values of inputs other than the RfDo accounted for approximately 94% (3m model; no gullies) and 92% (3m model; with gullies) of the variability in the mean ranch worker uranium HQ. The fivefold difference in the value of the RfDo, and uncertainty in all other stochastic inputs leading to the ranch worker HQ, contributed less than 6% and 8%, respectively, to the variability in the ranch worker HQ results.

34. INTERROGATORY CR R313-25-8(5)(A)-34/1: INTENT OF THE PA

Revise the text to correct the statement about the intent of the PA.

EnergySolutions' Response: The intent of the Depleted Uranium Performance Assessment is to satisfy the requirements of UAC R313-25-8(5)(a) which states,

> "*. . . a performance assessment [must] . . . demonstrate that the performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules will be met for the total quantities of concentrated depleted uranium and other wastes, including wastes already disposed of and the quantities of concentrated depleted uranium the facility now proposes to dispose.*"

Additionally, the purpose of PA in general is manifold, as a decision tool for regulators and site operators, in addition to evaluating regulatory compliance. The purpose of the PA Model is likewise manifold, in that it informs the PA, and in effect represents the site. By experimenting with the PA Model, decisions regarding facility design and the acceptance of candidate waste streams can be informed, while simultaneously evaluating compliance. The text is being modified as follows to clarify the role of PA and PA modeling.

[FRV1 Section 2.1, p. 21, second paragraph following numbered list:]

> *"The role of PA in a regulatory context is often restricted to the narrow use of evaluating compliance. In the present case, the Clive DU PA Model v1.0 can be used to evaluate compliance—and inform a PA document that presents the argument that demonstrates compliance—with 10 CFR 61 Subpart C and the corresponding provisions of the Utah Administrative Code. In addition to that role, however, and because of the long-term nature of the analysis, the intent of the Model is not necessarily to estimate actual long-term human health impacts or risks from a closed facility. Rather, the purpose is to provide a robust analysis that can examine and identify the key elements and components of the site, the engineered system, and the environmental setting that could contribute to potential long-term impacts. Because of the time-scales of the analysis and the associated uncertainty in knowledge of characteristics of the site, the waste inventory, the engineered system and its potential to degrade over time, and changing environmental conditions, a critical part of the PA process is also the consideration of uncertainty and evaluation of model and parameter sensitivity in interpretation of PA modeling results."*

35. INTERROGATORY CR R313-25-19-35/1: REFERENCE FOR COST PER PERSON-REM

Add the reference for the cited NRC estimate of the cost per person-rem.

EnergySolutions' Response*:* The text is being revised to reflect the appropriate reference, which is DOE:

DOE (US Department of Energy). 1997. Applying the ALARA Process for Radiation Protection of the Public and Environmental Compliance with 10 CFR

Part 834 and DOE 5400.5 ALARA Program Requirements, Volume 1 Discussion, DOE-STD-ALARA1draft. United States Department of Energy, Washington DC. April 1997.

This correct reference is provided on Page 39 in Section 4.1.2.11, and is being added to the first paragraph on page 16.

36. INTERROGATORY CR R313-25-8(4)(A)-36/1: ANT NEST EXTRAPOLATIONS

Specify the documents meant in the phrase *"reported in the literature"* with regard to ant nest characteristics.

EnergySolutions' Response*:* As detailed in Section 4.3 and 4.4 of the Biological Transport white paper (Appendix 9 of the Clive PA Model Report), nest volume distributions and maximum nest depth for Pogonomyrmex ants at Clive are based on correlations with nest surface area calculated from data collected at NNSS and detailed in Neptune, 2006. The text is being revised to reference Neptune (2006) and refer the reader to Appendix 9 of the PA Model Report.

37. INTERROGATORY CR R313-25-8(5)(A)-37/1: DISTRIBUTION AVERAGING

Describe the means of capturing "*the appropriate systems-level effect*" from the use of differential equations and multiplicative terms in the PA and describe what specific steps, model inputs, and model assumptions were modified for this purpose.

EnergySolutions' Response*:* References is being provided to the model inputs for which additional "care" was taken. The text is being revised to provide clarity in the intent here.

The underlying issue is that spatio-temporal scaling (upscaling) is necessary for the contaminant transport modeling performed for the Clive DU PA. The probabilistic simulations for the PA modeling involve randomly selecting values from all input distributions (outside of the exposure parameters), and then applying those values to the entire spatio-temporal domain of the model. Data that represent points in time and/or space cannot be used directly in this type of model. The data range and variance is too broad for the large spatial or temporal effects that are being modeled.

Upscaling in this context is a form of averaging to the time steps and spatial scale of a specific modeling application. This also means that the input distributions represent expected values and their uncertainty, which provides the basis for uncertainty analysis for the model.

However, averaging (expectation) is a linear operator, which means that the immediate response needs to be a linear function of the input. For example, animal burrow depth directly impacts movement of soil (and hence contaminants). Averaging over animal burrow depth data would result in narrowing the distribution of the data, and hence reducing the shallower and deeper effects. In this case the deeper effects matter the most.

Accordingly, the model is reformed by averaging the amount of burrow volume in each GoldSim cell for the depth interval of the model. Averaging is still performed, but at a different level. This discretized approach can also be adapted to continuous variables as necessary (using expectation of a function). The white papers in the appendices attached to the model describe the specific approaches taken for each input parameter (variable) in the model.

Consideration has been given during model development to appropriate upscaling for each parameter. Sometimes simple averaging is applied, but sometimes greater consideration needs to be given to the response, and adjustments are made to get closer to a linear response in the immediate dependent variable.

38. INTERROGATORY CR R313-25-8(5)(A)-38/1: FIGURES 5 AND 11 IN FRV1

Correct the caption for Figure 5 to reflect the nature of the plots and describe how Figure 5 demonstrates compliance with R313-25-8(5)(a).

***EnergySolutions*' Response**: The caption for Figure 5 is being corrected to read as follows:

[FRV1, Figure 5, p.56]

Figure 5. Time history of 99Tc well concentrations; 1,000 realizations shown.

The groundwater permit for the facility requires that groundwater concentrations be kept within specified concentration limits for 500 years, and specifies no concentration limits after 500 years.

The reason there is no groundwater drinking water exposure pathway shown on Figure 11 is that this exposure pathway is not credible. Groundwater salinities are such that the water is not potable, and it is not considered a drinking water source by the State of Utah. While water from the deeper aquifer near the mountain front is treated and used, water from the shallow, upper-unconfined aquifer is not used for anything, including dust suppression. As such, the lack of potable groundwater sources is exemplified by the fact that there is no current use of groundwater for this purpose, despite the presence of industry (including the Clive Site itself) and a permanent resident at the rest area on Interstate 80. Drinking water requirements for persons at these and other locations in the basin are satisfied using water delivered by truck.

Since groundwater is not a source of drinking water, the drinking water exposure pathway does not exist, and groundwater concentrations are not evaluated for this purpose. There is therefore no need to evaluate groundwater concentrations for 10,000 years.

Also see response to Interrogatory #15.

39. INTERROGATORY CR R313-25-8(5)(A)-39/1: FIGURE 6 CAPTION

Correct the caption for Figure 6 to reflect the nature of the plots.

EnergySolutions' Response: The caption for Figure 6 is being corrected to read as follows:

[FRV1, Figure 6, p.57]

Figure 6. Time history of 99Tc well concentrations: statistical summary of the 1,000 realizations shown in Figure 5.

40. INTERROGATORY CR R313-25-8(5)(A)-40/1: FIGURES 7, 8, 9, 10, AND 11

Label the axes for Figures 7, 8, 9, 10, and 11 and provide more discussion in the text on how to interpret the figures.

EnergySolutions' Response: The style of these plots is under revision, recognizing the challenge of presenting a lot of information in a small space. Specifically, axes labels are being added to the partial dependence plots. Furthermore, more text is also being included regarding the interpretation of these plots in the next version. In addition, the reader is being referred to section 2.4.2 of the Sensitivity Analysis white paper. More of the information from this section 2.4.2 is being included in the explanations presented in the revised Final Report.

41. INTERROGATORY CR R315-101-5.3(6)-41/1: TABLE 7

Resolve the discrepancy between the descriptive text and the title and content of Table 7.

EnergySolutions' Response: The text in the Final Report is being modified as follows:

[FVR1, Section 6.3.1, p. 68, first sentence:]

> *"The uranium hazard results are summarized in two tables: Table 7 shows the statistics for peak uranium hazard quotient for all receptors, without the gully screening calculations, for the cases of waste emplaced at 3 m, 5 m, and 10 m below the embankment cover."*

[FVR1, Section 6.3.1, p. 68, caption to Table 7:]

Table 7. Peak uranium hazard quotient, without consideration of gullies: statistical summary

The same issue exists with Table 8, so that is being changed as well.

[FVR1, Section 6.3.1, p. 68, caption to Table 8:]

Table 8. Peak uranium hazard quotient, with gully screening calculation: statistical summary

42. INTERROGATORY CR R315-101-5.3(6)-42/1: HAZARD QUOTIENT IN TABLES 7 AND 8

Resolve the discrepancy between the titles and content of Tables 7 and 8, in terms of whether they present the Hazard Quotient (HQ) or the Hazard Index (HI) and clarify what they signify for each receptor, the exposure pathways included and excluded, and the rationale for including or excluding them.

EnergySolutions' Response*:* As defined in the Definitions Table in Chapter 8 of EPA (1989), an HI is "*the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways.*" Although the use of the term HI in environmental risk assessment is more commonly used to refer to summation of HQs for multiple substances it is also applicable by this definition to the summation of uranium HQs for multiple exposure pathways.

Section 6.3 of the Final Report is being renamed "*Receptor Uranium Hazard Indices*". The first sentence of Section 6.3 is being revised to state:

> *"Uranium hazard indices (HIs) within 10,000 yr are calculated for each receptor scenario as the sum of hazard quotients (HQs) for the ingestion exposure pathways defined in Table 1, and are compared to EPA's standard HI threshold of 1.0."*

The text of Section 6.3 of the Final Report, Tables 7 through 10, and Figures 10 and 11, is being edited to replace the term hazard quotient with hazard index.

43. INTERROGATORY CR R313-25-19-43/1: PEAK DOSE IN TABLE 11

Clarify the meaning of the term *"peak"* in the context of Table 11. Explain why this information has relevance to the regulatory requirement in R313-25-19, which sets dose limits for "*any member of the public*" (i.e., in the singular).

***EnergySolutions*' Response**: Cumulative doses are monotonically increasing, so that the "peak" (maximum) cumulative population dose (or, rather, the total effective dose equivalent, or TEDE) must necessarily occur at the time equal to the duration of the time of interest.

The Table title is being changed by removing the word "Peak". It is not applicable here. The values in the table should represent statistics from the distribution of the cumulative population doses. However, per Interrogatory #88, and in light of upcoming changes to the model (ET cover), this table is being revised and corrections are being made in the text to reflect what is represented in this table.

Doses to individuals, which indeed are required explicitly in R313-25-19, are covered in the previous sections of the FRV1. The interpretation of the ALARA principle followed here is that all doses are to be kept ALARA, in what amounts to a cost/benefit analysis. The reason for doing so is to evaluate changes that might be made to the facility, (e.g. design, waste acceptance), which are incurred at some cost. To the extent that these changes would result in the benefit of reducing doses in the future, a decision is to be made about whether they are worth instituting. In order to include all potential receptors who might benefit from reduced doses, the appropriate method is to evaluate the population dose, which is the sum of all doses to all individuals through the performance period.

44. INTERROGATORY CR R313-25-8(5)(A)-44/1: OCCURRENCE OF INTERMEDIATE LAKES

Clarify the number meant by the term *"handful"* when referring to the occurrence of intermediate lakes. Describe intermediate lakes in terms of past or future total surface area and potential inundation of the Clive site.

***EnergySolutions*' Response**: In general, the spatial aspect of intermediate lakes that is of interest is whether the shore reaches the elevation of Clive. The total areal extent of these lakes is not accounted for in the present model, as this is not relevant to the issue of the site's potential inundation.

Intermediate lakes are modeled as a Poisson process with a rate of 0 to 7.5 lakes per 100 ky. The text indicated is being changed as:

"*intermediate lakes only occur on average 3 times per 100 ky.*"

Please refer to the following existing sections in the Deep Time Assessment white paper for further details regarding timing. Clarification is being added to the main text of the report.

Section 3.3, p. 10, para. 1

> "*For modeling purposes, a distinction is made between shallow, intermediate and large lakes. Large lakes are assumed to be similar to Lake Bonneville, occurring no more than once per 100 ky glacial cycle. Intermediate lakes are assumed to be smaller lakes that reach and exceed the altitude of Clive, but are not large enough that carbonate sedimentation can occur [at Clive]*."

Section 4.1.1.1, p. 14, para. 1

> "*The Great Salt Lake represents the current condition of a lake in the Bonneville Basin. Lakes such as this are likely to exist for periods of time during all future climatic cycles, but lakes that do not reach the elevation of the DU waste embankment at Clive will not affect the waste embankment, so they need are not modeled explicitly. However, it is assumed that during the 100 ky climatic cycles, larger lakes will occur, including lakes that reach the elevation of the DU waste embankment at Clive. Although a definitive distinction is not made, lakes that reach the elevation of Clive but do not develop into a large lake are considered intermediate lakes. These intermediate lakes are also assumed to be large enough that their wave action will destroy the waste embankment. Intermediate lakes might occur during the transgression and regression phases of a large lake, or might occur during a glacial cycle that does not produce a large lake, perhaps in conjunction with glacial cycles that are shorter and less severe than the 100 ky year glacial cycles previously discussed (for example, potentially the current 100 ky cycle).*"

Section 6.2, p. 23, para. 1 and 2

> "*In order to reflect the slow decrease in temperature over the 100 ky cycle, the occurrence time for intermediate lakes is modeled as a Poisson process with a rate that increases linearly over the cycle time, from a rate of 0 to 7.5 lakes per 100 ky. This process produces an average of about 3 intermediate lakes per 100 ky. There is little recorded basis for this number, but it matches reasonably with the heuristic model of Section 5.0, and was chosen so that long-term sedimentation rates matched the average from previous lake cycles, as estimated from the sedimentation of individual lakes developed in Section 6.3.*"

> "*There is virtually no information for the duration of intermediate lakes, due to the high mixing rate of shallow lake sediments, which makes dating of times within a single stratigraphic layer of a shallow lake sediment core extremely difficult. Thus, a distribution was chosen to roughly calibrate with the heuristic model: lognormal with geometric mean of 500 y and geometric standard deviation of 1.5.*"

45. INTERROGATORY CR R313-25-7(2)-45/1: INACCURATE CROSS-REFERENCE

Change the text to cite the correct location for the list of relevant radionuclides.

EnergySolutions' Response*:* The proper reference should be to Table 4. The text of the Conceptual Site Model white paper is being changed as follows:

[Conceptual Site Model white paper, section 4.2.2, p.18, second paragraph, second sentence:]

> *"The wastes under consideration for disposal in the present PA, however, contain more than simply isotopes of uranium, potentially including some radionuclides listed in the tables shown in Figure 4 in addition to the Ra-226 added by Utah (Figure 5)."*

46. INTERROGATORY CR R313-25-7(1)-46/1: TORNADOS

Provide complete and accurate information on tornados in Utah and discuss their potential impact on the long-term integrity of the embankment cover.

EnergySolutions' Response*:* Although not explicitly stated in the Erosion Modeling report, tornados are addressed. As quoted in the Basis for Interrogatory, tornados are considered a potential triggering event for gully formation. Therefore, the gully analysis encompasses potential impact from a tornado strike on the embankment.

This scenario must further be considered in terms of its very low probability. Tornadoes are rare phenomena in the State of Utah primarily due to the lack of atmospheric moisture and the presence of mountainous terrain. Utah tornadoes are much weaker and smaller than their central U.S. counterparts. Utah tornadoes stay on the ground for an average of only a few minutes and their path widths are usually one-eighth of a mile or less. As has previously been reported to the Division,

> "*The probability of tornado occurrence in Utah is 14 tornados in 61 years (NWC, 2013). Five tornadoes were observed in Tooele County for the*

period 1847–2010 (Brough, et al., 2010). Based on this historic record, the probability of a tornado strike at any one point in Tooele County is extremely low.

Because NRC (and the Division) deems insignificant impact to a closed embankment's ability to perform, NUREG-0706 estimates the bounding consequences of a tornado striking an actively operating cell, by modeling a tornado's impact to a uranium mill. In the NUREG-0706 bounding case, 12.6 tons of yellowcake is assumed to be entrained in the vortex, the vortex dissipates at the site boundary, all of the yellowcake is reparable in size, and the cloud is dispersed as a volume source by the prevailing winds. The model predicts a maximum exposure at 2.5 miles from the mill, where the 50-year dose commitment is estimated to be 0.83 micro-rem. At the fence line (1,600 feet) the dose is estimated to be 0.22 micro-rem.

While severe winds on the order of 35 m/s have been recorded in the Clive vicinity, the occurrence is infrequent and the duration is short. Using the same method as NUREG-0706, (i.e., an order of magnitude increase in airborne concentrations during severe wind conditions that occur approximately one percent of the time), the time-weighted average off-site exposure will increase by only 10 percent. This will result in a maximum additional annual collective TEDE of less than 1 mrem to any possible nearby population groups.

Depleted uranium wastes considered by EnergySolutions in this Performance Assessment have average activities considerably less than those modeled by NRC in NUREG-0706. As a result, the expected TEDE at receptor locations is bounded by NUREG-0706. Since there are no nearby population groups, this very small potential dose is even more insignificant." (Section 7 of EnergySolutions, 2013c, pg 7-7)

Although the probability of a tornado strike on the Clive facility is low, it need not be discounted completely. An unbiased way to include tornado activity as a part of local weather patterns is to rely on the records from meteorological sampling stations, as is being done. These stations record all manner of wind events, from straight-line winds to dust devils to tornados, should they occur. It is essentially a random sampling of natural weather processes, and the record is used in the atmospheric dispersion modeling at the site. In this fashion, tornados are not excluded from the analysis, and are included to the extent that they are recorded to occur. In addition to tornados as weather phenomena that contribute to atmospheric dispersion, they are implicitly included in their effects on erosion, since gully formation can be caused by severe tornadoes.

47. INTERROGATORY CR R313-25-7(1)-47/1: SELECTION OF BIOME

Correct the placement of the X on the Whittaker Biome Diagram to accurately represent site conditions.

<u>EnergySolutions' Response</u>: The 'X' is not located in the correct place in Figure 7 of the CSM Report. This is being corrected in a revision of the CSM Report. Correct placement of the X will shift its location to the Temperate Grassland and Desert biome near its intersection with the Woodland Shrubland and Subtropical Desert Biomes. Figure 7 is being revised to show the correct placement of the Clive Site within the biome diagram. No revisions to associated text are needed.

48. INTERROGATORY CR R313-25-7(9)-48/1: SOURCE AND COMPOSITION OF DU WASTE

Clarify the source of the DU waste considered in the analysis and how the PA accounts for potentially different radionuclide species compositions. Address concerns with the three sources of information on the characteristics of the DU waste.

<u>EnergySolutions' Response</u>:
<u>General Comment</u>. Every effort was made to find and use all information regarding the characteristics of DU currently proposed for storage at Clive, as well as future sources of waste. Deficiencies of SRS 2002 data are well documented in the Waste Inventory Report. The available SRS data were used when no other information was available (i.e., to also represent the GDP waste). Data from the SRS 2002, the State of Utah, 2010 and Energy*Solutions* (2010) was summarized in such a way to capture the variations between studies as well as within studies. This method results in considerably more uncertainty than if the all the results were pooled to estimate confidence around the overall mean value treating all the data as random samples. This characterizes the distributions for the mean value of the components of the waste inventory in a conservative manner compared to random allocation, but represents the between study variability. The use of the SRS data as a surrogate for the GDP waste is described in the Waste Inventory paper. Consequently, the specific statement called out in the Interrogatory ["Based on laboratory analysis of the contents of DU waste (including all radionuclides in the containers), the species in the disposed inventory include (Beals et al. 2002; Energy*Solutions* 2009b; Johnson 2010):…."] refers to all the waste.

<u>Comment 1, part a</u>. There is no evidence to indicate that the barrels sampled in 2002 were not randomly sampled. Furthermore; information indicates that the barrels stored at Savannah contain similar materials produced by similar processes. Assuming this is the case the sample size provides data that adequately represents the waste concentrations. The following document will be added to the

references: Loftin, S.G., and McWhorter, D.L., 2002, Sampling Plan for Depleted Uranium Trioxide Drums", InterOffice Memorandum, Westinghouse Savannah River Company. This document makes clear that the drums contain similar material produced from the same process over a roughly 30-year period (1950s to the late 1980s). The drums appear to have been selected essentially at random, and the waste mixture is homogeneous because the UO_3 was mixed prior to placing it in the drums. Because of the previous mixing drums were sampled from the top of each drum. Details are being added to the Waste Inventory paper. However, the drums appear to have been sampled at random, and the process by which the waste was produced appears to have been constant throughout the 30-year period of operation.

Comment 1, part b. Regarding the MDA level used in the Ra-226 measurements, at the time of the 2002 measurements this level was specified as being 1/10 the waste acceptance criteria level – presumably low enough to produce detectable results below the acceptance level. If any new samples are collected, they will specify a MDA value of 15 pCi/g. However; given that the Ra-226 is a product of U-238 decay, and the DU waste is pure uranium at the outset (other than the fission contaminants), uranium data has accurately been coupled with the established methods for modeling the decay chain of uranium suffice for accurate characterization of Ra-226.

Regarding I-129, while none was detected in the 33 samples, an input distribution of the mean value was set based on the MDA values. For 0 of 33 samples to not exceed the MDA, it is likely that the true mean is considerably lower and possibly zero. Nonetheless, with the input based on the MDA, I-129 was not found to be a contributor towards any impacts on groundwater. Therefore; it seems unlikely that additional samples with lower detection limits would change any conclusions. However, an approach is being evaluated that applies scaling factors to I-129 based on Tc-99 concentrations. If the scaling factor approach is considered appropriate, then a different distribution of I-129 will be used in the model. See response to Interrogatory #95.

Comment 1, part c. The term "statistically weaker" may not be applicable, it is not clear exactly how that term might be used. Inputs with fewer sample sizes are not "statistically weaker" than inputs with greater sample sizes, but they likely have wider confidence intervals, or the mean has greater uncertainty. The statistical methods account for different sample sizes by acknowledging the differences in uncertainty.

Comment 1, part d. With regards to the 2002 SRS uranium data, Energy*Solutions'* best effort suggest that the data needed (sample mass) to convert the 2002 results to activity concentration does not exist and therefore this cannot be resolved. Furthermore, it is not clear that Energy*Solutions* has the authority to demand additional samples be taken and analyzed by the Department of Energy. In 2010, Energy*Solutions* sought to fill this information gap by collecting 26 additional samples. Efforts could be made at collecting more samples from the SRS drums for uranium analysis, but the uranium inventory is not a sensitive parameter, in which case probably little will be gained by doing so.

Comment 2, part a. Drum samples collected in 2010 by Energy*Solutions* were randomly chosen. Additionally, inadvertently the barrels of waste were very likely re-randomized during the loading and unloading (i.e. we have no knowledge that the barrels were deliberated kept in any sequential order throughout the transport, and based on the 2002 sampling plan it appears that the drums have never been organized in a way that would allow for systematic sampling). With regard to the State of Utah 2010, data collection the Memorandum indicates that a simple random sampling methodology was followed. The barrels selected for shipment from SRS were NOT preferentially selected based on the qualities of their content – such preferential section would not have been possible since there is no prior knowledge that some drums contain, in some way different material than other drums. Therefore; no information suggests that the samples are not independent and identically distributed (i.e., randomly selected with similar expectations for each drum and sample).

Comment 2, part b. The uranium isotope data was estimated using the range of isotope proportions measured in the SRS 2002 study, coupled with the combined concentrations measured in 2010. In the Waste Inventory document, it is suggested that if this partitioning distribution is found to be a sensitive parameter, additional sampling may be warranted. However, it was not found to be sensitive. The available data all relate to the same waste stream. Some inherent sampling and measurement variability should be expected, but otherwise the samples represent the same waste stream, in which case all available data are considered useful.

Comment 3, part a. While the Johnson, 2010 memorandum references the EPA Waste Sampling Guidance (530-D-02-002), there is not sufficient information to see exactly how it was applied to the Utah sampling plan. The sample size calculations used in this collection effort are outlined in a letter to Dane Finerfrock from John Hultquist (January 21, 2010). From the letter, it is clear that the sample sizes were based on the goal of providing a specified degree of confidence for estimates of the proportion of drums with Tc-99 concentrations qualified that would qualify it as a Class A waste. There are many statistical problems with the approach that was taken to sample size determination, which Neptune documented in a memorandum to Energy*Solutions* in January 2010. The wrong statistical formula was used for answering the important question of the concentration of uranium in the DU waste. Sampling to answer a question based on proportions (proportion of what was never clear in the State sampling plan) is very different than answering the question of concentration or mean concentration. The State took far more samples than were needed to address the issue of concentration estimation if Type I and Type II errors had been applied in the DQO process evaluation of a relatively homogeneous waste stream. Using proportions as the end goal, is not the same as sampling to determine the average concentration for the waste inventory. The sample size used by the State of Utah is likely much higher than that would be recommended to estimate mean concentrations for a homogenous waste source. Other information about the details of the actual sampling procedure and drum selection is not discussed.

With regards to characterizing the waste inventory, a priori there is no ideal sample size needed to run the PA model. The samples sizes used to characterize inventory concentrations are accounted for in the width of the distributions. After the fact, it might be concluded that a given input has great impact on the end result by performing a sensitivity analysis. However, the sensitivity analysis results for the current model indicate that the output results are not sensitive to the inventory distributions.

Discussion

The Division's concerns about the representativeness of the samples used to characterize the waste inventory are understandable. However, none of the inventory distributions are sensitive, and they are all as "wide" as they can be given the data. To this end, the following actions are proposed.

- Specific sensitivity analysis (one-at-a-time) is being developed for select dose rates and hazard quotients focusing on inventory distributions as inputs. Initially, this effort will analyze data from existing model runs (after implementing the ET cover). This would provide information about the relative impacts of the inventory amounts and identify conditions where greater certainty is needed. This item relates to the comments raised in CR R313-25-8(5)(a)-30/1, CR R313-25-8(5)(a)-31/1 and CR R313-25-8(4)(a)-32/1.

- This sensitivity analysis will include evaluating the effect of ignoring some data sources.

49. INTERROGATORY CR R313-25-7(9)-49/1: COMPOSITION OF MATERIAL MASS

Clarify the material comprising masses discussed in the text.

***EnergySolutions' Response**:* The weight reference was calculated from information provided on the Uniform Low-Level Radioactive Waste Manifest – Forms 540 and 541. On these forms, the material description (Form 540, box 11) is listed as "*RQ, UN 3221, Radioactive material, low specific activity (LSA-II), 7, Fissile Excepted*." In the Radiological Description (Form 541, box 15) uranium component is described as "U-(dep)." Therefore this material is assumed to be DU Waste as described in the Waste Inventory Report.

The mass of the empty drums is assumed to be approximately 108 Mg, so the total waste mass is:

3,577 Mg of drummed waste - 108 Mg drum mass = 3,469 Mg of DU waste

which is a mix of uranium isotopes and contaminants, and where the uranium is assumed to be in the form of DUO3. Calculations are performed within the GoldSim model to attribute the total mass to the separate radionuclides, based on the available concentration data (i.e., based on the input distributions created from the available laboratory data).

Text clarifying how this is done is being added to the Waste Inventory Document.

50. INTERROGATORY CR R313-25-7(9)-50/1: SAMPLES COLLECTED

Correct the numbers given in the text for samples collected in January and April 2010 to match the corresponding tables.

EnergySolutions' Response: Section 2.2.2 of the Waste Inventory report is being revised to read:

> "*In January of 2010, EnergySolutions collected 11 samples that were analyzed for uranium isotopes (Table 14, in the Appendix). In April 2010 EnergySolutions collected 15 samples that were analyzed for uranium isotopes and ^{99}Tc (Table 15, in the Appendix).*"

As confirmed by checking the original sampling reports, 11 samples were collected in the January 2010 event and 15 samples were collected in the April 2010 event. The text referenced above is being corrected.

51. INTERROGATORY CR R313-25-7(9)-51/1: NATURE OF CONTAMINATION

Refer to other existing analyses for information on the nature and extent of contamination within the contaminated DU population for the GDPs.

EnergySolutions' Response: As with Energy*Solutions'* other historic performance assessment, the revised depleted uranium Performance Assessment accounts for variations in depleted uranium concentrations by modeling individual radionuclides at Class A limits (without taking credit for waste form or packaging). Therefore, the analysis is bounding and includes variances suggested by the references provided by the Division.

These references, and additional references that have been made available since submittal of the report in June 2011, are being consulted for additional information. The radionuclide content of the GDP DU is being modified in accordance with the information from those references found to provide new useful information.

Documents that are being evaluated to further characterize this source term, include:

- BJC (Bechtel Jacobs Company LLC), 2000, Recycled Uranium Mass Balance Project Oak Ridge Gaseous Diffusion Plant Site Report, BJC/OR-584, June 2000.
- BJC, 2000, Recycled Uranium Mass Balance Project Paducah Gaseous Diffusion Plant Site Report, BJC/PGDP-167, 14 Jun 2000.
- BJC, 2000, Recycled Uranium Mass Balance Project Portsmouth, Ohio Site Report, BJC/PORTS-139/R1, 19 Jun 2000.
- Croff, A.G., J.R. Hightower, D.W. Lee, G.E. Michaels, N.L. Ranek, and J.R. Trabalka, 2000, Assessment of Preferred Depleted Uranium Disposal Forms, ORNL/TM 2000/161, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Jun 2000.
- Croff, A.G., J.R. Hightower, and N.L. Ranek, 2000, Evaluation of the Acceptability of Potential Depleted Uranium Hexafluoride Conversion Products at the Envirocare Disposal Site, ORNL/TM 2000/355, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Dec 2000.
- DOE (U.S. Department of Energy), 1999, Final Plan for the Conversion of Depleted Uranium Hexafluoride, DOE/SO-0003, U.S. DOE Office of Nuclear Energy, Science and Technology, Jul 1999.
- DOE, 1999, Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride, DOE/EIS-0269, U.S. DOE Office of Nuclear Energy, Science and Technology, Apr 1999.
- DOE, 2000, Recycled Uranium, United States Production, Enrichment and Utilization, DOE/SO-0003, U.S. DOE, Aug 2000.

- DOE, 2003 Recycled Uranium, The Flow and Characteristics of Recycled Uranium Throughout the DOE Complex 1952 1999, DOE/EH-0617, U.S. DOE, May 2003.

- Haselwood Enterprises, Inc., 2000, Recycled Uranium Mass Balance Project Y 12 National Security Complex Site Report, Y/LB 16,036, Rev. 1, U.S. Dept. of Energy, Oak Ridge, TN, Dec 2000.

- Henson Technical Projects, LLC, 2006, Contents Categorization of Paducah DUF6 Cylinders Using Cylinder History Cards – Phase II, Draft for UDS Review, DUF6 G G STU 003, Uranium Disposition Services, LLC, Lexington, KY, Sep 2006

- Hightower, J.R. and J.R. Trabalka, 2000, Depleted Uranium Storage and Disposal Trade Study: Summary Report, ORNL/TM 2000/10, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Feb 2000.

- Hightower, J.R., L.R. Dole, D.W. Lee, G.E. Michaels, M.I. Morris, D.G. O'Conner, S.J. Pawel, R.L. Schmoyer, L.D. Trowbridge, and V.S. White, 2000, Strategy for Characterizing Transuranics and Technetium Contamination in Depleted UF6 Cylinders, ORNL/TM 2000/242, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Oct 2000.

- INEEL (Idaho National Engineering and Environmental Laboratory), 2000, Idaho National Engineering and Environmental Laboratory Site Report on the Production and Use of Recycled Uranium, INEEL/EXT 2000 00959, INEEL, Idaho Falls, ID, Sep 2000.

- INL (Idaho National Laboratory), 2010, Analyzing Losses: Transuranics Into Waste and Fission Products Into Recycled Fuel, 11th Information Exchange Meeting on Actinide and Fission Product Partitioning and Transmutation, INL/CON 10 20136, INL, Nov 2010

- Picel, K., R. Johnson, J. Peterson, K. Keil, A. Kolhoff, H. Spector, and J. DeVaughn, Evaluation of Uranium Enrichment/Depletion and Recycled Uranium Residuals in Soils and Groundwater at the Harshaw FUSRAP Site, Paper 9336, Waste Management 2009 Conference, Mar 2009.

- UDS (Uranium Disposition Services, LLC), 2009, Waste Management Plan, DUF6 UDS PLN 005, rev. 2, UDS, Lexington, KY, Jan 2009

52. INTERROGATORY CR R313-25-7(9)-52/1: MEASUREMENT TYPES FOR SAMPLING EVENTS

Clarify the reference for *"different measurement types between sampling events."*

EnergySolutions*' *Response: Clarification is being provided.
The concern for U-238 is that the 3 different sampling events exhibit different behavior as shown on Figure 1. Also, Figure 3 shows differences for the Tc-99 data for its three sampling events.

While available site knowledge and historical information suggest that the SRS waste is from similar processes and is similar in composition, the sampling events were treated as if they were sampling different populations. The reason for treating the sampling events as if they were sampling different populations was the differences between concentration data for the different sampling events. The text in question was an attempt to acknowledge that the data indicate differences that are more likely explained by different measurement methods (sampling and analysis) than any other reason, given the waste has not been changed in more than a decade. The text is being clarified to change the term "*measurement types*" to "*sampling and analysis methods*".

The statistical approach was to treat each sample independently within a sampling event, and to treat the sampling events as representing separate populations. The bootstrap simulations, hence, involved bootstrapping both within and across sampling events. This approach maximized the uncertainty that was carried into the distribution of the mean.

53. INTERROGATORY CR R313-25-7(9)-53/1: SUBSCRIPTS IN EQUATION 1

Correct the subscripts in the denominator of equation 1.

EnergySolutions*' *Response: Clarification of the meaning of c_i and c_j in the "where" block is begin added. The "where" block for equation (1) of the Waste Inventory white paper is being modified to read as follows:

$$A_i = \frac{c_i}{\sum_j c_j} \times 100$$

where

A_i = activity % of uranium component i,

c_i = activity concentration for uranium component of interest i, and

c_j = activity concentration for all enumerated uranium components j, which indexes $^{233+234}U$, $^{235+236}U$, and ^{238}U.

54. INTERROGATORY CR R313-25-7(9)-54/1: PARTITIONING IN THE SENSITIVITY ANALYSIS

Provide a specific cross-reference to the discussion of partitioning in the sensitivity analyses.

EnergySolutions' Response*:* The text in Section 3.2.1, page 14, of the Waste Inventory report is being changed to:

> "*In general, the differences this causes in uranium activity concentrations are fairly small relative to the likely effect on the PA model results, however, this will be tested in the model evaluation and sensitivity analysis (see Section 6 of the Clive DU PA Model Report).*"

The sensitivity analysis performed on this model and presented in the report is a global sensitivity analysis. All input parameters (variables) are changed simultaneously to determine which are most important predictors (most sensitive inputs) for the model output. The uranium inventory has not shown to be a sensitive parameter for any of the dose or risk outputs.

55. INTERROGATORY CR R313-25-8(5)(A)-55/1: URANIUM ISOTOPE DISTRIBUTIONS

Indicate whether analyses were conducted to determine if the uranium isotope distributions significantly affected the results of the PA.

EnergySolutions' Response*:* All stochastic inputs into the model are included in the global sensitivity analysis. This includes the radionuclide-specific abundances that make up DU waste, as represented by the GoldSim Stochastic element \Inventory\SRS_DU_Inventory\ActivityConc_SRS_DUWaste, in the Clive DU PA Model v1.0. The activity concentration of each radionuclide in DU waste, including all isotopes of uranium, is defined probabilistically through this element.

Note that the Waste Inventory white paper, like all topical white papers, is developed for model inputs and approaches, with no regard to results. Model results are summarized in the Final Report (FRV1). As shown in Section 6 of the Final Report, no model endpoints (e.g. doses to various receptors, and groundwater concentrations) were sensitive to the uncertainties in inventory, and by extension to uranium isotopic abundances.

The global sensitivity analysis methods used effectively consider changes in all input parameters simultaneously to determine which inputs are most important for the model output. Details are provided in the Sensitivity Analysis white paper.

56. INTERROGATORY CR R313-25-7(9)-56/1: INTERPRETATION OF BOX PLOTS

Interpret the information contained in the box plots in Figures 3 and 5, including the statistical parameters they display.

EnergySolutions' Response: Where the box-plots are first used and referenced on page 17, the following text is being added either within the text, or as a footnote, or as part of the figure caption.

> "*The box-plots shown in Figures 3 and 5 are standard typical box-plots (Tukey, 1977) used to illustrate and summarize the distribution of groups of data. The top, middle and bottom lines indicate the 75th, 50th (median) and 25th percentile of the data. The vertical lines "whiskers" extend to the largest or smallest point within 1.5 times the interquartile range (75th – 25th percentiles) of the 25th and 75th percentiles. Results falling outside the whiskers are considered to be outliers. This indicates that there is a reasonable chance they are from a different distribution. With several groups of data, box-plots can be used to informally compare the central values (median), spread or variances (width of the boxes) or distributions (symmetry).*"

This reference is being added to the References section:

> *Tukey, John (1977). Exploratory Data Analysis. Addison-Wesley*

57. INTERROGATORY CR R313-25-7(9)-57/1: DASHED LINES IN FIGURE 4

Explain the purpose of the dashed lines in Figure 4.

EnergySolutions' Response: In Section 3.3, the caption is being edited to include an explanation of the dashed vertical lines. The new caption reads,

> "*Distribution of Tc-99 mean values. Red lines indicate mean values of Utah-2010, ES-2010 and SRS-2002 results. The dashed lines indicate the 5th and 95th percentiles of the mean values of the resampled data.*"

To clarify, the resampled data represent the final simulated distribution (from the bootstrapping algorithm that was used). So, these are the 5th and 95th percentiles of the final distribution. The intent of these lines is to show where the original data means fall relative to the final distribution.

58. INTERROGATORY CR R313-25-7(9)-58/1: REFERENCE FOR PERSONAL COMMUNICATION

Provide complete information for personal communication citations in the reference list.

EnergySolutions' Response: The text is being edited as follows:

[Waste Inventory white paper, p. 23, second-to-last paragraph, last sentence:]

> *"These cylinders are also considered unlikely to be contaminated (personal communication, Tammy Stapleton, Uranium Disposition Services, LLC, to John Tauxe, Neptune and Company, Inc., 3 May 2011)."*

[Waste Inventory white paper, p. 24, first paragraph, third sentence:]

> *"Using expert opinion, this is estimated at less than 1%, with a best guess at no more than 10 cylinders contaminated (personal communication, Tammy Stapleton, Uranium Disposition Services, LLC, to John Tauxe, Neptune and Company, Inc., 3 May 2011)."*

Most style manuals suggest that a personal communication should not appear in the reference list, but rather remain only a parenthetical reference in the text. Nevertheless, the reference section is being revised as,

> Stapleton, Tammy, Uranium Disposition Services, LLC, personal communication via telephone to John Tauxe, Neptune and Company, Inc., 3 May 2011.

59. INTERROGATORY CR R313-25-7(2)-59/1: BATHTUB EFFECT

Clarify why, after the upper flow barriers are compromised, water will not collect above the clay liner and drive infiltration rates above those predicted by models.

EnergySolutions' Response: Because of the large differences between the cover layers in permeability the potential for the bathtub effect is being evaluated for both the rip rap and ET cover designs.

For this review of the model, which includes the rip-rap design, it is assumed that the "*top clay liner*" referred to in the Interrogatory is the top clay liner below the waste zone and not one of the radon barriers. The saturated hydraulic conductivity of this liner is too high to result in ponding (bathtub effect). The highest average annual infiltration estimated for the top slope of this waste cover is 0.11 inches/year (Whetstone, 2007, Section 3.4.1) which is equivalent to a hydraulic conductivity rate of $9E^{-11}$ m/s (assuming Darcy's Law flow and a unit gradient such that flux = K_{sat}). This infiltration rate of 0.11 inches/year is calculated using HELP which is generally considered to over-estimate infiltration (see Section 4.1.2.4.1). [This is being addressed in the ET cover model using HYDRUS instead of HELP.] The saturated hydraulic conductivity of the clay liner below the waste is reported to be $1.0E^{-6}$ cm/s (1.0E-8 m/s) in the Unsaturated Zone Model report (p. 5), which is 100 times greater than the infiltration rate so the bathtub effect is not possible. Any increase in saturated hydraulic conductivity of the clay liner below the waste due to naturalization will make the bathtub effect even less likely.

Note that the quoted text in the Interrogatory is not from Section 4.1, page 5, but rather from Section 3.2, page 15, of the Unsaturated Zone Model report.

60. INTERROGATORY CR R313-25-7(3)-60/1: MODELED RADON BARRIERS

Provide additional justification for the modeled post-installation upper and lower radon barriers.

EnergySolutions' Response: As is provided in response to Interrogatories CR R313-25-7(2)-05/1 the Evapotranspirative Cover is designed to protect the radon barrier from the impacts of burrowing insects, animals, and vegetation root systems. Similarly, analysis conducted by Hansen, Allen, and Luce in 2013 concluded,

> "*The frost depths calculated as part of this analysis give results that are in line with the depths of cover and frost protection proposed in the EnergySolutions ET Cover system design. The proposed radon barrier begins at depths ranging from 30-inches to 42-inches which provides frost*

> *protection for the calculated 100-year frost penetration depth of 22.4 inches to 27.8 inches for the top slope and side slope, respectively."* (Appendix E of Energy*Solutions*, 2013d)

The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions,* 2014) for the ET cover design's use on the Class A West Embankment. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

This interrogatory is closely linked to the Benson et al (2011) report published by the NRC, and is similar to Interrogatory CR R313-25-8(5)(A)-176/1. The Benson et al. (2011) reference is a credible report that emphasizes cover properties in general, not the specific cover types and materials proposed for the Clive site and the local climatic setting. The recommendations from the report, by itself, are not sufficient justification to require redesigning the cover system nor is it contradictory with the steady state infiltration rates developed from the HELP modeling. In fact, Benson et al. (2011) state "*If available, a site-specific saturated hydraulic conductivity that reflects in-service conditions should be used for performance predictions.*" Although site-specific hydraulic conductivities have not been measured, the site-specific estimates are considered to be more credible than the generic values in Benson et al. (2011).

With regard to the influence of biointrusion on model parameters, also refer to the response to Interrogatory CR R313-25-8(4)(A)-108/1 on biointrustion.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of cover design components and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility.

This interrogatory spans two topics: alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty). Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling.

There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. If a more comprehensive sensitivity analysis is needed for the infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

61. INTERROGATORY CR R313-25-8(4)(A)-61/1: MASS-BALANCE INFORMATION

Provide the mass-balance information for both the flow and contaminant transport from the model simulations.

EnergySolutions*' *Response: The mass balance of water flow is not in question, since it is up to GoldSim to assure that all flows are properly accounted for. GoldSim performs no solutions whatsoever to the hydraulics of the model. In the case of the unsaturated zone, the water flow through the vertical column is defined based on external calculations. Since there are no numerical calculations in GoldSim with respect to water flow calculations, mass balance of water has no mass balance error.

The Contaminant Transport Module is a mass transport model. That is, it tracks the mass of the species as it moves them through the pathway network. However, GoldSim does not automatically impose a mass balance on the transport media that it is moving between pathways (e.g., water). Mass balances for transport media must be specifically imposed by the user. In practice, this simply means that when specifying the media volumes and media flow rates for Cells (and other pathways), you must be careful to ensure that there is a flow balance. For some systems, ensuring a flow balance may be quite straightforward. For example, if the Cells represented portions of a saturated aquifer, the volume of water in each Cell remains constant, and you need to only ensure that the flows between Cells are consistent. (From GoldSim 2010, p. 150)

The mass balance of contaminants (radionuclides) is determined internally by the GoldSim software as part of its proprietary solution algorithms. The internal solver accounts for advective flows, diffusion in air and water (where applicable), partitioning between air, water, and solid phases, as well as radioactive decay and ingrowth. The modeler and the user are not privy to the internal mass balance calculations, but a good indication of how well the model is doing can be had by experimenting with the settings for solution precision, which are accessible to the user. Using the GoldSim interface, go to Model | Options dialog, and select the Contaminant Transport tab. Under the first set of options, General Options, there is a drop-down box where the user can set the solution precision, in qualitative terms: low, medium, and high. If choosing a higher solution precision does not result in substantially different results, then the user has an indication that the mass balance is acceptable, since refining the precision does not improve the calculation.

62. INTERROGATORY CR R313-25-7(2)-62/1: NUMERICAL TESTING OF RUNGE-KUTTA METHOD

Provide a reference for the statement about numerical testing with regard to the Runge-Kutta method and describe the bases for the conclusion that stable solutions were produced.

EnergySolutions*' Response: The Runge-Kutta solution method applied to this problem was extensively tested and verified, using test models in both GoldSim and Microsoft Excel. A more extensive documentation of this testing will be provided as an appendix to a revision to the Unsaturated Zone Modeling white paper.

63. INTERROGATORY CR R313-25-8(4)(A)-63/1: AIR-PHASE ADVECTION

Provide additional explanation and justification for the exclusion of air-phase advection from the PA model.

EnergySolutions*' Response: In the Clive DU PA volatile radionuclides are transported by aqueous advection and aqueous and gaseous diffusion. Fluctuations in barometric pressure at a site with an open ground surface have been shown by Massman and Farrier (1992) to result in the movement of fresh air into the subsurface during a barometric pressure cycle. Velocities simulated at the high point of the pressure cycle and the low point were equal in magnitude and opposite in direction indicating that the fresh air that migrates into the vadose zone moves back out of the vadose zone as the barometric pressure decreases. From a contaminant transport perspective, gas that migrates upward from depth in homogeneous permeable media during a low barometric pressure event will be pushed back down as the barometric pressure increases (Nilson et al., 1991).

The presence of fractures, however, has been shown by Nilson et al. (1991) to produce conditions for net outflow of gas from the vadose zone due to barometric pressure fluctuations. The effects on gas transport due to barometric pressure fluctuations shown in numerical simulations by Massman and Farrier (1992), Nilson et al. (1991) and others are considered to be negligible in the field by Weisbrod et al. (2009) who argue that the advective events required to drive these pressure fluctuations are infrequent and depend on local weather variability. The low frequency of atmospheric events required to drive advective transport and the need for fractures to make it effective are reasons that air advection is not considered in performance assessment models.

However, other processes may contribute to significant net transport of gas. Gas migration to the atmosphere due to thermally driven convection has been demonstrated in the field by Weisbrod et al. (2009). The experiment was conducted in the Negev Desert, Israel on a fracture with an aperture that varied from 1 to 5 cm. Temperature gradients due to daily thermal cycles were shown to be sufficient to induce convective venting. The aperture of the fracture tested was large and thermal gradients in the Negev Desert are steep. The significance of the process at the Clive site for contaminant gas transport and drying of the cover would have to be determined. Air flow should be measured or simulated for apertures considered to be representative of expected cracks in the proposed cover at Clive under site specific atmospheric conditions to determine the relevance of this process to the Clive site.

64. INTERROGATORY CR R313-25-8(4)(A)-64/1: YUCCA MOUNTAIN STUDIES

Consider more recent Yucca Mountain information in preparing the Geochemical Modeling report.

EnergySolutions' Response*:* The most recent version of ANL-WIS-MD-000010 (Rev 6) is being referenced, as suggested. The Yucca Mountain Project reference (SNL, 2007), as well as the previous YMP reference (LANL, 1997) base the solubility distributions on "conservative" estimates for solubility. With the complexity of performance assessment models, it is difficult to identify what a "conservative" assumption means because of the non-linearity of the model and because of multiple endpoints. An assumption might be conservative for one endpoint, but that same assumption might not be conservative for a different endpoint. It is better to create wider distributions where there is uncertainty in the solubility than it is to be "conservative."

SNL (2007) discusses solubility for almost all of the elements in the Clive PA model and models in detail the solubility of Am, Np, Pa, Pu, Th, and U. Some of the solubility values in SNL (2007) are presented in look up tables with pH and partial pressure of CO_2 as variables. It is assumed that the Clive system has a pH of 7-8 (consistent with the Geochemical Modeling report) and a pCO_2 of 3.5 to 1.5. The pCO_2 ranges from atmospheric CO_2 to 100 times atmospheric CO_2, where 10 times atmospheric CO_2 is most likely. This range of carbonate values is higher than that assumed in the Geochemical Modeling report, but it is consistent with the high carbonate concentrations observed at Clive.

To provide a basis for comparison of the Clive DU PA model solubilities to the SNL (2007) solubilities, the ranges that were used as inputs to distribution development min, max and most likely values from the Clive DU PA model were compared to SNL (2007). This comparison is the first step in developing revised solubility distributions for the Clive DU PA model. Revisions of these distributions in the Clive DU PA model would involve a statistical analysis to develop these ranges into model input distributions. A side-by-side comparison of solubility ranges for these two references by element is given in the table below.

Overall, there is good agreement in the table between the Clive DU PA solubilities and the most recent YMP solubilities.

Table. 2-64/1. Solubility ranges for the Clive DU PA model and for the most recent Yucca Mountain Project solubility reference (SNL, 2007).

Element	Clive DU PA Model Solubility Ranges (Geochem White Paper) All units are in mol/L		YMP Solubility Ranges (SNL, 2007) All units are in mol/L		SNL (2007) notes
	min	max	min	max	
Actinium	1.00E-08	1.00E-05			not modeled in SNL (2007) because of its "short" half life
Americium	1.00E-09	1.00E-06	6.6E-08	4.6E-06	from Table 6.9-2 (SNL, 2007)
Cesium	1.00E-02	1.00E+01			no solubility given for Cs in SNL (2007) because of its high solubility
Iodine	1.00E-04	1.00E+00			no solubility given for I in SNL (2007) because of its high solubility
Neptunium	1.00E-05	1.00E-02	9.2E-07	1.4E-05	Table 6.6-9 (SNL, 2007)
Protactinium	1.00E-08	1.00E-05	9.4E-07	1.5E-05	Table 6.11-2 (SNL, 2007)
Lead	1.00E-08	1.00E-05			transport of Pb not modeled because of its short half life
Plutonium	1.00E-10	1.00E-05	9.4E-09	2.5E-06	Table 6.5-1 (SNL, 2007)
Radium	1.00E-09	1.00E-05	3.1E-07	3.8E-07	Section 6.12, p. 6-143

Radon	1.00E-03	1.00E-01			**not modeled in SNL (2007)**
Strontium	1.00E-06	1.00E-03			**no solubility given for Sr in SNL (2007) because of its high solubility; also recognize that's conservative**
Technetium	1.00E-04	1.00E-02			**no solubility given for Tc in SNL (2007) because of its high solubility**
Thorium	1.00E-08	1.00E-06	5.0E-08	1.7E-05	**Table 6.8-1 (SNL, 2007)**
Uranium	5.00E-06	2.00E-03	6.8E-06	3.3E-03	**Table 6.7-3 (SNL, 2007)**

65. INTERROGATORY CR R317-6-6.3(Q)-65/1: COLLOID TRANSPORT

Discuss the potential for other types of colloids and colloidal-forming constituents in the waste (e.g., ligands). Explain how these phenomena might affect K_d coefficients in GoldSims and justify how and why the K_d values used are representative of or conservatively low for the actual site conditions.

EnergySolutions' Response: A more detailed discussion of potential colloid transport is being added to the Geochemical Modeling report to:

- provide brief background information on colloids, including describing the different kinds of colloids that can affect radionuclide transport;
- provide brief background information on how colloids can affect K_ds,
- clarify that references given in that paragraph, including Contardi et al. (2001) and Geckeis and Rabung (2008) refer to other types of colloids (besides actinide intrinsic colloids),
- provide clearer justification for why colloidal transport is not expected at the Clive site, including more justification on the effects of high ionic strength on colloid retention,
- include the reference for the statement, “Retention of colloids is favored at high ionic strength, low pH and in impermeable rock” (Geckeis and Rabung, 2008)

In doing so, text will be added to justify how and why the K_d values used are representative of site conditions. With the complexity of performance assessment models, it is difficult to identify what a “conservative” assumption means because of the non-linearity of the model and because of multiple endpoints. An assumption might be conservative for one endpoint, but that same assumption might not be conservative for a different endpoint. It is better to create wider distributions where there is uncertainty in the solubility than it is to be "conservative."

66. INTERROGATORY CR R313-25-8(4)(A)-66/1: COLLOID RETENTION

Provide references from technical, peer-reviewed publications to support the statement that retention of colloids is favored in solutions of high iconic strength.

EnergySolutions' Response*:* Degueldre et al 2000 states,

"*Factors decreasing the colloid stability include an increase in salt (Na+, K+) concentration and in water total hardness (Ca^{2+}, Mg^{2+}).*" (Degueldre et al 2000, p.1048 (p.6/9))

ANL 2000 states,

> "*High ionic strength solutions will destabilize and promote aggregation and flocculation of the colloids*." (ANL 2000, Section 6.2.1, p.20-21 of 57).

These references are being cited in the appropriate paragraph of the Geochemical Modeling report (Section 5.0, page 18) and inserted in the References section at the end of the report to support that retention of colloids is favored in high ionic strength solutions.

67. INTERROGATORY CR R313-25-8(4)(A)-67/1: SOLUBILITY AND SPECIATION OF RADIONUCLIDES

Consider the solubility and speciation work with radionuclides in high iconic strength brines performed to support the Waste Isolation Pilot Plant. If it is not relevant, explain how solubility and speciation in high ionic strength brines are addressed.

EnergySolutions' Response*:* Currently, throughout the Geochemical Modeling report there is some discussion of higher ionic strength and how it affects particular geochemical parameters. The WIPP documents suggested are being reviewed and a discussion of the relevance of the geochemistry of WIPP is being incorporated into the Geochemical Modeling report.

68. INTERROGATORY CR R313-25-8(4)(A)-68/1: DISTRIBUTION OF HYDRAULIC GRADIENTS

Provide any factors considered when developing the magnitude and distribution of hydraulic gradients from off-normal conditions.

EnergySolutions*' *Response: The distribution for hydraulic gradient is specific to horizontal gradients in the shallow aquifer. Vertical gradients were not considered in the model.

Monthly averages of the site-wide hydraulic gradient from 1999 through 2010 were calculated by Energy*Solutions* from water level measurements. These data were used to establish a distribution for the mean site-wide gradient. The influence of any off-normal conditions occurring during the time period of the water level measurement data would be included in this data. Analysis of the data indicated that there is considerable time correlation in the data with the values changing less from month to month than they do over longer time periods. To account for this behavior several auto-regressive, moving-average (ARMA) models (Brockwell and Davis 1996) were fit to determine a model that adequately captured the time with an adequate fit for the time correlation. Amongst these models, a best model was chosen based on the Akaike information criterion (AIC), and a standard error for the mean was established based on this model's fit.

A performance assessment is based on estimates of the expected performance of the site. To achieve a realistic estimate of expected performance spatio-temporal scaling (upscaling) is needed for defining parameter distributions in probabilistic models. These upscaled distributions represent a large area/volume and time frame instead of only points in time and space. Spatio-temporal scaling is critical for model definition and understanding the impact on uncertainty for estimating 95th percentiles (for example) of model output distributions. Without proper scaling, models outputs are compromised.

The influence of off-normal conditions on shallow groundwater flow is discussed in Envirocare (2004) for two cases. In the first, flow was affected by localized recharge from a surface water retention pond in the southwest corner of the facility in the spring of 1999 and in the second, a ground water mound formed between March 1993 and spring 1997 below a borrow pit excavated near the 11e.(2) cells that occasionally filled with rain water. The mound decreased and was negligible by the time of the report in 2004. The latter of these conditions was captured by the hydraulic gradient data set used to develop the distribution for the model. The influence of these conditions on the hydraulic gradient appear to be transient and of small magnitude. The only type of climate change considered in the model was the potential impact of glacial epoch pluvial lake events on the CAS waste embankment.

The hydraulic gradient (i) is modeled as normal distribution with a mean of 6.9×10^{-4} and a standard deviation of 1.27×10^{-4}. The influence of the range of the gradient given by the distribution can be evaluated by calculating a range of groundwater velocity derived from the gradient using Darcy's law. The saturated hydraulic conductivity (Ks) is modeled as a normal distribution with a mean of

9.6 x 10^{-4} cm/s and a standard error of 9.67 x 10^{-5} cm/s. Porosity (φ) is modeled as a normal distribution with a mean of 0.29 and a standard deviation of 0.05. From Darcy's law the groundwater flux (J) is:

$$J = K_s \ i$$

and the groundwater velocity (v) is:

$$v = J/\varphi$$

The range of groundwater velocity is estimated by choosing values from each distribution corresponding to the mean ± 3 standard deviations and calculating values of v from the equations above. Maximum and minimum values for groundwater derived from the hydraulic gradient distribution range from 4.2 times the mean to 1/5th of the mean.

The significance of uncertainty in the value of the hydraulic gradient was evaluated for the Clive DU PA model through a sensitivity analysis. The sensitivity analysis identifies which variable have distributions that exert the greatest influence on the response. The response evaluated in the sensitivity analysis for the PA model was dose. The results showed that hydraulic gradient was quantitatively determined to not be a sensitive parameter. The text of the Saturated Zone Modeling report is being modified to include this discussion.

69. INTERROGATORY CR R313-25-8(4)(A)-69/1: LONGITUDINAL DISPERSIVITY

Provide the longitudinal dispersivity value used in the model and references for any studies or calculations that demonstrate the GoldSim model grid spacings are sufficiently small. Provide the mass-balance information for both the flow and contaminant transport from the model simulations. Indicate the length and location of the horizontal domain used for groundwater flow and transport modeling in the GoldSim simulations.

EnergySolutions*' *Response: The text in Section 4.0 and subsections in the Saturated Zone Modeling report is being revised as follows:

[Section 4.0, first paragraph, p.4:]

> *"Calculations in the PA Model that are needed for estimating transport in the shallow saturated zone include the cross-sectional area normal to the flow direction (thickness times width), definitions of the material*

SatZone_Medium (hydraulic conductivity, porosity, and bulk density of Unit 2), the Darcy velocity (a function of gradient and hydraulic conductivity) and radioelement-specific solid/water partition coefficients (Kds). The distributions for bulk density and porosity have been described previously in Section 3.2 and the hydraulic gradient in Section 3.3. Aquifer dimensions are described in Section 4.1. Since the flow through the saturated zone is modeled as a horizontal column of discrete GoldSim Cell pathway elements, dispersivity is not explicitly defined as it would be for an analytical solution such as a plume. This is discussed in Section 4.2 The distributions for Kds are described in the Geochemical Modeling white paper."

[Section 4.1, p.4 et seq.:]

4.1 Saturated Zone Dimensions

"Both the unsaturated (vadose) and saturated zones are represented in the Clive DU PA Model as GoldSim Cell pathway elements. A Cell pathway is mathematically equivalent to a continuously-stirred tank reactor (CSTR), in which the contents are instantaneously and uniformly mixed throughout the volume. The representation of the saturated zone in the PA Model consists of a series of linked cells. The mass and rate of water flowing through the column of cells depends on the Darcy velocity and the cross-sectional area perpendicular to the flow direction. This area is simply the (stochastic) thickness of the aquifer times its width, which is dependent on the geometry of the embankment. The transport of contaminants in water through the vadose zone and into the saturated zone is modeled as advective mass flux links from the unsaturated zone vertical column into the various cells underlying the embankment. This contaminated recharge is distributed along the saturated zone flow pathway, with a fraction entering each saturated zone cell. The cell pathways and their interconnections are represented schematically in Figure 1."

[Section 4.1, p.5, last paragraph:]

"An assumption of the mixing cell approach is that all contaminant mass that enters the cell is completely mixed and equilibrated among all media in the cell, consistent with the mathematical representation of a CSTR. To provide contaminant mass balance, GoldSim requires information specifying the volume of the cells. For the Clive DU PA model, the extent of the saturated zone below the Class A South cell and the distance from the toe of the waste in the disposal cell to the compliance point are represented as a horizontal network of linked cells (Figure 1). GoldSim requires the specification of the length of the cell in the direction of flow

and the cross-sectional area of the cell. The length of each cell is the transport distance divided by the number of cells. The choice of the number of cells used is based on standard modeling practice, with more discussion provided in Section 4.2. The cross sectional area is the product of the cell width and height. For the Clive DU PA model, the cell width is set to the width of the Class A South cell perpendicular to the direction of flow ("length overall" in Figure 3 of the Embankment Modeling white paper). The height of the cell corresponds to the aquifer thickness."

[Section 4.2, p.11:]

4.2 Dispersion

"The process of spreading of a contaminant in groundwater that occurs in addition to movement by advective flow is represented in mathematical models by the dispersion coefficient. The dispersion coefficient represents both the mechanical (hydrodynamic) and chemical components of mixing and is written as:

[equation 2 and its where block remain as is]

Only longitudinal dispersion is considered for this discussion because of the geometry of the transport pathway. The width of the disposed waste is the dimension perpendicular to the groundwater flow direction. This distance is 1,429.6 ft ("length overall" in Figure 3 of the Embankment Modeling white paper). The distance from the edge of the waste to the compliance point is 90 ft as required by the groundwater discharge permit. The entire horizontal length of the saturated zone cells is this 90 ft plus the footprint of the embankment parallel to the direction of water flow (1775.0 ft, the "width overall" in Figure 3 of the Embankment Modeling white paper), making a total length of 1865 ft. With this geometry, the width of the source is more than 5 times the distance from the edge of the source to the point of compliance, making transverse dispersion insignificant.

In a numerical model such as the Clive DU PA Model, the discretization of the flow path into cells results in an effective (numerical) longitudinal dispersion (parallel to the flow direction) due to the full mixing of a CSTR even with no additional dispersivity defined. Because of this inherent numerical dispersion, no additional dispersion coefficient is included in the saturated zone transport calculations in the Clive DU PA Model.

Dispersion is discussed in the User's Guide for the GoldSim Contaminant Transport Module (GoldSim 2010) in the context of the GoldSim Aquifer *pathway element. The Aquifer element is a collection of linked Cell elements, and the saturated zone in the Clive DU PA Model is also represented as a collection (column) of Cell elements, which is somewhat more flexible than the predefined GoldSim Aquifer element. Longitudinal dispersivity is commonly approximated as 0.1 times the length of the transport path (GoldSim 2010). For the Clive DU PA Model the point of compliance is a fixed location 232 ft from the edge of the DU waste, since the length travelled under the side slope of the embankment, which contains no DU waste (142 ft), is added to the standard 90 ft. The estimated value of the dispersivity would then be 232 ft /10 = 23 ft. In order to reduce unwanted numerical dispersion, GoldSim (2010) recommends that the number of Cell elements used in the column be greater than the transport path distance divided by twice the dispersivity. For the Clive DU PA Model geometry, the number of cells should therefore be greater than 232 ft / (2×23 ft) = 5. The horizontal column of Cell elements that represents the saturated zone to the well in the Clive DU PA Model contains 20 cells and there are 2 cells under the side slope. The number of cells making up the transport path exceeds the minimum recommended. The influence of the value chosen for dispersivity on model results could be evaluated with some model modification in future sensitivity analyses.*

A diagram is being provided in the Saturated Zone Modeling report showing the location of the saturated zone modeling domain including the location of DU waste, the point of compliance monitoring well, the DU disposal cell's buffer zone, and outer boundaries of property owned and controlled by ES.

The mass balance of water flow is not in question, since it is up to the GoldSim programmer (the model author) to assure that all flows are properly accounted for. GoldSim performs no solutions whatsoever to the hydraulics of the model. In the case of the saturated zone, the water flow through the horizontal column is defined as a constant value all the way through the column. Since there are no numerical calculations in GoldSim with respect to water flow calculations, mass balance of water has no mass balance error.

The mass balance of contaminants (radionuclides) is determined internally by the GoldSim software as part of its proprietary solution algorithms. The internal solver accounts for advective flows, diffusion in air and water (where applicable), partitioning between air, water, and solid phases, as well as radioactive decay and ingrowth. The modeler and the user are not privy to the internal mass balance calculations, but a good indication of how well the model is doing can be had by experimenting with the settings for solution precision, which are accessible to the user. Using the GoldSim interface, go to Model | Options dialog, and select the Contaminant Transport tab. Under the first set of options, General Options, there is a drop-down box where the user can set the solution precision, in qualitative terms: low, medium, and high. If choosing a higher solution precision does not result in substantially different results, then the user has an indication that the mass balance is acceptable, since refining the precision does not improve the calculation.

70. INTERROGATORY CR R313-25-7(2)-70/1: GULLY SCREENING MODEL

Explain and justify why a more sophisticated erosion model than the initial screening-type gully model is not needed and why gully formation is restricted to locations only on the cover system and does not include other locations.

***EnergySolutions' Response**:* As committed in Section 1 of the "Condition 35 Compliance Report", Revision 1, significant quantities of depleted uranium will be disposed below grade to enhance assurance of continued isolation under geologic-time events. The impact of gullies on the dose assessment is minimal for the below-grade disposal scenario. Therefore, the screening-type gully model is adequate for this evaluation.

The Clive DU PA Model v1.0 evaluated the effects of the occurrence of gullies in a screening approach, as stated in the Final Report. The mathematical model used to represent a fully-formed gully provided a suitable proxy for a fully-fledged landscape evolution model, which would be a much more significant undertaking. A small number of gullies were used simply in order to determine if gullies presented any contribution to dose or threat to waste containment. One purpose of this v1.0 of the model, then, is to identify those processes that are of concern for the site. As the sensitivity analysis has made clear, gully formation is indeed a process of concern for the site, and in that sense, v1.0 of the Model has done its job.

This interrogatory suggests a scenario where sheet and gully erosion could begin in a nearby excavation, away from the disposal cell, and by head-cutting processes eventually erode the side and top slope areas of the embankment cover. For example, surface soil is excavated at the Clive site to provide material for clay liners and barriers in the waste cover systems. These excavations have left shallow borrow pits of unconfirmed stability in the vicinity of radioactive waste disposal embankments.

While the detachment and movement of soil particles by water and wind is a natural process occurring at very slow rates since the soil was formed, the steeper slopes remaining from the borrow pit construction may act to increase the rate of erosion on the faces of the borrow pits and upslope from them. As accelerated erosion continues the heads of small channels formed at the borrow pit face by surface water flow migrate upslope away from the face. To investigate the likely rates of this headward erosion process a suite of landscape evolution models using the SIBERIA code were developed for a representative face of a borrow pit to predict the response of the pit face to water erosion processes during runoff events.

The models provide a quantitative description of the evolution of slopes and channels over time. The objective of the models was to provide a realistic estimate of the rate of progression of hillslope erosion loss and channel development towards the existing embankments. Results at 1,000 years showed the greatest elevation change at the crest of the pit wall as expected with channels extending upslope only 100 m to 150 m depending on the rainfall intensity used. Sediment from upslope accumulated at the base of the pit wall effectively decreasing the slope with time. These results represent bare soil conditions. The presence of rock, vegetation, and plant litter are likely to reduce the rates of hillslope erosion and channel growth. Model parameters were based on soil texture measurements at the site and photographs of erosional features, but the model was not calibrated. SIBERIA model predictions of long-term erosion effects for the borrow pits should be considered as approximate assessments of their evolution. The lack of site specific runoff and sediment yield data and the assumption of steady-state landscape forming events make long-term predictions uncertain.

The results of the SIBERIA modeling for the borrow pit are being abstracted and adapted to the disposal mound in the model of the ET Cover. Because of the slope differences, this will over-estimate sediment transport offsite, and will over-estimate depth of gullies formed. This will be included in the next version of the model and the report. Further erosion modeling needs will be evaluated after that model and report are reviewed.

Note also, that under the scenario that the DU waste is disposed below grade, the erosion consequences are likely to be minimized. This is evident in the current model results by comparing the three pairs of scenarios.

See also Interrogatory #120.

71. INTERROGATORY CR R313-25-8(4)(A)-71/1: BIOTIC PROCESSES IN GULLY FORMATION

Provide additional rationale for excluding potentially important biological processes when considering gully formation.

EnergySolutions' Response: One part of this question pertains to the initiation and formation of gullies. Page 4 of the Erosion Modeling report states that animal burrowing is but one mechanism that could lead to gully formation on the cover system.

For the purposes of the model, several simplifying assumptions are made. One of these assumptions is that the gully functions independently of the main model processes. This component of the model looks at the effects of gully formation on the rest of the model. The mechanism of gully formation (e.g., burrowing animals, tree throw, OHV use, tornados) is not important in the function of the model, only that the gully exists.

The various mechanisms that might start a gully are to be considered in the determination of input distributions that would represent the number and timing of gully forming. In the Clive DU PA Model v1.0, no such sophisticated analysis was done—rather, a simple distribution was used as a screening tool in order to determine whether gully formation would be a significant process at the site.

Another part of this question addresses gully penetration into and possibly through the cover, and what effects that may have on dose assessment. It is true that plants that root in gullies or animals that burrow into the bottom or slopes of gullies that have already formed would be closer to the waste than plants and animals on the surface of the cover. The thinner cover at gullies could also result in enhanced infiltration and enhanced radon flux from the wastes below, especially if the radon barrier were compromised.

72. INTERROGATORY CR R313-25-8(4)(A)-72/1: DE MINIMIS DOSE VALUE

Provide the justification for proposing a de minimis (i.e., below regulatory concern) dose value.

EnergySolutions' Response: NRC was required under Section 10 of the Low-Level Waste Policy Amendments Act of 1985 to

"*establish standards for determining when radionuclides in waste streams were in sufficiently low concentrations or quantities as to be below regulatory concern, thereby potentially exempting them from NRC Low-Level Waste regulation*" (NRC, 2007; NUREG-1853, Section 3.5).

The de minimus risk level introduced in Section 3.3.3 of the Dose Assessment report is not related to establishing concentrations or quantities "below regulatory concern" in disposed waste. Rather, this level was introduced to support a methodology for evaluating collective (population) radiation dose in relation to the as-low-as-reasonably-achievable (ALARA) assessment endpoint of the Performance Assessment.

The rationale for establishing and applying a de minimus risk level in the assessment of collective dose is described in Section 3.3.3 of the Dose Assessment report as follows:

> "*In the context of the current assessment, and in lieu of guidance that defines what an 'acceptable' population dose might be; a means must be applied so that all populations (e.g., the entire United States) are not assessed, as this would be burdensome and meaningless. For instance, it is known that a large population will indeed be exposed to the site if current conditions continue; i.e., the population of drivers on Interstate-80. However, as previously mentioned, each of these drivers would be exposed for very short periods of time. In order to gauge the importance of quantifying dose for this population, and indeed any population that might be exposed for brief periods and/or to very low concentrations, the de minimus risk approach will be applied. As explained previously, according to the EPA a 0.05 mrem/year dose corresponds to approximately a 1-in-1-million excess cancer risk. Receptors other than Ranchers, Sport OHVers, or Hunters will be evaluated using this individual dose threshold to determine whether their doses should be considered when computing collective dose. Cumulative population dose will not include contributions from these receptors unless individual doses are above 0.05 mrem/year."*

Clarification along these lines is being added to the Report.

73. INTERROGATORY CR R313-25-19-73/1: ALARA CONCEPT

Ensure that the information provided on the ALARA concept is consistent with that in International Commission on Radiological Protection (ICRP) Publication 101b.

EnergySolutions' Response: Sections 1 and 2 of the Decision Analysis Methodology report are being revised to incorporate ICRP Publication 101b. ICRP 101b (2006) describes updates to previous ICRP publications addressing ALARA, BATNEEC (best-available technology, not entailing excessive costs), and optimization. The ICRP document is not limited to radioactive waste issues, therefore not all of the recommendations are germane to radioactive waste disposal, particularly not in the US. However, in general, the ICRP recommendations align with the spirit of the decision analysis approach applied in the PA. For example, ICRP (2006, p. 71) states that "the principle of optimisation is defined by the Commission as the source-related process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable below the appropriate dose constraints, with economic and social factors being taken into account."

Individual doses are addressed in the PA via comparisons with individual dose limits (consistent with NRC and UDEQ regulations), and ALARA is addressed via estimation of collective population dose over the performance period plus 'conversion' of this to economic terms, consistent with NRC guidance (see Section 6.4, pages 76–77, of the Neptune and Company, Inc., Final Report for the Clive DU PA Model version 1.0, June 1, 2011: Appendix A of EnergySolutions, Utah Low-Level Radioactive Waste Disposal License – Condition 53 (RML UT2300249) Compliance Report, June 1, 2011).

For example, the PA's approach specifically addresses the following characteristics of the population (from Table 3.1, p. 83 of ICRP, 2006):

- Gender
- Age
- Habits
- Characteristics of the exposure
- Distribution of exposures in time and space
- Number of individuals
- Minimum individual dose
- Maximum individual dose
- Mean individual dose
- Statistical deviations
- Collective dose associated with ranges of individual doses

Thus, to the extent possible under the current applicable regulations, the DU PA's ALARA approach is consistent with ICRP (2006). The ALARA analysis that was performed (and that needs to be updated and fixed) was based on population dose endpoints and on the "cost to society" of such population doses. The dose costs used originated in an expert elicitation sponsored by NRC, and resulted in an estimate of $1,000 per person rem per year. This has been updated since, but the underlying principle was that this dose cost would be used to represent all associated costs and values. In effect the $1,000 per person rem per year value judgment is meant to capture many aspects of cost and value judgments.

It could probably be argued (and we would argue) that there are better approaches than using default values provided by NRC and/or DOE. It would be better to develop costs and value judgments that are specific to the site. NRC recently endorsed site-specific Performance Assessments, and this should be a component of a site specific assessment. We would argue that more effort should be put into these aspects of the model so that waste disposal, closure and long term maintenance/monitoring can be optimized. ALARA opens the door for this type of analysis, but at the moment we have tried to move the process forwards a few steps by actually incorporating an ALARA analysis of this type.

Note also, there are other aspects described in the ICRP document, such as social considerations/value or environmental (e.g., ecological impacts) considerations, which are not directly addressed in PAs. It is arguable whether the original $1,000 per person rem per year value includes these aspects. The basic decision analysis approach could certainly be expanded to incorporate any of the types of analysis discussed in ICRP (2006; e.g., Annex A) depending on the particular need. We agree with the ICRP that PAs should move toward a more holistic, decision-analysis basis; as this approach would allow broader set of considerations to be assessed in a rational decision-making framework. This would lead to much more effective disposal, closure and long term maintenance/monitoring decisions. The approach employed in the DU PA is a step in this direction.

74. INTERROGATORY CR R313-25-8(5)(A)-74/1: TAILORED DISCUSSION OF SENSITIVITY ANALYSIS

Expand on the Sensitivity Analysis report to discuss the sensitivity index and the partial dependence plots for specific parameters modeled in the Clive DU PA.

EnergySolutions' Response*:* The purpose of the white papers is to provide details about inputs to the process, and, in this case, the SA methods used for model evaluation and identification of sensitive parameters (variables). It is not intended to describe results. However, the results section in the main text is being expanded, or an appendix is being added that more fully describes the sensitivity analysis output, and provide more context when certain types of input (such as inventory) are not identified as sensitive.

75. INTERROGATORY CR R313-25-7(9)-75/1: BRANCHING FRACTIONS

Provide a reference list with complete information for Tuli, 2005.

EnergySolutions' Response*:* A References Section is being created and the following reference is being added to the Model Parameters report.

> *Tuli, J.K., 2005, Nuclear Wallet Cards, National Nuclear Data Center. Brookhaven National Laboratory. Seventh edition, April 2005.*

76. INTERROGATORY CR R313-25-7(10)-76/1: QUALITY ASSURANCE PROJECT PLAN SIGNATURE PAGE

Provide a complete signature page for the Quality Assurance Project Plan and its appendices.

EnergySolutions' Response*:* The Quality Assurance Project Plan and appendices are being updated to include signatures of Neptune and Company officials. There were no Utah approvals required.

77. INTERROGATORY CR R313-25-7(10)-77/1: QUALITY ASSURANCE PROJECT PLAN PAGE NUMBERING

Provide page numbers in the Quality Assurance Project Plan.

***EnergySolutions*' *Response*:** The Quality Assurance Project Plan is being revised to include page numbers.

78. INTERROGATORY CR R313-25-7(10)-78/1: GOLDSIM MODEL CALIBRATION

Describe the role of model calibration in substantiating that GoldSim adequately simulates the physical, chemical, and biological processes at the Clive site.

***EnergySolutions*' *Response*:** Calibration of a model refers to demonstrating that the model is capable of producing values of the state of a system consistent with observed values. Calibration is accomplished by determining the combination of model structure, parameters, boundary conditions, and forcing functions that produce the values of the state of a system that give the best possible fit to the observed values. Model calibration is one approach used for model parameter estimation. Model calibration is usually considered to be a step in the model development process rather than part of model corroboration and verification. However, traditionally model calibration is used on models that are parameter rich and data poor, in which case the calibration (really estimation) must be constrained, so they cannot cover the entire parameter space. For this reason, Bayesian methods would be better, but this is not the current direction of traditional calibration.

The system states simulated by the Clive DU PA model are the concentrations of radionuclides in media (and eventually dose) over extremely long time periods. For calibration, these concentrations in media would be required as calibration targets. Radionuclide concentrations representing transport for long time periods have been identified at natural analog sites but are not available for most disposal sites. Because of the long time periods considered, a calibration exercise for the Clive DU PA model where parameter distributions are adjusted to match observed concentrations is not feasible.

An approach different from calibration was used to represent parameters for the Clive DU PA model. Due to natural heterogeneity and random variability a model parameter is often more accurately represented by a statistical distribution than by a single value (EPA, 2009). The data range and variance of the spatial and temporal effects being modeled for the Clive DU analysis are too broad for data that represent points in time and/or space to be used directly. The probabilistic simulations for the PA modeling involve randomly selecting values from all input distributions (outside of the exposure parameters), and then applying those values to the entire spatio-temporal domain of the model. Spatio temporal scaling (upscaling) is the methodology used to transform point data into distributions representing expected values of a parameter and their uncertainty for model input. Upscaling in this context is a form of averaging to the time steps and spatial scale of a specific modeling application. The upscaled parameter input distributions also provide the basis for the uncertainty analysis for the model.

Approaches for the model evaluation process including verification and corroboration are described in the response to Interrogatory CR R313-25-7(10)-80/1: Testing of GoldSim Abstractions.

The Clive DU PA Model is a highly-integrated system model, with many interrelated processes. Given that these processes influence each other, and their combination can produce sometimes counter-intuitive results, there is no practical way to verify the calculations. The main approaches used for model evaluation for the DU PA model are reasonableness testing during model development, and global sensitivity analysis. Global sensitivity analysis is used for far more than simply identifying sensitive parameters. It is used throughout model testing to evaluate the model, determine if the model is performing in ways that are expected, and for evaluating if there are components of the model that need refinement. Because all the inputs are probabilistic, the global sensitivity analysis varies all inputs simultaneously. It is essentially a regression analysis, but piecewise non-linear regression. As such the output can be interpreted directly. If the results do not match expectations of the model, then the sensitivity analysis will very quickly indicate that there is something not quite right, and the model is investigated for the unexpected results. This is a very powerful tool for model evaluation. The approach is very different than the calibration approach described above, but provides justification for the model, and a basis for model updating as more data are collected. This cycle of model building and sensitivity analysis will continue throughout the PA Maintenance program.

Otherwise, the only process that is actively calibrated within the Clive DU PA Model v1.0 is that of the air-phase diffusion of radon gas. This is deemed necessary since the relatively short half-life of 222Rn (under 4 days) adds a challenge to numerical analysis of diffusive transport of species that decay quickly relative to the rate of diffusion. (The interested user can research Dahmköhler numbers.) The calibration is to the analytical solutions provided in the Nuclear Regulatory Commission Regulatory Guide 3.64 (NRC 1989).

79. INTERROGATORY CR R313-25-7(10)-79/1: CRITICAL TASKS AND SCHEDULE

Update the schedule and completion dates for the critical tasks.

EnergySolutions' Response*:* The Quality Assurance Project Plan (QAPP) is being revised to include actual completion dates for scheduled tasks and those that were indicated as TBD at the outset of the project as appropriate.

80. INTERROGATORY CR R313-25-7(10)-80/1: TESTING OF GOLDSIM ABSTRACTIONS

Provide information on the verification and benchmarking exercises that were designed to test the GoldSim abstractions against results obtained from process-level analytical and/or numerical models.

EnergySolutions' Response*:* Neptune uses a process for the model validation/verification and benchmarking described in this Interrogatory to test the GoldSim abstractions against results obtained from process-level analytical and/or numerical models. For the DU PA Model v1.0, model verification primarily consisted of reasonableness checking and did not include formal model benchmarking processes.

81. INTERROGATORY CR R313-25-7(2) AND 7(6)-81/1: COMPARISON OF DISPOSAL CELL DESIGNS

Provide a detailed annotated comparison of (1) the design of the Class A South embankment design[1] described in FRV1 and upon which the DU PA dated June 1, 2011, was based, (2) the Division-approved Class A West embankment design discussed in the 2013 Compliance Report (Revision 1, 2013) and (3) the Federal Cell design now proposed for DU disposal. The comparison should include design features and design criteria that are common to the three cells, as well as those that are different among the three designs. The comparison should include such factors as physical dimensions, materials used, types of waste, infiltration rates, depth of waste burial, waste depth compared to native grade, design life of the cell, liner and cover system specifics and other assumptions used in groundwater modeling, such as soil layer porosity and permeability, soil/water partition coefficients (K_d values) and solubilities. Explain and justify why the Class A West Cell design is relevant and applicable to the new DU disposal cell to be constructed in the far southwest corner of Section 32.

[1] At a minimum, this would include both *Amendment Request Class A South/11e.(2) Embankment*, Revision 0, dated January 4, 2008 (Energy*Solutions* 2008), and *Class A South/11e.(2) Embankment Revised Application & Response to Completeness Review*, dated June 9, 2009 (Energy*Solutions* 2009).

Also explain and justify why current construction specifications and quality assurance/quality control requirements used at the Class A West Cell (or any other Clive disposal cell) have relevance to the DU PA, now that DU Waste disposal is to be examined for at least 10,000 years.

Provide a single, stand-alone engineering design report, including drawings and construction specifications, for the cell where DU waste will be disposed. Include detailed cross-sections to clearly identify the specific below-grade depth interval that the DU waste will occupy, as well as design elevations for all pertinent site and disposal embankment features. If Energy*Solutions* plans to implement any evapotranspirative cover design for the DU cell, provide specific, discrete, and detailed engineering plans and specifications for the cell where this disposal will take place. Explain the current status in obtaining approval from DRC of an evapotranspirative cover design for the Class A West Cell.

Describe the types, forms, and locations of intruder barriers that will be provided for the DU waste in the disposal cell selected. Elaborate on how these barriers can and will endure across deep time periods (i.e., at least 10,000 years).

EnergySolutions' Response*:* Drawing series 14004 is provided in Section 4.0 to this response to clarify Federal Cell design and placement of significant quantities of depleted uranium therein.

See also the response to interrogatories CR R313-25-7(6)-84/1 and CR R313-15-1009(2)(B)(I)-158/1.

82. INTERROGATORY CR R313-25-20-82/1: LIMITATION ON INADVERTENT INTRUDER SCENARIOS

Explain and justify why the language of R311-25-7(8) limits the types of intrusion scenarios to be considered.

EnergySolutions' Response*:* Limitation and selection of credible inadvertent intruder scenarios are addressed in the response provided to Interrogatory CR R313-25-8(4)(B)-07/1.

83. INTERROGATORY CR R313-25-20-83/1: INTRUDER-DRILLER AND NATURAL RESOURCE EXPLORATION SCENARIOS

Explain why a lack of subsurface mineral resources renders the intruder-driller scenario inapplicable. Evaluate inadvertent intrusion at locations within the facility's buffer zone and determine all exposure pathways and doses to a member of the public.

Explain the reason for excluding the intruder-driller scenario from this PA, taking into account the fact that the guidance in NUREG/CR-4370 refers to an intruder drilling for water, not mineral resources, and the fact that such a scenario was included in a prior site-specific PA.

EnergySolutions' Response: See the response to Interrogatory CR R313-25-8(4)(b)-07/1. Addition justifications and scenario descriptions are included in Report Appendices 1 "*Clive DU PA FEP Analysis*", 2 "*Clive DU PA CSM",* and 11 "*Dose Assessment".*

84. INTERROGATORY CR R313-25-7(6)-84/1: BELOW-GRADE DISPOSAL OF DU

Explain how Figure 1-2 demonstrates that the entire inventory of DU can be disposed below grade. Provide calculations demonstrating that below-grade disposal will be achieved in the Federal Cell and that the burial depth is sufficient to protect the DU waste.

Indicate the drum/cylinder dimensions and orientation after placement on the respective waste lifts. Indicate the container packing arrangement (e.g., cubic, rhombic, octhahederal) and the minimum, maximum, and average distance that will be left between DU containers. Explain how a degraded embankment would continue to adequately control radiation dose to a member of the public and describe the types, forms, and locations of intruder barriers and how they will endure for a period of 10,000 years or more.

EnergySolutions' Response*:* Figure 1.2 has been clarified to reflect Energy*Solutions'* commitment that only a volume of depleted uranium that can be disposed of below grade in the Federal Cell will be managed, regardless of placement geometry.

"Below grade" is defined as being below the original grade elevation of the Clive site with no minimum additional cover. The performance assessment demonstrates that it is highly unlikely that a pluvial lake will encroach on the embankment within the compliance period; therefore, significant quantities of depleted uranium will remain buried beneath the overlying above-grade portion of the Federal Cell and its cover system. No additional cover or barrier is required to demonstrate performance to the compliance criteria.

NRC has confirmed that depleted uranium, even in significant quantities, is Class A LLRW. Thus, there is no requirement for an intruder barrier, let alone a demonstration that it could persist for 10,000 years or more.

In order to address the current round of interrogatories, the model is being revised to replace the rip-rap cover with an ET cover. This will have a significant effect on infiltration (lowering infiltration) so that disposal of DU below grade is not expected to adversely impact groundwater. In addition, an erosion model is being included that addresses both sheet and gully erosion based on the properties of the ET cover. Upon this evaluation, a more informed response can be provided concerning the potential effects of erosion on waste buried below grade.

Regarding the comment on pluvial lake recession, more recent research indicates that the return of a pluvial lake is extremely unlikely in this climate cycle (less likely than modeled) because of the combination of expectation of insolation in the current climate cycle and current CO2 levels. However, aeolian deposition will continue unabated, at rates that are at least 0.1 mm/yr (and perhaps considerably more). Consequently, by the time a lake returns, the site will be partially buried by aeolian sedimentation, or if the next lake does not arrive until the next climate cycle, completely buried. An update to the model is warranted given this new information. Consequently, under some reasonably possible, or even likely, future scenarios the site will not be destroyed by the first lake, but will instead be further covered instead. The aeolian deposition rates should be considered as part of the relatively near-term erosion modeling and the deeper time modeling. In both cases the seolian deposition seems likely so enhance site stability.

The response to Interrogatory #18 describes the available information on aeolian deposition, and further research is being performed prior to completing the next version of the model.

85. INTERROGATORY CR R313-25-8(4)(A)-85/1: UNCERTAINTY DISTRIBUTIONS ASSIGNED TO DOSE CONVERSION FACTORS

When discussing the uncertainty associated with the risk coefficients in Federal Guidance Report 13, the discussion should include the work performed by Pawel et al. (2007), which was an update of the uncertainty analysis in Federal Guidance Report 13 for the cases of inhalation and ingestion of radionuclides and expands the analysis to all radionuclides addressed in that report. In addition, reference should be made to the guidance provided in NCRP, 1996; NCRP, 1998; NCRP, 2007; NCRP, 2009; NCRP, 2012; and Puncher and Harrison, 2013.

EnergySolutions' Response*:* With regard to part (1) of the last paragraph of the Basis for Interrogatory, please see the final paragraph of Section 3.4.3 of the Dose Assessment report:

> "*Note that this method only addresses one component of uncertainty associated with DCFs, and thus must be viewed as a pilot effort.*"

The text of Sections 3.4.3 and 3.4.4 of the Dose Assessment report is being revised to include a summary of the literature that discusses the other factors that contribute to uncertainty in the DCFs and the rationale for developing distributions that addressed only a limited portion of DCF uncertainties, as requested in parts (2) and (3) of the last paragraph of the Basis for Interrogatory. Key points from the supplemental information related to DCF uncertainty provided below are being used for these revisions.

Additionally, the last sentence of the first paragraph of Section 4.4 is being modified as:

> "*Distribution development for one source of uncertainties inherent in DCFs (i.e., associated with REFs) was described previously."*

Supplemental Information

Issues Associated with Addressing DCF Uncertainties in Addition to the REFs

1. Some sources such as EPA (EPA 2007, or Pawel et al. 2007) evaluate uncertainty associated with risk, not dose. It is difficult to separate out sources of dose-related uncertainty from those associated with dose-response (i.e., risk) in EPA's work. However, because EPA has already conducted the considerable research to develop uncertainties associated with radionuclide-specific risks, an efficient alternative would be to evaluate cancer risk as part of the PA modeling and as an endpoint in addition to radiation dose. There are substantial advantages to a risk-based approach. While dose is essentially a proxy for risk, risk is likely better understood by stakeholders and decision-makers than dose; and would allow other analyses such as PAs for mixed chemical-radionuclide waste to be conducted, comparisons to be made between radioactive waste disposal and other forms of hazardous waste disposal, and so on. However, all of the present radioactive waste regulations focus on dose. If NRC was willing, EPA's or a similar risk assessment approach could be applied alongside the dose assessment for comparative purposes. The cancer risk results can be used to inform the PA model sensitivity analysis. Dose could still be used to assess regulatory compliance, and cancer risk can be used to inform sensitivity analysis and risk communication and optimized decision making.

2. There would be considerable benefit to quantifying the full range of uncertainties associated with DCFs and/or risk. At present the total uncertainty associated with DCFs (aside from REFs) and/or risk conversions (see above) is not quantified in the PA, and thus total uncertainty in the PA modeling results is underestimated. Underestimation of total uncertainty can lead to suboptimal decisions; as the final dose or risk distributions will be too 'narrow' (i.e., expressing overconfidence in results). DCF and risk uncertainty could be considerable contributors to total uncertainty, and indeed could

overwhelm other sources of uncertainty in the PA modeling that have been previously identified as major contributors in the sensitivity analysis only because the scope of DCF/risk uncertainty assessment has been limited. In other words, if DCF and/or risk uncertainty are included in the sensitivity analysis, they may be ranked quite high in terms of contribution to total uncertainty.

3. As the only source of uncertainty associated with DCFs that was evaluated was the REF, a review of the broader literature was not considered necessary. However, if further sources of uncertainty are to be evaluated, then this literature should be reviewed. A brief example of such a review follows.

4. A major implicit assumption in the use of DCFs and dose limits is that ionizing radiation exhibits a linear, no-threshold dose-response curve with regard to carcinogenicity (the linear no-threshold hypothesis, or LNT). This has been assumed for many years, but there is a large and growing literature that counters this assumption; i.e., that ionizing radiation exhibits thresholds of effect and/or triggers adaptive response (depending upon the type of radiation, target organ system, etc.). If cancer risk is evaluated, then this could potentially allow thresholds of effect to be evaluated. This would likely affect estimated risks dramatically, as at present the assumption that there is no threshold of effect (with 100% confidence) may identify low-dose risks where none exist.

5. Quantification of other-than-REF uncertainties associated with DCFs would require some effort that is beyond the scope of this project alone. In some cases, these may be available in the literature (e.g., the work of Puncher and Harrison 2013), but such work has been performed for only a few of the radionuclides of interest. An efficient process may be to start with the radionuclides that have been evaluated by other researchers in order to demonstrate the impact of incorporating other-than-REF uncertainties in the dose assessment.

6. Incorporation of other sources of DCF uncertainties, or cancer risk uncertainties, will require model and distribution development, and thus can only be addressed in a future PA model revision.

<u>Brief Review of Relevant Literature.</u>

A number of groups have investigated uncertainty in radiation dose that is delivered to internal target organs (i.e., effective dose, via use of DCFs). For example, the US National Committee on Radiation Protection and Measurements (NCRP) has published a general methodological guide for uncertainty analysis in dose and risk assessments (NCRP 1996), a guide for evaluating the reliability of the biokinetic and dosimetric models used to assess individual doses (NCRP 1998), and assessments of uncertainties associated with internal (NCRP 2009) and external (NCRP 2007) dosimetry. Additionally, the United Kingdom's Health Protection Agency's (HPA's) Centre for Radiation has conducted uncertainty analyses of internal and external dosimetry (Puncher and Harrison 2012, 2013).

Major sources of uncertainty associated with effective dose estimation include the following (Puncher and Harrison 2012):

- Biokinetic models and their parameter values that are used to predict the dynamic distribution of radioactivity within the body
- The geometric relationship of source and target tissues, their dimensions and masses. These influence the amount of energy deposited in tissues
- The relative effectiveness of different radiation types in causing cancer and differences between tissues in their sensitivity to radiation induced cancer

Estimation of disease dose-response and risk (i.e., risk assessment) and associated uncertainties involves 'translating' effective dose into estimation of additional disease (typically cancer) probability. The Biological Effects of Ionizing Radiation (BEIR) VII report (National Research Council 2006) contains extensive information on the state of knowledge regarding radiation dose-response, including a limited uncertainty analysis. Both NCRP (2012) and the US Environmental Protection Agency (EPA 2007) have investigated some sources of uncertainty in risk assessment.

With regard to evaluating radiation risk, major sources of uncertainty include the following (NCRP 2012):

- Issues associated with epidemiological and animal study design and application, including low statistical power and precision
- Inadequate or simplistic modeling of radiation risk (especially at low doses), or assumption of one generic model (typically the the linear no-threshold hypothesis, or LNT, model)
- Extrapolation or generalization of risk estimates to different populations

As an example, EPA (2007) estimated uncertainties for radionuclides that have published risk coefficients in EPA's Federal Guidance Report (FGR) No. 13 (EPA 1999). They addressed the following sources of uncertainty:

- Biokinetic models describing the biological behavior of ingested or inhaled radionuclides
- Specific energies that relate emissions from source organs to energy deposition in target organs
- Risk model coefficients representing the risk of cancer per unit absorbed dose to sensitive tissues from radiation at high dose and high dose rates
- Tissue-specific dose and dose rate effectiveness factors (DDREF); and tissue-specific high-dose relative biological effectiveness (RBE)

Uncertainties associated with alternative dose-response statistical models (i.e., aside from the LNT model) were not addressed by EPA (2007). EPA (2007) employed a combination of modeling and expert opinion in the analysis, and concluded that "the assessed uncertainty in the radiation risk [as opposed to dose] model was found to be the main determinant of the uncertainty category for most risk coefficients, but conclusions concerning the relative contributions of risk and dose models to the total uncertainty in a risk coefficient may depend strongly on the method of assessing uncertainties in the risk model".

All groups that have attempted to analyze uncertainties associated with radiation effective dose and risk have acknowledged that this is a difficult undertaking, and there is no generic "one-size-fits-all" solution. Each type of radiation and target organ dose-response has unique characteristics. Therefore, the most straightforward way to evaluate uncertainties in dose and risk may be to employ the FGR 13 central values and 'uncertainty categories' published by EPA (1999, 2007). These are represented as a ratio of the 95th to the 5th quartiles:

Table 2-85/1. EPA Uncertainty Categories.

Uncertainty category	Definition
A	$Q_{95}/Q_5 < 15$
B	$15 \leq Q_{95}/Q_5 < 35$
C	$35 \leq Q_{95}/Q_5 < 50$
D	$50 \leq Q_{95}/Q_5 < 150$
E	$Q_{95}/Q_5 \geq 150$

As an example, if an uncertainty factor is 100, then a risk coefficient could vary from the published FGR 13 value by a factor as great as 10 (the square root of 100). Most radionuclides fall within categories A or B.

Unlike any other sources reviewed, ratios are available for a large (>800) number of radionuclides. The exact ratio values (as opposed to the letter categories) are available for all radionuclides with risk coefficients in FGR 13 (EPA 1999). Assuming a distributional shape such as lognormal, distributions can then be developed.

If uncertainties associated with effective dose only are evaluated, the scope of existing and published work is much more limited. For example, Puncher and Harrison (2012, 2013) only evaluated uncertainties for 9 radionuclides via ingestion and inhalation.

Recommended Approach for Incorporating Uncertainty in Radiation Dose / Risk

A possible initial approach might be to evaluate:

1) Uncertainties in risk estimates using the uncertainty factors in EPA (2007) as applied to applicable risk coefficients in FGR 13 (EPA 1999).

2) Uncertainties in DCFs using the Puncher and Harrison (2012) estimated distributions presented in Section 3.4 in that report. As mentioned above, these distributions are only for a limited set of radionuclides, but this will provide a 'proof of principle' exercise and a point of comparison with the risk distributions estimated using EPA (1999, 2007).

Note that neither of these approaches estimate uncertainty associated with choice of dose-response model (e.g., alternatives to the LNT approach). However, they will provide a more complete assessment of uncertainty compared with the REF-only uncertainty evaluated in the first version of the PA model. Once incorporated into the PA model and sensitivity analyses are conducted, a decision can then be made as to next steps; i.e. if the risk and/or DCF uncertainties are ranked high in the sensitivity analysis, then further investigation may be warranted. Regardless, eventual incorporation of dose-response model uncertainty will likely be important in terms of assessing the full range of uncertainty associated with estimated risks.

86. INTERROGATORY CR R313-25-8(5)(A)-86/1: CONSEQUENCES OF SEDIMENTATION ON DISPOSAL CELL

The deep time assessment needs to consider the relative rates of progeny in-growth and pluvial lake sedimentation. It should determined if there are points in time when individual exposures can be greater than at the time of peak activity, due to the influence of sedimentation on reducing surface concentrations of contamination or of wave-cutting increasing access to waste and doses received by receptors.

EnergySolutions*' *Response: There are two issues with this interrogatory statement. First, individual doses are evaluated only in the first 10,000 years of the PA using multiple exposure scenarios. Exposure scenarios with dose assessments are not evaluated in the second stage of the PA – deep time assessments. Instead radioactive species concentrations in lake sediments are tracked for multiple glacial cycles extending from 10,000 years to 2.1 Ma (see the first paragraph of the top of page 41 of Appendix A of the PA document).

Second, as explained in the first full paragraph of page 29 of Appendix 13 Deep Time Assessment, the first lake in the glacial cycle is assumed to remove and mix the above grade embankment material including both the above grade and below grade DU and associated waste. All of the DU waste in the disposal system is dispersed by lake-driven transport processes with the arrival of the first lake. The timing of the first lake arrival is modeled as a Poisson process with a rate that increases linearly over the glacial cycle time of 100 ka. Subsequent lakes (intermediate and large lakes) remix the sediment-waste with coincident dissolution of wastes into the water column and burial under new cycles of lacustrine sediments. In-growth of uranium progeny continues throughout the deep time assessment but is secondary to complete removal and dispersal of all buried DU waste in the first lake cycle. Overall sediment concentrations decrease through sequential glacial cycles because lake sedimentation continues but the only changes to the total waste inventory in the sediment mixtures are from decay and ingrowth.

No changes in the text are required.

As is noted in response to Interrogatory #18, the current modeling does not account for aeolian deposition prior to the return of the first lake. Given the current climate cycle is now considered unlikely to produce a lake that inundates Clive, the time frame over which aeolian deposition might happen could result in partial or complete burial of the disposal mound prior to the return of a lake. Aeolian deposition affects both erosion in the 10ky Compliance Period and longer term stability in deep time. Please see the response to Interrogatory #18.

87. INTERROGATORY CR R315-101-5.3(6)-87/1: ORAL TOXICITY PARAMETERS

The approach used in the Dose Assessment report with regard to oral toxicity should be revised based on the established drinking water standard for uranium and a review of recent literature on hazards from uranium ingestion. The report should also explain how the oral toxicity factors used in the PA were derived, as they may understate risk.

EnergySolutions*' *Response: Since ingestion of groundwater is not a dose pathway, the Dose Assessment report is correct, as provided. See the response to Interrogatory CR R313-25-7(2)-91/1 for more detail.

The proof-of-principle approach used in the Dose Assessment report to represent the oral toxicity of uranium was based on EPA's toxicity assessment supporting the current drinking water standard (maximum contaminant level [MCL] of 30 µg/L), and is correct. The uranium oral reference dose (RfD) of 0.0006 mg/kg-day associated with the derivation of the final uranium MCL is defined on page 76713 of Federal Register, Volume 65, No. 236, December 7, 2000 (Section I.D.2d). The discrepancy with the calculation provided stems primarily from the fact that the uranium oral RfD of 0.0006 mg/kg-day derived by EPA is related to a best-estimate drinking water equivalent level of 20 µg/L, rather than the final uranium MCL of 30 µg/L.

The EPA oral RfD of 0.003 mg/kg-day that is used in the PA is not that for "Uranium, natural" but rather for "Uranium, soluble salts." The basis for this oral RfD, which is published in the Integrated Risk Information System (IRIS) supporting the Superfund Program, is an EPA toxicity assessment published in 1985.

The discrete distribution used in the PA for uranium non-radiological oral toxicity assigns equal weight to the two oral RfDs. These RfDs reflect current EPA science policy associated with EPA's Superfund Program and Office of Water. A 50/50 probability was assigned to these oral RfDs to determine in the Sensitivity Analysis whether selecting one or the other of these published values was a significant contributor to uncertainty in the uranium Hazard Index in any exposure scenario. As discussed in response to Interrogatory CR R315-101-5.3(6)-33-1, the difference between the two uranium RfD values contributed less than 10% to uncertainty in receptor hazard index results.

Note that the global sensitivity analysis effectively changes all parameters simultaneously to find the most important (sensitive) parameters for a given endpoint. The uncertainty expressed in the uranium RfD could perhaps be expressed in different and arguably better ways, but the difference between the two values used appears to be swamped in the model by other uncertainties. Hence, the uranium RfD does not show up as a sensitive parameter.

88. INTERROGATORY CR R313-25-19-88/1: COLLECTIVE DOSE AND ALARA

Confirm that the population (collective) doses over 10,000 years presented in FRV1 Table 11 are not in error, underestimating those doses by about a factor of 10. If the doses are correct, explain and justify why it should stand as written.

EnergySolutions*' *Response: It is acknowledged that an error was made in calculation of collective doses. This error is being addressed in the next version, and is being coupled with the revised ET Cover design that is being incorporated into the next revision (hence all values will change, and will be reported correctly).

89. INTERROGATORY CR R313-25-7(9)-89/1: CONTAMINATION LEVELS IN DUF6

Review the basis for setting contamination levels in the DU PA and consider the substantial amount of contamination information available from the GDPs in lieu of surrogate data based on DU from SRS. Direct particular attention to contamination remaining in the heels of the DUF_6 cylinders. Describe in the PA how Energy*Solutions* will ensure that the cylinders shipped to Clive do not contain contaminated heels resulting from introduction of recycled uranium into the GDP process streams.

Revise the PA report to do the following:

1. Incorporate the new technical literature information for nuclide activity in the GDP DU waste.
2. Explain and justify why the already buried nuclear inventory for Clive was not included in the DU PA model, as required by R313-25-8(5)(a).

EnergySolutions*' *Response: Responses to the two items that are the subject of this interrogatory follow:

1. Incorporate the new technical literature information for nuclide activity in the GDP DU waste.

   While the reports in question are available, the analysis relies primarily on information provided by personnel at the U.S. Dept. of Energy and personnel associated with the DUF6 Project in Piketon (near Portsmouth), OH, and Paducah, KY, since they are most familiar with the particular population of GDP DU that is the subject of this PA exercise. After many conversations with various DUF6 Project personnel, Neptune was advised to rely on the Hanson (2006) report, as it had been produced with the benefit of the Hightower et al. (2000) report and other technical memoranda from Oak Ridge National Laboratory in 2000. As such, the DU literature and DU waste is being revised in the Clive DU PA Model, as appropriate.

   It should be noted, however, that the sensitivity analysis of the Clive DU PA Model v1.0 does not indicate that the fraction of contaminated cylinders or their precise isotopic composition were good predictors of model endpoints—therefore, refining the definitions of these parameters is unlikely to result in meaningful differences in these results, or in the decisions made based on those results.

Contaminated cylinders will not be cleaned during the deconversion process. They will be inspected, and those deemed to have sufficient integrity will be reused, contaminated heels or not, for storage, transport, and disposal of U3O8 (personal communication from Jack Zimmerman to John Tauxe). Those without such integrity will be disposed as waste, not subject to this PA.

Also see response to Interrogatory #51.

2. Explain and justify why the already buried nuclear inventory for Clive was not included in the DU PA model, as required by R313-25-8(5)(a).

   The average concentration of DU historically disposed by Energy*Solutions* prior to January 2010 is 1,988 pCi/g (which is less than the 5-percent limit promulgated in UAC R313-25-8(2)(c) of 1.8E+4 pCi/g - as clarified by the Division on May 24, 2010).

90. INTERROGATORY CR R313-25-7(1–2)-90/1: CALIBRATION OF INFILTRATION RATES

Explain how the infiltration rates predicted with HELP/UNSAT-H and HYDRUS were calibrated against actual field data. Explain and justify which infiltration rate should apply to the DU disposal embankment (Federal Cell) at Clive, addressing radon barrier damage via frost heave, root penetration, animal burrowing, insect burrowing, and desiccation.

EnergySolutions' Response*:* In development of the new evapotranspirative (ET) cover design, Energy*Solutions* examined the performance of other similar cover systems in use in the arid west (Appendix D of Energy*Solutions*, 2013b). Energy*Solutions* also examined natural localized plateaus and land features in the Clive area similar in shape, surface soil type, and slope to that proposed for the Federal Cell (Appendix D of Energy*Solutions*, 2013b). Furthermore, Energy*Solutions* used as input to the models site-specific meteorological data obtain at their Clive meteorological station since 1993 (MSI, 2014).

Additionally, Energy*Solutions* has historically been required to consider bounding input and overly conservative assumptions in its various performance assessments. These in turn have always predicted infiltration at rates orders of magnitude higher than anything observed onsite via collection lysimeter and Cover Test Cell performance.

The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

While the Clive DU PA Model v1.0 relied on HELP modeling by Whetstone for determining the infiltration rates, this is being revisited in the next version of the model. The new modeling evaluates the hydraulic behavior of an evapotranspirative cap, rather than the former design of a rip-rap armored cap. This change in cap design makes moot the hydraulic modeling performed for the Clive DU PA Model v1.0.

91. INTERROGATORY CR R313-25-7(2)-91/1: DESIGN CRITERIA FOR INFILTRATION

Include specific design criteria for infiltration into the Class A South Cell (subsequently called the Federal Cell) and explain how the Utah groundwater protection levels will be met for 10,000 years. Explain and justify which infiltration rate will apply to the DU disposal cell and how a 500-year PA analysis for the groundwater pathway is compliant with R313-25-8(5)(a) in terms of both model prediction time and determination of peak dose.

EnergySolutions' Response*:* Revisions underway to the depleted uranium Performance Assessment GoldSim model demonstrate that infiltration into the Federal Cell's evapotranspirative cover complies with limitations of Energy*Solutions'* GWQDP.

The interrogatory, however, erroneously conflates R313 radiological dose standards with R317 non-degradation standards. The former, at R313-25-8(5), clearly does require a compliance period of 10,000 years for the "*...performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules…*" The performance standards of 10 CFR Part 61 and corresponding Utah rules are based on radiological dose to human receptors. There is not a requirement in 10 CFR Part 61 or rules adopted under Utah's Agreement State program implementing 10 CFR Part 61 to eliminate potential environmental impacts that do not cause radiological doses to be exceeded. Rather, 10 CFR 61.41 states: "*Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably* *achievable.*" The corresponding Utah rule is found at R313-25-19: "*Reasonable efforts should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.*" Releases to the general environment should be minimized, subject to the principle of ALARA.

Utah ground water protection rules for Class IV aquifers at R317-6-4.7 set a standard subject to interpretation: "*Protection levels for Class IV ground water will be established to protect human health and the environment.*" No timeframe is provided; nor does this general statement in and of itself require a non-degradation standard. Rather, the Director is provided with discretion to set reasonable criteria for Class IV groundwater. This has been implemented (Part I.D.1 of Permit UGW450005) as requiring radioactive waste disposal facilities to demonstrate non-degradation of the groundwater for 200 years for non-radiological contaminants and 500 years for radiological contaminants. It should be noted that non-radiological contaminants consisting of heavy metals have an infinite environmental half-life; while radiological contaminants such as Tc-99 decrease with time, albeit over very long timeframes for nuclides with long half-lives. It should further be noted that the Division sets a considerably higher standard for radioactive waste disposal facilities than for any other groundwater discharge permittee in the state.

As a groundwater quality standard, non-degradation has been demonstrated using groundwater protection levels based on a potential dose of 4 mrem/year. In establishing this standard, certain simplifying assumptions were made regarding human consumption. That is, an assumption is made that the untreated water could be consumed and thus represents a dose pathway. For highly saline sources of groundwater, the consideration of untreated consumption in evaluating health protection determinations can be particularly critical and is consistent with the discretion described in NUREG-1573. For groundwater at the Clive facility, untreated consumption would of course lead to death within a matter of days for the consuming individual due to the high salt content. Consequently, for performance assessment purposes, considering site-specific data regarding groundwater quality, uses, and reasonable receptor pathways is an appropriate approach and is consistent with prior and current performance assessment approvals for the facility.

The non-degradation standard applies for a "*minimum*" of 500 years in accordance with Part I.D.1 of the Ground Water Quality Discharge Permit. As is summarized below, every approved PA for LLRW disposal at Clive has clearly documented a potential for Tc-99 and other mobile isotopes to exceed 4 mrem at some point after 500 years.

Table 2-91/1. Part I.D.l of the Ground Water Quality Discharge Permit

Embankment	Nuclide	Year Exceeding	Source
Class A West	Side Slope (0.168 cm/yr)		11/28/2011 Modeling Report
	Bk-247	500	
	Ca-41	500	
	Cl-36	500	
	I-129	500	
	Re-187	500	
	Tc-99	500	
	Si-32	530	
Class A West	Top Slope (0.090 cm/yr)		11/28/2011 Modeling Report
	Bk-247	500	
	Ca-41	500	
	Cl-36	500	
	I-129	705	
	Tc-99	715	
	Re-187	855	
	Si-32	1080	
Mixed Waste	Top Slope (0.183 cm/yr)		11/22/2000 Modeling Report
	Bk-247	500	
	Cf-249	500	(Cf-249 subsequently changed)
	Cl-36	500	
	Ca-41	640	
	I-129	1500	
	Tc-99	1500	
	Re-187	1500	
Mixed Waste	Side Slope (0.096 cm/yr)		11/22/2000 Modeling Report
	Bk-247	780	
	Cl-36	775	
	Cf-249	845	(Cf-249 subsequently changed)
	Ca-41	1080	
Class A Combined (Class A North)	Top Slope (0.244 cm/yr)		4/2006 Modeling Report
	Re-187	625	
	Tc-99	810	

Embankment	Nuclide	Year Exceeding	Source
	I-129	855	
	K-40	1010	
Class A Combined (Class A North)	Side Slope (0.507 cm/yr)		4/2006 Modeling Report
	Re-187	500	
	Tc-99	500	
	I-129	500	
	K-40	565	
	Si-32	1500	
Class A Combined (Class A North)	Side Slope (0.451 cm/yr)		4/2006 Modeling Report
	Ca-41	500	
	Re-187	500	
	Tc-99	555	
	I-129	585	
	K-40	705	
Western LARW	Top Slope (0.265 cm/yr)		7/19/2000 Modeling Report
(Class A)	Re-187	745	
	Tc-99	785	
	I-129	830	
	K-40	990	
Western LARW	Top Slope (0.310 cm/yr)		7/19/2000 Modeling Report
(Class A)	Re-187	640	
	Tc-99	670	
	I-129	710	
	K-40	845	
Western LARW	Frost-Protected Side Slope (0.364 cm/yr)		7/19/2000 Modeling Report
(Class A)	Re-187	500	
	Ca-41	510	
	Tc-99	525	
	I-129	555	
	K-40	670	
LARW	Side Slope (Base Case, 1.50 cm/yr)		2/12/1998 Modeling Report
	Cl-36	110*	
	Tc-99	210*	

Embankment	Nuclide	Year Exceeding	Source
	I-129	215*	
	K-40	275*	
LARW	Top Slope (Sensitivity Analysis, 0.279 cm/yr)		2/12/1998 Modeling Report
	Cl-36	460*	
	I-129	705	
	K-40	860	
11e.(2)	Top Slope (2.30 cm/yr)		7/26/2001 Modeling Report
	None	NA	
11e.(2)	Side Slope (1.69 cm/yr)		7/26/2001 Modeling Report
	None	NA	

* Note that isotopes projected to exceed GWPLs in less than 500 years were limited by the Radioactive Material License to concentrations for which the model demonstrated compliance up to year 500.

In review and approval of prior PA work, DRC has established a reasonable regulatory interpretation that the ground water protection standards are a non-degradation rather than dose issue; and that the non-degradation standard has a reasonable timeframe of 500 years.

Groundwater at the Clive site is not a potential dose pathway. As demonstrated in Table 3-2 of the 2013 Compliance Report, untreated consumption would lead to death for 100 percent of the receptors within a matter of days. Revised calculations in response to interrogatory 181 do not change this basic conclusion. It is not reasonable to assume that groundwater in the shallow unconfined aquifer would be treated for TDS then consumed. While technically possible, the shallow unconfined aquifer is of low yield; better groundwater production and quality is available at other locations in the west desert.

R313-25-19 requires an ALARA analysis to be applied to efforts to minimize potential environmental impacts. When these impacts have zero dose implications, they fail to pass the ALARA analysis. Even the analysis and modeling of potential groundwater impacts fails to pass an ALARA analysis, since zero person-rem are avoided. Nonetheless, it is reasonable under R317-6-4.7 to consider a non-degradation standard for 500 years consistent with current and prior PA approvals.

The radionuclides of concern in groundwater with this DU PA review are identical to those demonstrated to exceed after 500 years in prior approved PA work. This work was accepted under both R313-25-19 and R317-6-4.7. Thus, there is no reason to abandon the existing regulatory distinction between non-degradation standards applying for 500 years and accepting the reality that groundwater is not a potential dose pathway either before or after that time.

92. INTERROGATORY CR R313-25-20-92/1: INADVERTENT INTRUDER DOSE STANDARD AND SCENARIOS

1. Justify why 25 mrem/yr should not be used as the dose limit for inadvertent intruders and instead why a 500 mrem/yr limit should be applied for inadvertent intruder analysis in unrestricted areas.
2. Include analysis in the PA for additional inadvertent intruder scenarios.

EnergySolutions*' Response: Limitation and selection of credible inadvertent intruder scenarios is addressed in the response provided to Interrogatory CR R313-25-8(4)(B)-07/1.

In guidance to staff published by U.S. NRC stated,

> "*Given the significant uncertainties inherent in these long timeframes, and to ensure a reasonable analysis, this performance assessment should reflect changes in features, events, and processes of the natural environment such as climatology, geology, and geomorphology only if scientific information compelling such changes from the compliance period is available. In general, this analysis should strive to minimize radiation dose with the goal of keeping doses below a 500 mrem/yr analytical threshold.*" (SRM-SECY-2013-075, February 2014).

In its "Basis of Interrogatory," DRC acknowledges that NRC regulations establish a dose limit for members of the public of 500 mrem/yr. However, DRC concludes that a 25 mrem/yr dose limit should apply for disposal of DU because, among other things:

1. "[T]he NRC did not consider shallow land disposal of large quantities of concentrated DU waste in the original 10 CFR Part 61 rulemaking."

2. "Since its original promulgation of 10 CFR Part 61, the NRC has amended its rules in 10 CFR Part 20 to reduce the dose limit in unrestricted areas to 25 mrem/yr TEDE (see current 10 CFR 20.1402). This same limit is reflected in the Utah rule at R313-15-402."

3. Although DRC agrees that "the NRC license termination rules allow for a 500 mrem/yr dose to public in unrestricted areas, should certain conditions be met," R313-15-403 limits the applicability of that dose standard "only to ancillary surface facilities that support radioactive waste disposal activities."

4. The amendments to Part 61, which contemplate a 500 mrem/yr inadvertent intruder dose limit, have yet to be finalized.

As explained in more detail below, there is ample basis in existing and pending NRC rules for a 500 mrem/yr dose limit and a more stringent state limit violates state statutes.

<u>NRC Rules</u>.

Dose Limit v. Disposal Requirements. The dose limit is intended to protect an individual who is exposed to radiation from a site containing radioactive material. The requirements for disposal and long-term site management to assure compliance with such a limit may vary depending on the nature of the material, but the dose limit itself is based on protection of the exposed individual and not on the particular type of material at the site. SECY-13-0075, dealing with the pending proposal to amend Part 61 to address unique waste streams (including DU) explicitly acknowledges that the purpose of the dose limit is to protect the exposed individual – not to reflect the nature of the material at the site:

> "*A further protective assurance analysis should be performed for the period from the end of the compliance period through 10,000 years. Given the significant uncertainties inherent in these long timeframes, and to ensure a reasonable analysis, this performance assessment should reflect changes in features, events, and processes of the natural environment such as climatology, geology, and geomorphology only if scientific information compelling such changes from the compliance period is available. In general, this analysis should strive to minimize radiation dose with the goal of keeping doses below a 500 mrem/yr analytical threshold. The radiation doses should be reduced to a level that is reasonable achievable based on technological and economic considerations.*"[2]

Thus, in considering disposal and post-closure management of large volumes of DU (and other unique wastes), NRC appropriately focuses on the mechanisms to assure that the dose limit is below the 500 mrem/yr threshold, not on whether a different dose limit should be imposed depending on the particular waste at the site.

Unrestricted Use/Inadvertent Intruder. The NRC rules provide that a

[2] Memorandum from Annette L. Vietti-Cook, Secretary, to Mark a Sartorius, Executive Director for Operations, *Staff Requirements – SECY-13-0075 – Proposed Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61) (RIN 3150-A192)* at 2 (Feb. 12, 2014) (http://www.nrc.gov/reading-rm/doc-collections/commission/cvr/2013/2013-0075vtr.pdf.) ("SECY-13-0075").

> *"site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and that the residual radioactivity has been reduced to levels that are as low as reasonable achievable (ALARA)."*

10 CFR 20.1402. The 25 mrem/yr dose in 10 CFR 20.1402 is a criterion, which if met, means the site is "acceptable for unrestricted use." The NRC rules also provide for license termination under restricted conditions, and under certain circumstances provide for a 500 mrem/yr dose limit for an individual (including an inadvertent intruder) exposed at the site. 20 CFR 20.1403.

An "inadvertent intruder" is "*a person who might occupy the disposal site after closure and engage in normal activities . . . in which the person might be unknowingly exposed to radiation from the waste*." 10 CFR 61.2. An inadvertent intruder could enter a site that meets the criterion for unrestricted use and thus the dose limit would be 25 mrem/yr; or the inadvertent intruder might enter a site that meets the criteria in 10 CFR 1403 for a dose limit of 500 mrem/yr.

Pending Amendments to Part 61. When Part 61 in its current form was promulgated in 1982, NRC had not considered the disposal of large quantities of DU. The current NRC "Disposal of Unique Waste Streams" rulemaking is intended in large part to take into account the issues pertaining to disposal of significant amounts of DU. [3]

As noted above, NRC is close to publishing the proposed amendments to Part 61, and based on SECY-13-0075, will propose a 500 mrem/yr dose limit:

> *"The proposed rule should clearly indicate that the intruder assessment should be based on intrusion scenarios that are realistic and consistent with expected activities in and around the disposal site at the time of site closure. . . . A further protective analysis . . . should strive to minimize radiation dose with the goal of keeping doses below a 500 mrem/yr analytical threshold."* [4]

It is true that there is not yet a final rule; however, the indications are very clear that NRC will propose a 500 mrem/yr dose limit for inadvertent intrusion, and for that limit to be reduced to 25 mrem/yr in the final rule will require a major change

[3] *See, e.g.,* Technical Basis For Proposed Rule To Amend 10 CFR Part 61 To Specify Requirements For The Disposal Of Unique Waste Streams, Including Large Quantities Of Depleted Uranium (FSME-10-XXXX), http://pbadupws.nrc.gov/docs/ML1110/ML111040419.pdf.

[4] SECY-13-0075 at 1.

in direction after the proposed rule is published. If DRC requires a 25 mrem/yr dose limit for inadvertent intruders in the PA, it will most likely be inconsistent with the NRC rule without any basis to demonstrate why the NRC rule would be inadequate to protect the inadvertent intruder.

State Law.

No More Stringent Rule. Utah law prohibits the Radiation Control Board from adopting rules "for the purpose of assuming responsibilities from the United States Nuclear Regulatory Commission with respect to regulation of sources of ionizing radiation, that are more stringent than the corresponding federal regulations which address the same circumstances" unless the board "makes a written finding after public comment and hearing and based on evidence in the record that corresponding federal regulations are not adequate to protect public health and the environment of the state," and such findings are "accompanied by an opinion referring to and evaluating the public health and environmental information and studies contained in the record which form the basis for the board's conclusion." Utah Code Ann. § 19-3-104(8) and (9).

As DRC acknowledges, the current NRC rules allow for a 500 mrem/yr dose limit, but points to UAC R313-15-401(1), which applies that limit only to "ancillary surface facilities." Given that R313-15-401(1) is more restrictive than its federal counterpart, it should not have been promulgated without going through the steps required by Utah Code Ann. § 19-3-104(8) and (9).

Requiring a 25 mrem/yr dose limit for inadvertent intruders in the DU PA would also violate state statutes if, as seems likely, NRC adopts a 500 mrem/yr dose limit for inadvertent intruders in its pending rulemaking. Once that rule is finalized, and assuming that the rule will contain a 500 mrem/yr dose limit for inadvertent intruders, a requirement for a 25 mrem/yr dose limit imposed by the State will run afoul of state statute unless the process set forth in statute for setting a more stringent rule by the state is followed.

Conclusion.

Neither NRC rules nor state law requires a 25 mrem/yr requirement for DU. There is no need to petition the Radiation Control Board for an exemption or rule change, as existing law supports a 500 mrem/yr dose limit.

93. INTERROGATORY CR R313-25-22-93/1: STABILITY OF DISPOSAL SITE AFTER CLOSURE

1. Include long-term PA analysis for a scenario where wave-cut action from a pluvial lake breaches the Federal Cell cover system and DU waste. Alternatively, redesign the Federal Cell to locate the DU waste and its overlying radon barrier at an elevation that is below the native ground surface.
2. Revise the consideration of the span of time used in the PA modeling to go beyond the time period for which the disposal embankment maintains its designed condition and function, and explain and justify why the span of time used in the PA modeling for engineering design requirements was adequate to comply with the requirements of R313-25-8(4) and (5).

EnergySolutions*' *Response: Appendix 13 Deep Time Assessment includes a scenario and PA assessment of the return of a pluvial lake and erosion of the DU waste embankment. The details of the scenario used to asses a future lake cycle are described in section 4.0 Conceptual Overview of Modeling Future Lake Cycles; the model results for this scenario as concentrations of radionuclides in lake waters and lake sediments is presented in section 6.5 of the Clive DU PA Model version 1.0 Final Report. See also the responses to the following interrogatories:

1. Interrogatory 86 discuss the consequences of sedimentation after lake erosion of the embankment,

2. Interrogatory 129 discusses the processes of lake erosion and the justification for the conservative assumption of complete erosion of the embankment during the first lake return to the Clive site, and

3. Interrogatory 131 discusses process of wave erosion at lake shorelines and the possible consideration of the use of analogue studies of erosional features of preserved shorelines in the Lake Bonneville basis to revise erosion scenarios of the waste embankment.

In summary, the lake erosion scenario assumes complete erosion of the DU embankment during the return of the first pluvial lake to the Clive elevation. All waste, including both the above grade and below grade DU and associated waste, are mixed into the lake sediments. Subsequent lakes (intermediate and large lakes) remix the sediment-waste with coincident dissolution of wastes into the water column and burial under new cycles of lacustrine sediments.

Overall sediment concentrations decrease through sequential glacial cycles because lake sedimentation continues but the only changes to the total waste inventory in the sediment mixtures after the first episode of lake erosion are from decay and ingrowth. Collectively, the lake erosion scenario uses conservative assumptions. In reality, the details of lake erosion depend on the timing of the return of the first pluvial lake, the degree of erosional burial of the embankment by aeolian sediments prior to the first lake arrival, the variability in depth of erosion during lake advances and retreat, and the interplay between lake erosion and lake sedimentation for sequential pluvial lake cycles. Multiple factors in the dynamics of these processes could significantly reduce lake sediment concentrations below the conservative estimates used in the current deep-time assessments.

The PA model uses four time periods for assessment (Section 5.1.2 Time Periods of Concern in the Clive Du PA Model version 1.0 Final Report) of the DU waste including:

1. Quantitative dose endpoints for 10,000 years including peak mean dose for comparison with performance objectives and the ALARA analysis.

2. An institutional control period of 100 years when doses are not calculated because there is no public access to the site.

3. Groundwater concentrations are compared with performance objectives for the first 500 years of the PA model consistent with the Utah requirements.

4. The deep-time model is run for 2.1 million years tracking peak radionuclide concentrations in lake water and sediment.

These composite time spans comply with the requirements of R313-25-8(4) and (5).

94. INTERROGATORY CR R313-25-3(8)-94/1: ULTIMATE SITE OWNER

Provide written evidence that the site owner shall be legally responsible for the Federal Cell, including all environmental liability that may develop for that disposal unit.

EnergySolutions' Response: Satisfaction of UAC R313-25-3(8), ultimate site owner is discussed in detail in Section 1 of the RML Condition 35 Compliance Report, Revision 1. As stated therein,

> "*Energy*Solutions *recognizes the following policy issues that must be resolved before disposing of concentrated depleted uranium in the Federal Cell . . .(2) Completion of a Memorandum of Agreement with DOE assuming long-term stewardship of the Federal Cell."* (Energy*Solutions*, 2013a, pg 1-1).

Therefore, it is recognized that any ultimate approval to dispose of depleted uranium must only come after DOE agreement that they will become the ultimate site owner and will be legally responsible for the Federal Cell, including all environmental liability that may develop for that disposal unit. However, while a prerequisite to the physical disposal of large quantities of depleted uranium, this acknowledgement does not prevent the Division's review and acceptance of this depleted uranium Performance Assessment (in compliance with Condition 35 of License UT2300249).

95. INTERROGATORY CR R313-25-8(4)(A)-95/1: ESTIMATION OF I-129 CONCENTRATIONS

Consider an alternative approach to estimating I-129 concentrations in the waste and revise the PA accordingly. Alternatively, explain and justify why a proxy nuclide already in the PA model report could be used to account for the I-129 activity/dose in the environment near the Clive facility.

EnergySolutions' Response*:* The wording is being changed to reflect that very small quantities of I-129 might be expected given the presence of Tc-99, given that they are both fission products.

Using the ratio of Tc-99 to I-129 provides a better path to a more reasonable estimate of I-129 concentrations. However, the EPRI reference provided does not contain sufficient information and acknowledges that there are very few actual I-129 measurements included in the data.

Neptune has consulted EPRI on this issue (personal communication from Billy Cox, EPRI, to Paul Black, Neptune and Company, Inc.). There is process knowledge that may be brought to bear: The equilibrium burnup ratio for Tc-99 to I-129 is about 200:1. That is, in spent fuel, the activity of Tc-99 is about 200 times the activity of I-129. The first step of fuel reprocessing is to dissolve the fuel in nitric acid, in order to facilitate the wet chemistry extraction of U, Pu, or other desirable constituents. In this process of dissolution in nitric acid, about 99% of the iodine is volatilized, and none of the technetium is volatilized. This alters the ratio of Tc-99 to I-129 by another factor of about 100. Once the acid has been neutralized in preparation for other processes, including whatever processes were used to bring the contaminated reactor return uranium to its current form as UO_3 powder, this ratio of 100×200:1, or about 20,000:1, is maintained. As such, it the activity concentration of I-129 can be estimated as 0.00005 times the activity concentration of Tc-99.

There are a number of reports written by DOE and contractors regarding the fate of reactor return uranium (see the bibliography developed in response to interrogatory #51). Although it is unlikely that many of these focus on the contaminants in the process, they are being examined for more information that could shed light on this issue.

The use of ratios to develop a distribution for I-129 is also being evaluated. The Waste Inventory white paper is being revised to address this issue of scaling and the distributions utilized in the model.

96. INTERROGATORY CR R313-25-8(4)(A)-96/1: CURRENT AND FUTURE POTABILITY OF WATER

Demonstrate that there will only be non-potable water at the Clive site for 10,000 years, considering the potential for desalination, reverse osmosis, and other water treatment activities and the potential for higher groundwater quality in deep aquifers. Provide reliable evidence that (1) groundwater near Clive will not improve in quality in the future, (2) currently available treatment technology cannot render Clive groundwater useable for municipal or industrial purposes, (3) no potable or treatable groundwater exists at Clive in deeper aquifers, and (4) there is no current or future treatment technology that could render saline waters suitable for culinary or industrial use.

EnergySolutions*' *Response: Energy*Solutions* acknowledges the technical feasibility of treating saline waters at effectively any initial salinity. However, technical feasibility does not equate to probability of implementation. Within the west desert, there are numerous sources of surface and ground water for treatment that are of higher initial quality. In addition, regardless of the future ability to treat groundwater, there is not viable way to produce significant quantities of water from the upper, unconfined aquifer beneath Clive.

Furthermore, treatment of groundwater is a scenario that crosses from inadvertent to deliberate intrusion. Utah drinking water quality standards, as well as all state and federal standards, include criteria for radionuclides. If the need and technology for groundwater treatment is present, one must presume that a technical context recognizing the potential presence and hazards of radioactive constituents is also present. In accordance with NRC guidance, the inadvertent intruder must be protected but a deliberate intruder cannot be subject to the same dose protection criteria; since a deliberate intruder by definition knows of the radiological hazard and proceeds to disturb the disposal site regardless (Section 4.2.1 of NRC, 1981).

Please refer to the response provided to Interrogatory CR R313-25-8(4)(B)-07/1 regarding unreasonable speculation and projection of current known scenarios.

97. INTERROGATORY CR R313-25-8(4)(A)-97/1: NEED FOR POTABLE AND/OR INDUSTRIAL WATER

Add a discussion of various existing and historical examples of the waste industry in the Clive area and explain how they address the potential need for potable and/or industrial water in the area. Provide reliable evidence to substantiate claims that no moderate- or high-yield aquifers exist at depth near Clive and evaluate economic considerations for current and future beneficial uses of deep groundwater.

EnergySolutions' Response: Historic consideration of the nature and uses of Clive's native groundwaters is well documented (Energy*Solutions*, 2014b). Industrial facilities in the west desert use groundwater from recharge zones adjacent to the Cedar Mountains and the Grayback Hills. Drinking water is trucked to these sites from Grantsville. See also the response to Interrogatory CR R313-25-8(4)(a)-96/1.

Please refer to the response provided to Interrogatory CR R313-25-8(4)(B)-07/1 regarding unreasonable speculation and projection of current known scenarios.

98. INTERROGATORY CR R313-25-7(1)-98/1: MONTHLY TEMPERATURES

Describe the nature of the "*monthly temperatures*" referenced in the Conceptual Site Model report.

EnergySolutions' Response: Section 3.2.1 of the Report is being revised to clarify that the range in monthly temperatures cited are the ranges in mean monthly temperatures from 1992 through 2009.

The text in question is also in the DU PA in Section 4.1.2.3.1 which cites Whetstone (2006). Whetstone (2006) cites MSI (2004) as the data source of the 12-year average temperatures at the EnergySolutions site.

This reference will be replaced with MSI (2009), which describes the collection of hourly air temperature data in 2009 and how it compares to the 17-year record (1993-2009) in Tables 4-3 and 4-4. The hourly air temperature data for 2009 is included in Appendix C where it is apparent that mean monthly air temperature is calculated as the monthly average of hourly data. Since these datasets compare well, it is reasonable to assume that the 17-year record is calculated in the same manner.

The Interrogatory questions how the temperature range is calculated. The DU PA text states

> "*Data from the Clive Facility from 1992 through 2009 indicate that monthly temperatures range from about -2°C (29°F) in December to 26°C (78°F) in July (Whetstone, 2006).*"

The Report text in question is being changed to the following:

> "*Data from the Clive Facility from 1992 to 2009 indicate that monthly temperatures range from about -2.4°C (27.7°F) in December to 26.4°C (79.5°F) in July (MSI, 2009) where monthly average temperatures are assumed to be calculated as the monthly average of hourly air temperatures for that month based on comparison with hourly data collected for 2009 and reported in MSI (2009).*"

99. INTERROGATORY CR R313-25-7(1)-99/1: EVAPORATION

Clarify the meaning of the term "*evaporation*" as used in the Conceptual Site model report and provide documentation that evaporation exceeds precipitation.

EnergySolutions' Response*:* Evapotranspiration is defined in Section 2.1.10 of Energy*Solutions*, (2013d). Furthermore, responses to Interrogatories 7.1 through 7.4 and 8.1 through 8.7 of Appendix B; and responses to Interrogatories 7.2 through 7.4 and 8.1 through 8.7 of Appendix F from this same reference demonstrate that evapotranspiration exceeds precipitation for the evapotranspiration cover design. See also MSI, 2014, for documentation that pan evaporation measured at the site meteorological station greatly exceeds precipitation.

The italicized text above is being revised to the following:

> "*The Clive facility is characterized as being an arid to semi-arid environment where annual pan evaporation greatly exceeds annual precipitation (MSI 2009). Average annual pan evaporation is 52 inches (MSI 2009, p. 4-7) while average annual precipitation is 8.5 inches (MSI 2009, p. 4-8). As a general rule of thumb, reference evaporation can be calculated from pan evaporation by multiplying pan evaporation by about 0.6 to 0.7 (e.g. http://ag.arizona.edu/azmet/et1.htm). Therefore, annual average reference evapotranspiration exceeds precipitation by about a factor of four.*"

100. INTERROGATORY CR R313-25-7(1)-100/1: GROUNDWATER RECHARGE FROM PRECIPITATION

Address considerations that would affect the amount of groundwater recharge due to precipitation and snow melt, such as concentration of water in topographic depressions, increase in cover-system hydraulic conductivity, and inhibition of evaporation because of large-grain materials.

EnergySolutions' Response*:* Revision 1 of the GoldSim model evaluates performance of an ET cover design against the traditional rock armor mulch on the Federal Cell.

Section 3.2.3 on page 8 of the Conceptual Site Model report is being revised. The statement "*Because of the high evaporation rate, the amount of groundwater recharge due to precipitation is likely very small, except during high intensity precipitation events (Adrian Brown, 1997a).*" has been removed and the discussion on recharge in Section 3.4.2.1 Groundwater Flow Regime will be expanded.

> "*Recharge to the aquifer in the vicinity of Clive is thought to be composed of three components; a small amount due to vertical infiltration from the surface; some small amount of lateral flow from recharge areas to the east of the site; and the majority of recharge believed to be from upward vertical leakage from the deeper confined aquifer (Bingham Environmental (1994). Average annual groundwater recharge from the surface in the southern Great Salt Lake Desert in the precipitation zone typical of Clive was estimated by Gates and Krauer (1981). An estimated 300 acre feet per year were recharged to lacustrine deposits and other unconsolidated sediments over an area of 47,100 acres. This is a recharge rate of approximately 0.08 inches/year. Groundwater recharge from lateral flow occurs due to infiltration at bedrock and alluvial fan deposits away from the Site which moves laterally through the unconfined and confined aquifers (Bingham Environmental, 1994). This is evidenced by the increasing salinity of the groundwater due to dissolution of evaporate minerals as water moves from the recharge area to the aquifers below the Facility (Bingham Environmental, 1994). The majority of recharge to the shallow aquifer is believed by Bingham Environmental (1994) to be due to vertical leakage upward from the deep confined aquifer due to the presence of upward hydraulic gradients.*"
>
> *"Deeper saturated zones in Unit 1 below approximately 45 ft bgs are reported to show higher potentiometric levels than the shallow unconfined aquifer. Differences in potentiometric levels are attributed to the presence of the Unit 2 clays (Bingham Environmental, 1994). Vertical gradients between shallow and deeper screened intervals in the monitor well*

clusters were calculated by Bingham Environmental (1994). An upward vertical gradient was observed ranging in magnitude from 0.02 to 0.04 based on the distance between the screen centers. For a vertical hydraulic conductivity of 1 x 10-6 cm/s (Bingham Environmental 1994) this corresponds to a recharge range from 0.25 in/yr to 0.5 in/yr."

"Estimates of vertical recharge from the surface take into account natural processes such as snow accumulation and melting, concentration of water in topographic depressions, drainages, fractures, holes, or burrows and increased surface permeability due to frost heave or plant roots. When features such as topographic depressions, drainages, or fractures result in enhanced infiltration, the vertical infiltration below the localized recharge points flows laterally at the water table toward the lower elevations of the water table (Freeze and Cherry, 1979). The effect of animal burrowing on subsurface moisture content was investigated in a field experiment at the Hanford Site by Landeen (1994). Over the course of five testing periods, three during the summer and 2 during the winter soil moisture measurements showed no influence of burrowing activities on long-term water storage."

"Degradation models for changes in cover properties over time were discussed in the Benson et al (2011) report published by the NRC. While this is a useful report, the topic of cover performance is a complex topic with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. The cover design components and assigned physical properties in models of cover performance must be carefully chosen for applicability to the climate and hydrogeological setting of the Clive disposal facility. To provide a comprehensive sensitivity analysis for the influence cover degradation on modeled surface recharge, refined modeling of closure cover performance could be performed using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into a probabilistic performance assessment model."

Given the change in design, items related to rip rap performance in this interrogatory are no longer applicable.

101. INTERROGATORY CR R313-25-7(1)-101/1: NATURE OF UNITS 1 AND 2

Indicate how the thickness of Unit 1 is accounted for in the numerical GoldSim model, and describe the nature of the confining unit. Provide information about local downward components of hydraulic gradient at the site that result in groundwater mounding.

EnergySolutions' Response*:* The description of Unit 1 in Section 3.3.1, page 9, of the Conceptual Site Model report is being revised:

> *"Unit 1 underlies Unit 2 and is saturated beneath the facility, containing a locally confined aquifer. Unit 1 extends from approximately 45 ft bgs and contains the deep aquifer. The deeper aquifer is reported to be made up of lacustrine deposits consisting of deposits of silty sand with some silty clay layers. One or possibly more silty clay layers overlie the aquifer (Bingham Environmental 1994)."*

The aquifer system in the vicinity of the Clive Facility is described by Bingham Environmental (1991, 1994) and Envirocare (2000, 2004) as consisting of unconsolidated basin-fill and alluvial fan aquifers. Characterization of the aquifer system is based on subsurface stratigraphy observations from borehole logs and from potentiometric measurements. The aquifer system is described as being composed of two aquifers; a shallow, unconfined aquifer and a deep confined aquifer. The shallow unconfined aquifer extends from the water table to a depth of approximately 40 ft to 45 ft bgs. The water table in the shallow aquifer is reported to be located in Unit 3 on the west side of the site and in Unit 2 on the east side.

The deep confined aquifer is encountered at approximately 45 ft bgs and extends through the valley fill (Bingham 1994). The boring log from a water supply well drilled in adjoining Section 29 indicated continuous sediments to a depth of 620 ft bgs (DWR 2014, water right number 16-816 and associated well log 11,293). The deepest portion of the basin in the Clive area is believed to be north of Clive in Ripple Valley where the basin fill was estimated to be 3,000 ft thick (Baer and Benson (as cited in Black et al., 1999)).

Deeper saturated zones in Unit 1 below approximately 45 ft bgs are reported to show higher potentiometric levels than the shallow unconfined aquifer. Differences in potentiometric levels are attributed to the presence of the Unit 2 clays. These observations are interpreted as indicating that the shallow unconfined aquifer below the site does not extend into Unit 1 but is contained within Units 2 and 3 (Bingham Environmental, 1994)

Vertical gradients between shallow and deeper screened intervals in the monitor well clusters were calculated by Bingham Environmental (1994). An upward vertical gradient was observed ranging in magnitude from 0.02 to 0.04 based on the distance between the screen centers.

Hydraulic conductivities measured from bailing tests are reported to average 7.45 ft/day (2.6E^{-03} cm/s) by Envirocare (2004). Bailing tests in boreholes provide a saturated hydraulic conductivity more representative of the horizontal hydraulic conductivity than the vertical. Based on 3 measurements of vertical hydraulic conductivity on silty clay cores made by Bingham Environmental (1991), Envirocare (2004) and Bingham Environmental (1994) use a value of 1 x 10^{-6} cm/s for the vertical hydraulic conductivity. This corresponds to an anisotropy ratio Kv/Kh of 1:2600. Average linear vertical groundwater velocity ranged from 0.05 ft/yr to 0.10 ft/yr based on these vertical gradients, a porosity of 0.4 and a vertical hydraulic conductivity of 1 x 10^{-6} cm/s (Bingham, 1994).

Horizontal groundwater velocities were calculated by Bingham Environmental (1994) for 17 monitoring wells having measurements of hydraulic conductivity and estimated gradients. Hydraulic conductivities ranged from 2.9 x 10^{-5} cm/sec to 9.5 x 10^{-4} cm/sec and horizontal hydraulic gradients ranged from 2 x 10^{-4} to 1 x 10^{-3}. Average linear horizontal groundwater velocity ranged from less than 0.02 ft/yr to 2.1 ft/yr based on a porosity of 0.3. The ratio of linear horizontal velocities to linear vertical velocities ranged from 0.4 to 21.

The influence of downward hydraulic gradients on shallow groundwater flow is discussed in Envirocare (2004) for two cases. In the first, flow was affected by localized recharge from a surface water retention pond in the southwest corner of the facility in the spring of 1999 and in the second, a ground water mound formed between March 1993 and spring 1997 below a borrow pit excavated near the 11e.(2) cells that occasionally filled with rain water. The mound decreased and was negligible by the time of the report in 2004.

Unit 1 in the GoldSim Model:

Unit 1 is not included in the numerical GoldSim model. The confining unit at the top of Unit 1 forms the bottom boundary of the model. The shallow aquifer is represented in the model as being completely contained within Unit 2. The point of assessment for the groundwater pathway is a monitoring well located 90 ft horizontally from the toe of the waste. The monitoring well extends through the shallow aquifer in Unit 2 ending at the top of unit 1. A Figure will be added to Section 7.1.1 Groundwater Flow and Transport in the Conceptual Site Model report depicting the engineered features of the landfill, the hydrostratigraphic units below the waste in the unsaturated and saturated zones, the location of the water table of the shallow aquifer, and the lower boundaries of the GoldSim model.

102. INTERROGATORY CR R313-25-7-102/1: SEISMIC ACTIVITY

Address the fact that active faults tens of miles away from the site can potentially cause local ground accelerations, even if the site itself does not have any known active faults in its vicinity, or explain and justify why the issue is not important to the long-term stability of Clive embankments.

EnergySolutions' Response*:* The lack of Quaternary and/or capable faults in the vicinity of the Clive site is not sufficient evidence to dismiss seismic activity as a potential issue of concern. While the absence of surface faults in the site is consistent with a low probability of surface-fault rupture, ground shaking associated with background earthquakes require assessments (i.e. moderate-size earthquakes (M 5.5 – 6.5) that do not cause surface rupture, see Wong et al., 2013).

Seismic hazard assessments have been evaluated previously for the Clive site including assessments of active or potentially active faults in the region and background earthquakes. The peak ground accelerations for both seismic sources is 0.24 g. The peak ground accelerations for the Clive site are within the range of estimated ground accelerations for two DOE regulated and approved low-level waste disposal sites (Area G, Los Alamos, New Mexico (LANL, 2008), and Area 5, Nevada National Security Site, Shott et al. 2008). Performance assessments for these sites conclude that the impacts of ground shaking on waste disposal systems are minor (and are overshadowed by the longer-term effects of subsidence).

The negligible effects of the peak ground accelerations on the long-term stability of Clive's embankments has previously been demonstrated and found acceptable by the Division. No new information on seismic hazards has been identified that would change or require revisions of the previous work. The text in Appendix 2, Conceptual Site Model and in Section 6.0 of Appendix 1, Clive DU PA FEP

Analysis is being revised and will reference the existing seismic hazard assessments.

The following sections summarize the results of seismic hazard assessments for the Clive site:

> *"The seismic hazard assessment is based on an assessment of the peak ground acceleration (PGA) associated with the Maximum Credible Earthquake (MCE) for known active or potentially active faults in the site region, and the PGA obtained from a probabilistic seismic hazard analysis (PSHA) to assess the seismic hazard for earthquakes that may occur on unknown faults in the area surrounding the project site (i.e., background seismicity). For fault sources, the PGA is calculated at the 84th percentile level and is based on the maximum rupture length and rupture area for each fault. The return period for ground motions resulting from a background earthquake is identified as 5000 years (equal to a one percent probability of exceedance in 50 years). The approach to select a MCE PGA from the larger of the values associated with the deterministic MCE for faults or the PSHA result for background earthquakes at a 5000 year return period is consistent with the discussions among AMEC, ES, Utah DEQ and their peer reviewer, URS Corporation, and is consistent with the recommendations of the Utah Seismic Safety Commission (2003) and as required by the Utah Division of Water Rights (Dam Safety Section) for assessment of dams.*
>
> *The deterministic assessment follows the approach described in our October 25, 2011 letter, and is updated in the following paragraphs. Potential fault sources are shown on Figure B-1.1 and are listed in Table B-1.1 of Appendix B, including an assessment of the fault parameters, source to site distance, and PGA. Specific fault parameters and other information in Table B-1.1 include fault name, slip type, maximum magnitude, location of site on hanging wall or footwall, fault dip, rake, maximum rupture length (fault length), downdip rupture width, distance measures required for ground motion attenuation relationships, and PGA for median and 84th percentile levels. We use a suite of four Next Generation Attenuation (NGA) relationships . . . all of which are applicable for the site conditions and types of sources in Utah and the Intermountain Region. Additional parameters for attenuation relationships include site shear wave velocity, VS30, taken as 305 m/s as described in the October 25 Letter, and depth to top of bedrock (Z1.0 and Z2.5), taken as default values calculated from the site VS30 as recommended by the authors of the NGA relationships (also as described in the October 25 Letter).*

The maximum magnitude for each fault is based on rupture of the full length of the fault, and where available is taken as the maximum value published by the Utah Working Group on Earthquake Probabilities (WGUEP, 2011), except for the Stansbury fault as noted below. For faults not assessed in the previous studies, including the Skull Valley fault, the maximum magnitude was assessed using the same methodology as the WGUEP study, based on maximum rupture length, rupture width, and the empirical relationships of Wells and Coppersmith (1994). For short faults where the calculated maximum magnitude is less than MW 6.5, a maximum magnitude of 6.5 is adopted because this is judged to be a reasonable minimum value of magnitude for earthquakes that rupture to the ground surface.

For the Stansbury fault, the maximum magnitude is assessed as MW 7.3 based on consideration of the maximum rupture length, fault width, and maximum fault displacement identified in previous investigations. . . The value of MW 7.5 listed in the October 25 Letter and by the WGUEP is judged to be too conservative because it is higher than the maximum value obtained from empirical relationships, considering all combinations of rupture length, rupture width, and maximum fault displacement cited in those previous investigations. We note that it may be reasonable to consider an extreme value with a very low weighting (e.g., less than 10 percent) in a probabilistic analysis, but that it is not reasonable practice to adopt an extreme value for the MCE for a deterministic analysis.

The maximum of the 84th percentile PGA values calculated for the Mmax events on the fault sources is equal to 0.24 g, as obtained for the Stansbury and the Skull Valley faults (Table B-1.1). For the PSHA, we used the current version (Ver. 7.62) of commercial program EZ-FRISK to calculate the PGA for the background earthquake. The program developer, Risk Engineering, has prepared input fault and background seismicity files for Utah for use in calculating seismic hazard; these files are based on the same fault source parameters and independent seismicity catalog used by the U.S. Geological Survey (USGS) to prepare the 2008 National Seismic Hazard Maps.

The seismicity catalog is an independent (de-clustered) catalog based on moment magnitude (MW) that covers the Western United States; the seismicity in the vicinity of the project site is shown on Figure B-1.1. The recurrence rates for the background seismicity are based on the same recurrence models and maximum magnitudes used by USGS, which is a spatially smoothed gridded approach, with a maximum magnitude of 7.0 for Utah (Peterson et al., 2008). As for the deterministic analysis, we use the same suite of four NGA relationships and the site VS30 of 305 m/s. The

PGA is taken as the weighted average of the mean values for the four NGA relationships at a return period of 5000 years (equal to 0.24 g, Table B-1.1).

The largest PGA from the deterministic assessment of fault-specific sources and the probabilistic assessment of the background earthquake is 0.24 g. The maximum magnitude varies from 7.0 to 7.3 for the sources that result in the maximum PGA; we identify the largest value, MW 7.3, as appropriate for use in the seismic stability analyses for this project."(EnergySolutions, 2012, pg. 2-3).

In review of this information and its implications on the Class A West Embankment design, the Division concluded, "Based on the information summarized above, the Division concludes that the Licensee's proposed design basis conditions and justification for the design criteria for waste placement and backfill for the CAW Embankment are acceptable." (DRC, 2012, pg. 33).

103. INTERROGATORY CR R313-25-7-103/1: HISTORICAL FLOODING

Discuss historical non-chronic flooding that has occurred on site and how this can potentially impact infiltration, especially once the cover system is compromised by erosion, burrowing, and other events. Discuss flooding that has occurred on the site prior to the human historical record but within the historical geologic record (based on evidence from the field).

EnergySolutions' Response: The ability of Clive's exterior berm system and embankments to withstand the impacts of a Probable Maximum Flood has previously been demonstrated (Appendices E and G of Energy*Solutions*, 2013b). No changes in present methodology or meteorology have been observed that warrant revising this recent analysis.

104. INTERROGATORY CR R313-25-7(2)-104/1: INFILTRATION IN THE PRESENCE OF RIP RAP OR NATURAL ROCK

1. Realistically quantify the impacts on infiltration or water penetration when the presence of rip rap or natural rock on the embankment cover decreases both evaporation and transpiration. Include technical evidence to support the conclusions made regarding evapotranspiration effects on water infiltration.
2. Specify the total length of the soil zone path used in unsaturated flow modeling and describe the characteristics of the soil involved.
3. Explain and justify how much time will be needed to complete the cover system siltation and establishment of a permanent and viable plant community after closure of the DU cell, including how much of the cover system vertical profile will be in-filled with silts and other Aeolian deposits.

4. Explain and justify why the proposal to use human intervention to help mitigate the effects of future events that could jeopardize the stability of the engineered facility at Clive is congruent with the rule requirement to eliminate active maintenance of the disposal site.

<u>EnergySolutions' Response</u>:
Energy*Solutions* currently plans to use an evapotranspiration (ET) cover design rather than the design requiring rip rap specified in the Clive DU PA model. Given the change in design, items 1 and 3 (and the example reference to rip rap in 4) in this interrogatory are no longer applicable. In response to item 2, the CSM report is being revised to contain a detailed description of the entire vadose zone path modeled.

In response to item 4, the referenced CSM report text is referring to human intervention in the context of applying different types of engineering controls, not with respect to active maintenance. This is elucidated in the sentence beginning, "*For example, the disposal cell could be protected…*" Active maintenance of the disposal site has not been assumed in the PA. The cell is designed and projected to perform in accordance with R313-25-7(2), which requires "elimination **<u>to the extent practicable</u>** of long-term disposal site maintenance" [emphasis added].

The third sentence of the first paragraph of Section 7.2.1.6 of the CSM report is being revised to state:

"*If in the future another ice age were to occur similar to those that have occurred during the Pleistocene, disposal cell design could help mitigate the effects of future events that could jeopardize the stability of the engineered facility at Clive*."

105. INTERROGATORY CR R313-25-8(4)(A)-105/1: HUMAN USE OF GROUNDWATER

Identify the human uses for which the groundwater at the Clive site is suitable, and consider the potential human uses of the groundwater after treatment.

<u>EnergySolutions' Response</u>: Uses and modeling of Clive's groundwater in this Depleted Uranium Performance Assessment are consistent with Energy*Solutions*' other various Performance Assessments.

Energy*Solutions* acknowledges the technical feasibility of treating saline waters at effectively any initial salinity. However, technical feasibility does not equate to probability of implementation. Within the west desert, there are numerous sources of surface and ground water for treatment that are of higher initial quality and production.

Furthermore, treatment of groundwater is a scenario that crosses from inadvertent to deliberate intrusion. Utah drinking water quality standards, as well as all state and federal standards, include criteria for radionuclides. If the need and technology for groundwater treatment is present, one must presume that a technical context recognizing the potential presence and hazards of radioactive constituents is also present. In accordance with NRC guidance, the inadvertent intruder must be protected but a deliberate intruder cannot be subject to the same dose protection criteria; since a deliberate intruder by definition knows of the radiological hazard and proceeds to disturb the disposal site regardless.

Please refer to the response provided to Interrogatory CR R313-25-8(4)(B)-07/1 regarding unreasonable speculation and projection of current known scenarios.

Additionally, it should be noted that desalination occurring in the Persian Gulf and Israel is to fulfill a pressing human need for a dense population. Neither of these exists at Clive.

106. INTERROGATORY CR R313-25-8(4)(A)-106/1: DESALINATION POTENTIAL

Modify the text to reflect the fact that TDS concentrations at Clive are not a barrier to desalination to potable water levels.

***EnergySolutions' Response**:* Section 3.4.2.2 of the Conceptual Site Model is being revised to acknowledge the technical feasibility and practical improbability of groundwater desalination at Clive.

While it is true that desalination occurs in the Persion Gulf and Israel, it is done to fulfill a pressing human need for a dense population. Neither of these currently exists at Clive, nor is it likely to.

The text of the CSM document is being changed as follows:

[Conceptual Site Model white paper, section 3.4.22:]

> "*The underlying groundwater in the vicinity of the Clive site is of naturally poor quality with high salinity and high TDS, as a consequence, is not suitable for most human uses (NRC, 1993). Brodeur (2006) reports that groundwater beneath the Clive site had a total dissolved solid (TDS) content of 40,500 mg/L (40.5 ‰). The majority of the cations and anions are sodium and chloride, respectively. This is not potable for humans or livestock, nor is it suitable for irrigation. Groundwater is used for dust control, however, this water is pulled from the deeper aquifer, not the low-*

yielding, shallow-unconfined aquifer found beneath Clive. For comparison purposes, sea water typically has a salinity content three to five times that of the groundwater at the site, thus the salinity content at the site is higher than average sea water."

107. INTERROGATORY CR R313-25-7(1)-107/1: PREDOMINANT VEGETATION AT THE CLIVE SITE

Reconcile apparent discrepancies with respect to which type of vegetation predominates at the Clive site and revise the Conceptual Site Model report to be consistent with the research conducted previously by Energy*Solutions* contractors at Clive.

EnergySolutions' Response: Assessment by SWCA in 2013 of predominant vegetation species surrounding the Clive site has been provided to the Division (Section 2.3 of Appendix C from Energy*Solutions*, 2013d). As reported therein,

> "*The vegetation communities that occur on and near Clive, and the shrub, forb, and grass species that comprise them were documented during 2010 and 2012 field studies (SWCA 2010, 2012). Inter-Mountain Basins Mixed Salt Desert Scrub (Lowry 2007) is the dominant vegetation cover type on analogs to the Clive site. The target vegetation community on the ET cover consists of approximately 15% cover of small stature native shrub species (Atriplex confertifolia, Atriplex canescens, Bassia americana, Picrothamnus desertorum, and Suaeda torreyana), with additional cover provided by sparse native forbs and grasses."* (pg. 31, Appendix C, Energy*Solutions*, 2013d).

Section 3.5.1 of the Conceptual Site Model is being revised accordingly.

The Conceptual Site Model does say on page 11 that the predominant vegetation is shadscale. It then goes on to say,

> *"Shrubs are widely spaced, totaling between 1.5% and 20% ground cover, depending upon vegetation association. The shadscale-gray molly community covers most of the South Clive site, with black greasewood becoming prominent only on the eastern quarter of the site. SWCA (2011) found very little transition between the shadscale-gray molly and black greasewood vegetation associations, and that shadscale and gray molly totaled less than 0.5% cover in the greasewood association, suggesting that the shadscale-gray molly-black greasewood community identified by Envirocare (2000) is perhaps better classified as a pure greasewood community. Envirocare reported that the black greasewood-gardner saltbush community only occurs in the far northeast corner of the Clive site."*

This indicates that there are three main vegetation types at the site, and these are investigated further by SWCA (2011). Of the three main vegetation types, shadscale saltbush makes up 60% of the site based on percent cover (Envirocare 2000, p.3 section 2.2), making the claim that it is the predominant vegetation at the site accurate.

It is inappropriate to discuss the results of the SWCA 1 ha plot surveys (SWCA 2011) with regards to total plant cover at the site. The three 1 ha plots were chosen to each be in the primary vegetation associations at the site, so by definition they are different vegetation types. These plots do not indicate overall coverage at the site as they are not a representative sampling of percent cover, but rather provide good data on the proportion of vegetation types within each of the three habitat types. As stated on page 1 of that report (SWCA 2011), the purpose of this survey was to identify plant species present and estimate the percent cover and stem densities of grasses, forbs, shrubs, and trees in each vegetative association. This survey was not designed to determine coverage of each vegetative association at the site, but the percent cover of species within each vegetative association.

The text in the CSM that states that shadscale is the predominant vegetation over most of the site is not contraindicated by the vegetation assemblages in the 2011 SWCA plots. The 2011 plots were selected precisely because they do represent different vegetation assemblages in the vicinity of Clive. The PA model evaluated both the predominant assemblage at the site (shadscale-gray molly) and less common assemblages (black greasewood, halogeton-disturbed, mixed grassland, juniper-sagebrush) with the recognition that any of those assemblages could colonize the cover depending on future changes in temperature, precipitation, and/or soil salinity.

With regard to the comment "For Plot 3, "Shadscale makes up only 1/10th of 1% of ground cover, so it can hardly be called predominant here," as mentioned above this sampling design was not intended to provide any data on overall coverage at the site. Previous surveys had shown that shadscale was the predominant vegetation. This sampling design was simply describing the plant composition within each vegetation type.

With regard to the comment

> "*In Plot 5, located to the west of most current operations, shadscale saltbush does dominate among shrubs and forbs, at 12.5%, but the coverage is relatively small compared to biological soil crust coverage at 70.7%,"*

biological soil crust is not a plant (but rather a community of organisms including cyanobacteria, green algae, microfungi, mosses, liverworts, and lichens). When discussing dominant vegetation, the plant species with the most cover is used, even if much of the area is biological soil crust or bare ground.

108. INTERROGATORY CR R313-25-8(4)(A)-108/1: BIOINTRUSION

Include additional information about biointrusion from SWCA (2012).

EnergySolutions' Response*:* Assessment by SWCA in 2013 of predominant burrowing animal species surrounding the Clive site has been provided to the Division (Section 2.2 of Appendix C from Energy*Solutions*, 2013). Section 3.5.2 of the Conceptual Site Model is being revised to incorporate and reference this work, performed during the 2.5 years between when the DU Performance Assessment was submitted and reviewed.

Discussion of mammal bioturbation in the CSM was based on information and data collected by SWCA as part of the initial performance assessment, including small mammal trapping, mammal burrow surveys, and ant nest surveys within the Clive plots (SWCA, 2011). The CSM is being updated based on work performed by SWCA subsequent to the PA. Excavation of cover materials by badgers was included in the PA based on data collected by SWCA, 2011. Because badgers occurred at very low frequency at the site compared to small burrowing mammals (primarily deer mice and kangaroo rats), all burrowing mammals were lumped together to derive distributions of burrow density and burrow volume. Mammal burrowing was modeled to a maximum depth of 2 m based on the likely average vertical extent of multiple badger excavations (Kennedy et. al, 1985).

The text is being updated with the more recent information collected by SWCA, and the new data is being evaluated to determine if changes are needed to the model.

Also see response to Interrogatory R313-25-8(4)(A)-28/1.

109. INTERROGATORY CR R313-25-7(2)-109/1: GEOCHEMICAL DEGRADATION OF RIP RAP

Address the issue of the geochemical degradation of the rip rap over time and indicate why potential rip rap degradation will not require perpetual care.

EnergySolutions' Response: Selection of an ET cover design eliminates the need to address this issue for the DU PA.

Energy*Solutions* currently plans to use an evapotranspiration (ET) cover design rather than the design requiring rip rap specified in the Clive DU PA model.

Given the change in design, this interrogatory is no longer applicable. The CSM report is being revised to contain a detailed description of the revised design.

110. INTERROGATORY CR R313-25-8(4)(A)-110/1: RADON TRANSFER FROM WATER

Provide a basis for stating that radon has a preference for remaining in water.

EnergySolutions' Response*:* The statement that radon has an affinity for water is made in the sense that relative to other radioactive noble gases, radon has a higher affinity for water. The Henry's Law constant, expressed as a dimensionless air/water concentration ratio, is about 4.6 for radon. It is over 16 for krypton, and nearly 30 for argon. So, by comparison, radon has a higher water/air concentration ratio than these other gases. It is all relative. Nonetheless, the text can be changed, as follows, since the only thing that matters is the actual value.

[Conceptual Site Model white paper, section 7.1.3.1, last paragraph:]

> "*Radon that does enter the environment partitions between air and water. Soil moisture therefore retards the migration of radon as it migrates through the soil, making it less available to diffusion in air under wetter soil conditions*."

[Conceptual Site Model white paper, section 9.4.1, fifth paragraph, first sentences:]

> "*Radon partitions between air and water, per its Henry's Law constant (KH). For this reason, wet soils are much better at attenuating radon migration than dry soils.*"

111. INTERROGATORY CR R313-25-7-111/1: LIKELIHOOD OF LAVA DAM FORMATION

Describe why the future likelihood of lava dam formation is considered small, given that lava dams formed during the Pleistocene and affected Lake Bonneville.

EnergySolutions' Response*:* The intention of the sections cited in the interrogatory statement (Conceptual Site Model, Deep Time Assessment) is not to imply that future volcanic activity in and near Lake Bonneville is unlikely to form lava dams or affect glacial lake cycles. Lava dams in the northern parts of Lake Thatcher and Lake Bonneville affected the rise and drainage history of the lakes during the Pleistocene (Link et al., 1998) and volcanic activity likely affected drainage into Lake Bonneville during and following the last glacial maximum. Basaltic volcanic eruptions associated with the Black Rock Desert volcanic field

(Nash, 1989) pre-date, were contemporaneous with, and post-date the multiple stages of Lake Bonneville (Nash, Oviatt and Nash, 1989, 2014).

Volcanic eruptions near the Clive site are low probability events during the 10,000 year first stage of the DU performance assessment. However, Quaternary basaltic and rhyolitic eruptions occurred along the length of the eastern margin of the Great Basin (north-south zone through central Utah) and will occur again within the Bonneville lake region during the 2.1 Ma interval of the deep time assessment. These future events will affect anticipated glacial lake cycles. However, the magnitude of these effects on lake levels is small compared to the fluctuations in lake levels associated with the modeled 100 ka glacial cycles.

Future volcanic events are typically screened from consideration in a performance assessment on the basis of a low probability of occurrence and/or limited consequences. The scenarios of a major asteroid impact and a future volcanic eruption at Yellowstone volcanic center (caldera cycle eruption) were similarly not screened. Instead, the impacts of these events are so catastrophic on a global scale that consideration of their impact on a low-level radioactive waste disposal site at Clive is literally inconsequential.

The text of the cited sections is being revised accordingly to clarify the importance of lava dams and volcanic activity.

112. INTERROGATORY CR R313-25-8(4)(A)-112/1: HYDRAULIC CONDUCTIVITY

Revise the hydraulic conductivity values to be consistent with the values in NUREG/CR-7028. Increase the model's radon barrier permeability by at least two orders of magnitude and re-run the simulations, or provide evidence, explanation, and justification as to why the DRC Director should accept the current assumptions as presented.

EnergySolutions' Response*:* The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

See also the response to Interrogatory CR R313-25-8(5)(A)-176/1.

113. INTERROGATORY CR R313-25-8(5)(A)-113/1: PLACEMENT OF BULK LOW-LEVEL WASTE AMONG DU CANISTERS

Describe modeling and consequent assessment related to the placement of bulk low-level waste between, above, or below the DU canisters.

EnergySolutions' Response: Bulk Class A LLRW will be placed above the DU. It will not be placed below or between the concentrated DU, in order to conserve cell space below grade for only significant quantities of depleted uranium. Performance assessment for these nuclides is addressed via the ET cover performance assessment currently undergoing DRC review (Energy*Solutions*, 2013d). Consistent with the historic Division-accepted practice, this assessment took no additional credit for migration restriction attributable to waste container or waste form. As such, the condition of the disposal of other Class A low-level radioactive bulk wastes within the Federal Cell is a modeled condition. Therefore, it is unnecessary to repeat this analysis in this Depleted Uranium Performance Assessment.

The goal of the Clive DU PA Model v1.0 has been simply to evaluate the potential future human risk from the SRS and GDP sources of DU proposed for disposal.

114. INTERROGATORY CR R313-25-19-114/1: ELEVATED CONCENTRATIONS OF TC-99

Discuss the transport of technetium in groundwater at the site, including Tc-99 soil/water partitioning coefficients used in the GoldSim model and results of model predictions for transport of technetium in groundwater at the site for periods of at least 10,000 years. Describe steps that can be taken to limit the presence of technetium in groundwater to concentrations less than or equal to the Utah groundwater protection level of 3,790 pCi/L.

EnergySolutions' Response: Revision 2 of the GoldSim model is being prepared to evaluate an ET cover design. It is expected that the reduced infiltration afforded by this design will reduce predicted Tc-99 levels in groundwater. See also response to Interrogatory 163 regarding the period of performance for groundwater.

It should be noted that the GWPLs for the Clive site, as documented in the Ground Water Quality Discharge Permit No. UGW450005, apply for only the first 500 years following closure of the site. There is, therefore, no regulatory need to evaluate groundwater concentrations of radionuclides after that period of compliance. See the response to Interrogatory CR R313-25-7(2)-91/1.

As for soil/water partition coefficients for Tc addressed in (1), the most extensive discussion available is that in the *Geochemical Modeling* white paper, Part (2) is addressed above.

Nevertheless, there are two approaches that could be implemented that would reduce concentrations of ^{99}Tc in groundwater in general. One approach, as discussed in the Final Report, is to situate the DU that is contaminated with ^{99}Tc higher in the waste layering. In modeling various waste placement strategies, it is clear that this results in lower groundwater concentrations of ^{99}Tc. However, the modeled cover design is being changed from the riprap layer to an ET cover, which will affect infiltration and hence mobility of ^{99}Tc in the system.

A second strategy, would be to not dispose of contaminated DU in the first place, especially considering the below grade capacity is considerably exceeded by the DU that needs a disposal option. This approach would still allow for disposal of roughly 95% of the GDP DU, which has no such contamination, and is the first to undergo deconversion at any rate. The deconversion plants in Piketon and Paducah intend to work through their contaminated DUF_6 inventories as the last of their deconversion efforts (personal communication from Jack Zimmerman, Uranium Disposition Services, LLC, to John Tauxe, Neptune and Company, Inc.), and so are unlikely to produce any contaminated DU_3O_8 for at least 20 years.

In the meantime, other disposal protocols may be developed, for example, iron could be added to the grout or other components of the system to change the geochemical conditions and enhance iron facilitated co-precipitation. This would reduce the mobility of the Tc-99 in the system. Note that there is iron in the disposal system containers, and no credit has been taken for that in the model to date.

115. INTERROGATORY CR R315-101-5.3(6)-115/1: URANIUM TOXICITY REFERENCE DOSES

Expand the discussion of uranium toxicity to include the Superfund and drinking water RfDs, indicate whether they are for soluble or insoluble uranium salts or both, describe why there is a five-fold difference between the two RfDs, and indicate the basis for assigning a 50/50 probability to each RfD.

***EnergySolutions*' *Response*:** Additional text is being added to Section 3.4.5 of the Dose Assessment report:

> "*A discrete distribution is used to represent the uranium oral RfD based on current EPA science policy associated with EPA's Superfund Program*

and Office of Water. A uranium oral RfD of 0.0006 mg/kg-day is associated with the derivation of the final uranium drinking water maximum contaminant level (MCL) is defined on page 76713 of Federal Register, Volume 65, No. 236, December 7, 2000 (Section I.D.2d). A uranium oral RfD of 0.003 mg/kg-day for soluble salts of uranium is published in the Integrated Risk Information System (IRIS) supporting the Superfund Program. A 50/50 probability is assigned to these oral RfDs to determine in the Sensitivity Analysis whether selecting one or the other of these published values is a significant contributor to uncertainty in the uranium Hazard Index in any exposure scenario."

116. INTERROGATORY CR R313-25-8(4)(A)-116/1: CS-137 DECAY

Change Figure 1 and the Excel file to show the correct amount of Cs-137 decaying to Ba-137.

EnergySolutions' Response*:* Although Tuli (2005) does not recognize this decay mode, it is noted in Kocher (1981), as follows:

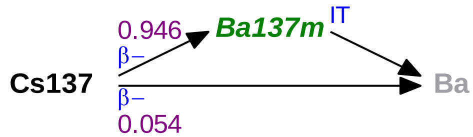

Figure 2-116/1, Cs-137 Decay Modes

This decay mode is being included in the Clive DU PA Model, and the figure is being updated. There is no effect on the model, since dose conversion factors from the decay of 137Cs implicitly include that of 137mBa as well.

Since the decay product 137mBa is short-lived and is not modeled for contaminant transport, it does not appear in the Species list, nor in the "Clive PA Model Parameters.xls" Excel file. Therefore, no modification of the Excel file is indicated.

117. INTERROGATORY CR R313-25-8(5)(A)-117/1: GROUNDWATER PROTECTION LIMIT FOR TC-99

Provide documentation (e.g., a Result Mode GoldSim file) that supports the contention that the Tc-99 GWPL will be met for 10,000 years. In addition, explain why Energy*Solutions* is proposing to include a Tc-99 waste source term concentration limit of 1,720 pCi/g under the side slope, given statements in various places in the PA report that no DU is to be included under the side slopes.

EnergySolutions' Response: Revisions underway to the depleted uranium Performance Assessment GoldSim model demonstrate that infiltration into the

Federal Cell's evapotranspirative cover will subsequently comply with limitations of Energy*Solutions'* GWQDP.

The interrogatory, however, erroneously conflates R313 radiological dose standards with R317 non-degradation standards. See the response to Interrogatory CR R313-25-7(2)-91/1.

118. INTERROGATORY CR R313-25-7(10)-118/1: GOLDSIM RESULTS

Provide the GoldSim model files (i.e., .gsm files) that support the results (i.e., groundwater concentrations, receptor doses, receptor uranium HQs, ALARA, and deep time results) that are reported in FRV1.

EnergySolutions' Response*:* The current model is being revised to include the ET Cover design. Once that model is completed, then a complete set of GoldSim model runs will be provided for comparison.

119. INTERROGATORY CR R313-25-8(4)(A)-119/1: RESUSPENSION AND AIRBORNE PATHWAYS

Revise the model inputs and re-run the simulations as noted, or provide documentation and justification that the analysis of exposures due to the air pathways in the PA is conservative, in particular with regard to the resuspension flux entered into GoldSim and the model's calculation of the resuspension rate and airborne radionuclide concentrations, particularly when gullies that extend into the buried DU are present.

EnergySolutions' Response*:* Energy*Solutions* has committed to dispose of significant quantities of depleted uranium only below grade in the Federal Cell. Therefore, gullies will not extend into buried DU and the model does not need to be revised as suggested.

1) Three values of friction velocity were used to calculate high, mid, and low estimates of average-annual PM10 emission rates. A distribution is being fit to these results that will improve on the distribution described in the Atmospheric Transport Modeling report and on the distribution used in the DU PA model.

2) An incorrect link was used in the model for calculating the soil resuspension rate. The link is being corrected providing a consistent approach for the calculations.

3) Radionuclide exposure concentrations in airborne dust in the container Exposure_Dose.Media_Concs.Transport_Media is being revised to account

for the contribution of dust resuspension from gullies. Correction of this error will require additional modeling.

120. INTERROGATORY CR R313-25-8(4)(A)-120/1: GULLIES AND RADON

Provide justification as to why the presence of gullies in the embankment has no impact on the radon flux at the surface of the embankment, and thus no impact on the general population doses. Alternatively, modify the GoldSim model to have the embankment surface radon flux account for the presence of gullies within the embankment, include the “short-circuiting” of radon migrating upwards though the degraded cap and the release of radon directly to the atmosphere from any gullies that extend downwards into the disposed DU.

EnergySolutions' Response*:* The Clive DU PA Model v1.0 evaluates the effects of the occurrence of gullies in a screening approach, as stated in the Final Report. The mathematical model used to represent a fully-formed gully provided a suitable proxy for a fully-fledged landscape evolution model, which would be a much more significant undertaking. A small number of gullies were used simply in order to determine if gullies presented any contribution to dose or threat to waste containment. The effects of the gullies on biotic activities, enhanced infiltration, or enhanced radon flux were not examined. The potential for exposure of the waste was noted, confirming the significance of gully formation as a process to be considered more fully in subsequent model iterations.

One purpose of this v1.0 of the model, then, is to identify those processes that are of concern for the site. The Interrogatory identifies the ground surface flux of radon as one such process. As the sensitivity analysis has made clear, gully formation is indeed a process of concern for the site, and in that sense, v1.0 of the Model has done its job.

The next version of the model changes from the riprap cap to an ET cap. SIBERIA modeling has been performed on the Borrow Pit, the results of which are being abstracted and adapted to the disposal mound in the upcoming model of the ET Cover. Because of the slope differences, this over-estimates sediment transport offsite, and over-estimates depth of gullies formed. This is being included in the next version of the model and the report. Further erosion modeling needs is being evaluated after that model and report are reviewed.

Note also, that under the scenario that the DU waste is disposed below grade, the erosion consequences are likely to be minimized. This is evident in the current model results by comparing the three pairs of scenarios.

See also Interrogatories #070 and 071.

121. INTERROGATORY CR R313-25-19-121/1: GULLIES AND RECEPTOR LOCATION

When gullies are assumed to be present in the embankment, provide justification for using the radionuclide soil concentration and radon flux averaged over the entire embankment surface (including areas without and with gullies) when calculating exposures to hunters, ranchers, and off-highway vehicle (OHV) enthusiasts. Alternatively, provide the estimated exposures to these receptors when they are assumed to spend all (or most) of their time in the gullies.

EnergySolutions' Response*:* Discussion is being added to the text of the Erosion Modeling report per below:

> *"In the GoldSim implementation of gully erosion, a gully is assumed to form (via rainfall, etc.) after the initiating event of an OHV disturbing the rip-rap outer cover material; i.e., the OHVs are only initiating the gullies. The gullies that are modeled are deeply-incised to the extent that they reach the waste layers with side walls at the angle of repose and a wedge shape with a narrow top and broader base where the gully meets the level grade surrounding the disposal cell. The steep-walled profile of the eventual deeply-incised and narrow gullies would likely preclude extensive OHV activity in the gullies themselves; i.e., once a gully forms, OHV users (if any) would likely ride elsewhere on the cap. Thus, the use of area-average embankment air and soil concentrations in the Dose Container for OHV user exposure across the entire disposal unit, including gullies, is appropriate and likely to be protective."*

Given this conceptual explanation, even 5% of time spent in gullies seems conservative, if the area of gullies is 5% of the total area. The deeply incised portions of the gullies are too narrow for OHVing.

Note that this provides a conceptual explanation. However, the model is being updated to address removing the riprap cap and replacing it with an ET cover. An erosion model is being abstracted and adapted to these conditions from previous work performed on the Borrow Pit. Questions about erosion and gullies are being re-addressed.

122. INTERROGATORY CR R313-25-8(4)(D)-122/1: SIZE OF PLUVIAL LAKES

Provide complete references to support assumptions with respect to the size of recurring pluvial lakes. Revise the Deep Time Assessment report to rely on more recent paleolake evidence focused on the Bonneville Basin.

EnergySolutions' Response*:* It is acknowledged that there is uncertainty associated with "*number, timing, and recurrence interval*" of lakes, as well as the existence of smaller-scale cycles. The heuristic model for the glacial lake cycles in the deep time assessment is not designed to be an exact representation of the depositional record of the Clive site. Instead the model is designed to represent the long-term variability in climate and glacial-lake cycles for the next 2.1 million years.

The occurrence of large and smaller lakes is discussed in the sections following Section 3.1 of the Deep Time Assessment white paper. Following is text replacing the quoted text above in the white paper (following the existing paragraph):

> "*Slightly different external forcing and internal feedback mechanisms can lead to a wide range of responses in terms of the causes of glacial-interglacial cycles. The collection of longer ice core records, such as the European Project for Ice Coring in Antarctica (EPICA) Dome C core located in Antarctica, has highlighted the clear distinctions between different interglacial-glacial cycles (Jouzel et al., 2007). Variation in climatic conditions appears to be sufficient that large differences have occurred in each of the past 100 ky cycles. At the present time, the EPICA Dome C core is the longest (in duration) Antarctic ice core record available, covering the last 800 ky (Jouzel et al., 2007).*"
>
> *"Note that there is considerable uncertainty associated with the number, timing, and recurrence interval of lakes in the Bonneville Basin. The 100 ky glacial cycle is roughly correlated with the occurrence of large lakes (Balch et al. 2005, Davis 1998), and there appear to be smaller, millennial scale ("Dansgaard-Oeschger") cycles within this larger cycle that are not necessarily uniform (Madsen 2000). For example, the Little Valley lake cycle peaked in elevation at about 135 ky, the Cutler Dam lake cycle peaked about 65 ky, and the Bonneville lake cycle peaked about 18 ky BP (Machette et al. 1992). The following sections discuss these cycles in more detail."*

123. INTERROGATORY CR R313-25-8(4)(D)-123/1: TIMING OF LAKE CYCLES

Incorporate other existing literature on lake cycles in the Bonneville basin for a complete perspective on lake cycles in the Bonneville basin. Describe why the Burmester core data are applicable to the Clive site, including location and distance from Clive, ground elevation, and geologic setting.

EnergySolutions' Response*:* There is uncertainty associated with the timing of lake cycles (see also comment #122). The heuristic model for the glacial lake cycles in the deep time assessment is not designed to be an exact representation of the depositional record of the Clive site. Instead the model is designed to represent the long-term variability in climate and glacial-lake cycles for the next 2.1 million years. Additional justification for employing the Burmester core data, as well as text changes for clarification, are provided below:

> *"Various studies have investigated previous lake cycles in the Bonneville Basin. These include studies of Lake Bonneville shoreline geomorphology (Currey et al. 1984), palynological (i.e., pollen) studies of deep boreholes (Davis 1998), and studies of the geochemistry of deep-water lacustrine depositional sequences (Eardley et al, 1973; Oviatt et al, 1999, Balch et al. 2005). Analysis of these sediment cores is used to help understand previous lake levels and characteristics as well as establish the approximate age of previous lake cycles (e.g., Oviatt et al., 1999). "*
>
> *"Oviatt et al. (1999) analyzed hydrolysate amino acid enantiomers for aspartic acid, which is abundant in ostracode protein. Ostracodes are small crustaceans that are useful indicators of paleo-environments because of their widespread occurrence and because they are easily preserved. Ostracodes are highly sensitive to water salinity and other limnologic changes. Therefore, portions of sediment cores that contain ostracodes indicate fresher, and hence probably deeper, lake conditions than the modern Great Salt Lake (Oviatt et al., 1999). To establish the approximate timing of previous lake cycles, Oviatt et al. (1999) examined sediments from the Burmester sediment core originally collected in the early 1970s near Burmester UT (Eardley et al. 1973). Burmester is approximately 65 km east of Clive on the southern edge of the Great Salt Lake, at an elevation of 1286 m. This is the closest deep core site that is relevant to the Clive area (elevation 1307 m). Oviatt has also collected sediment data from Knolls (to the west of Clive) and at Clive itself (described further in Section 3.3). These data are largely consistent with the more recent layers from Burmester, indicating similar sedimentation processes at work at least during these time periods."*
>
> *"Data from the 307 m Burmester core suggest that a total of four deep-lake cycles occurred during the past 780 ky (Table 2). Oviatt et al. (1999) found that the four lake cycles correlated with marine δ18O stages 2 (Bonneville lake cycle: ~24-12 ky), 6 (Little Valley lake cycle: ~186-128 ky), 12 (Pokes Point lake cycle: ~478-423 ky), and 16 (Lava Creek lake cycle: ~659-620 ky)."*

[NOTE: the following is inserted from interrogatory #124, as the white paper text was changed in response to that comment.]

"Oxygen isotope stages are alternating warm and cool periods in the Earth's paleoclimate which are deduced from oxygen isotope data (Figure 2). These correlations suggest that large pluvial lake formation in the Bonneville Basin occurred in the past only during the most extensive Northern Hemisphere glaciations. There are many interacting mechanisms that could control or 'force' glaciation and deglaciation. For example, Oviatt (1997) and Asmerom et al (2010) suggested that these extensive glaciations were controlled by the mean position of storm tracks throughout the Pleistocene, which were in turn controlled by the size and shape of the ice sheets. Other glaciation forcing mechanisms have been suggested. The review by Ruddiman (2006) suggests that insolation changes due to orbital tilt and precession, greenhouse gas concentrations, changes in Pacific Ocean circulation, and possibly other interacting mechanisms could contribute to glaciation and deglaciation cycles in North America, and thus pluvial lake existence and size. Lyle et al. (2010) suggests that lake levels in the Pleistocene western US were influenced by stronger spring/summer precipitation fed by tropical Pacific air masses, rather than higher numbers of westerly winter storms. Regardless, the high-level, conceptual modeling of lake cycles that was conducted here did not assume any particular mechanism of glaciation/deglaciation. For example, the modeling simply assumed a 100 ky cycle, regardless of the mechanism."

[NOTE: Continued response to the present comment below]

"Balch et al (2005) conducted a more recent detailed study on ostracode fossils in Great Salt Lake sediment (i.e., under the lake). Other fossil invertebrates were also used as paleoecological indicators in this study. Both brine shrimp and brine fly fossils are indicators of hypersaline environments because they have a much higher salinity tolerance than most other invertebrates. This study's findings were consistent with Oviatt et al.'s (1999) later cycles, but as the core was not as deep the findings are not as useful for the present purpose as the Burmester data. The Burmester core data are most germane to the present modeling effort because they represent a relatively long time period in which to establish the occurrence of pluvial lakes in the region. However, note that there is considerable uncertainty associated with the number, timing, and recurrence interval of lakes in the Bonneville Basin. The 100 ky glacial cycle is roughly correlated with the occurrence of large lakes (Balch et al. 2005, Davis 1998), and there appear to be smaller, millennial scale cycles within this larger cycle that are not necessarily uniform (Machette et al. 1992, Madsen 2000). It is likely that shallow lakes have also occurred in each glacial period, but the shorelines have been destroyed by later lakes. Sediment mixing that occurs during lake formation can also mask the

existence of previous shallow lakes. Thus, it is impossible to have complete confidence in historical lake formation characteristics and formation."

"But, it can be said that large lakes have occurred in the past, as have intermediate lakes and shallower lakes. The model addresses these concepts by allowing large lakes to return in some glacial cycles, and by allowing intermediate lakes to occur as part of the transgressive and regressive phases of lake development."

124. INTERROGATORY CR R313-25-8(4)(D)-124/1: MECHANISMS FOR PLUVIAL LAKE FORMATION

The discussion of mechanisms for pluvial lake formation is incomplete. Describe other possible forcing mechanisms that have been proposed for the formation of Great Basin pluvial lakes and present the basis for the selected approach.

EnergySolutions' Response: Following are text changes for clarification:

"Oxygen isotope stages are alternating warm and cool periods in the Earth's paleoclimate which are deduced from oxygen isotope data (Figure 2). These correlations suggest that large pluvial lake formation in the Bonneville Basin occurred in the past only during the most extensive Northern Hemisphere glaciations. There are many interacting mechanisms that could control or 'force' glaciation and deglaciation. For example, Oviatt (1997) and Asmerom et al (2010) suggested that these extensive glaciations were controlled by the mean position of storm tracks throughout the Pleistocene, which were in turn controlled by the size and shape of the ice sheets. Other glaciation forcing mechanisms have been suggested. The review by Ruddiman (2006) suggests that insolation changes due to orbital tilt and precession, greenhouse gas concentrations, changes in Pacific Ocean circulation, and possibly other interacting mechanisms could contribute to glaciation and deglaciation cycles in North America, and thus pluvial lake existence and size. Lyle et al. (2010) suggested that lake levels in the Pleistocene western US were influenced by stronger spring/summer precipitation fed by tropical Pacific air masses, rather than higher numbers of westerly winter storms. Regardless, the high-level, conceptual modeling of lake cycles that was conducted here did not assume any particular mechanism of glaciation/deglaciation. For example, the modeling simply assumed a 100 ky cycle, regardless of the mechanism."

Note the heuristic nature of the model, which is consistent with the regulatory requirement to perform "*qualitative modeling with simulations*". This heuristic model does not attempt to predict the exact timing and size of lakes in the long-distant future, but instead acknowledges that large lakes have occurred in the past, as have intermediate lakes and shallower lakes, and that the model addresses these concepts by allowing large lakes to return in some glacial (100-ky) cycles, and by allowing intermediate lakes to occur as part of the transgressive and regressive phases of lake development. Large lakes are associated with an elevation in the model, so the rate of intermediate lakes depends on the elevation of the large lakes. This captures the essence of the 100-ky cycles lake effects and the associated build up of sediment over time.

Also, see responses to Interrogatories from #s 122-126.

125. INTERROGATORY CR R313-25-8(4)(D)-125/1: DEEP LAKE CYCLES

Correct the age ranges for the Lake Bonneville flood events to reflect more recent information.

***EnergySolutions' Response**:* The text below (Section 3.2, page 8, of the Deep Time Assessment white paper) is being changed for clarification:

> "*Most studies indicate that the high-stand (i.e., the highest level reached) of the lake at the Zenda threshold (1,552 m), located north of Red Rock Pass, occurred approximately 18.3–17.4 ky BP. The high-stand of the lake was followed by an abrupt drop in lake level due to the catastrophic failure of a natural dam composed of unconsolidated material at approximately 17.4 ky BP. As a result of this flood, the lake dropped to a level of 1,445 m, called the Provo level. The Provo level is the maximum level that any future deep lake is likely to reach (Currey et al. 1984, Oviatt et al. 1999). A more recent study (Miller et al. 2013), using radiocarbon dating for Provo shoreline gastropod deposits, estimates that the dam collapse and Bonneville flood event occurred between 18.0 and 18.5 ky BP, and therefore the high-stand may have occurred earlier. However, Miller et al. (2013) indicate that "uncertainties in [gastropod] shell ages may be as large as thousands of years, and the major shorelines of Lake Bonneville and the Bonneville flood require more work to establish a reliable chronology." The lake regressed rapidly during the last deglaciation, then increased again to form the Gilbert shoreline between 11.2-12.9 ky BP which coincided with the Younger Dryas global cooling event (Oviatt et al., 2005).*"

126. INTERROGATORY CR R313-25-8(4)(D)-126/1: SHALLOW LAKE CYCLES

Examine the presumed shallow lake cycles within the context of other references regarding lake cycles from other areas of the Great Basin.

EnergySolutions' Response*:* There were typographical errors in the quoted paragraph cited (Section 3.3, page 9 of the Deep Time Assessment white paper) that are corrected below. Intermediate lakes are defined in the white paper as lakes that at least reach the elevation/location of Clive, so the text as indicated reads "*intermediate*" instead of "*shallow*". Additionally, references to "*shallow*" lakes in Table 3 of the white paper are being changed to "*intermediate*". The paragraph describing these distinctions is being moved to a position before the quoted paragraph. The name of Section 3.3 (Shallow Lake Cycles) will also be changed as indicated:

3.3 Shallow and Intermediate Lake Cycles

"For modeling purposes, a distinction is made between shallow, intermediate and large lakes. Large lakes are assumed to be similar to Lake Bonneville, occurring no more than once per 100 ky glacial cycle. Intermediate lakes are assumed to be smaller lakes that reach and exceed the altitude of Clive, but are not large enough that carbonate sedimentation can occur. The Gilbert shoreline of Lake Bonneville is an example (Currey et al 1984). Shallow lakes are assumed to exist at all other times. The current Great Salt Lake is an example. For the purpose of modeling, the depths of these lakes are not as important as the areal extent in terms of modeling the occurrence. Under current climate conditions, it is assumed that intermediate lakes will not occur. Under future climate conditions, some glacial cycles will produce a large lake in the Bonneville Basin, and intermediate lakes will occur during the transgressive and regressive phases of a large lake, or during glacial cycles that do not exhibit a large lake."

"Intermediate lake events have occurred in the Clive area. These are documented in Table 3 (C.G. Oviatt, Professor of Geology, Kansas State University, personal communication December 2010, January 2011, and email communication herein referred to as 'C.G. Oviatt, personal communication'). These events are evident when analyzing a pit wall interpretation at the Clive site (Appendix A; C.G. Oviatt, unpublished data) as well as at the ostracode and snail record present in the Knolls (12 km west of Clive near the Bonneville Salt Flats) sediment core (Appendix B; C.G. Oviatt, unpublished data). The pit wall study conducted by Oviatt occurred during early development of the Clive disposal facility. From the Clive pit wall interpretation, it is presumed that at least three intermediate lake cycles occurred prior to the Bonneville cycle, although there is uncertainty

associated with that estimate. For example, these intermediate cycles could in fact be part of the transgressive phase (i.e., rising lake level) of the Lake Bonneville cycle (C.G. Oviatt, personal communication). By analyzing the Knolls core interpretation, the Little Valley cycle is present at approximately 16.8 m from the top of the core. Given the pit wall at Clive was 6.1 m deep and does not capture the Little Valley cycle, it is possible that that other smaller lake cycles occurred in the Clive region in addition to the three intermediate lake events noted in Table 3 (labeled as Pre-Bonneville Lacustrine Cycles). There are few data to support the specific number of lakes that may reach Clive and the rate of sedimentation. There is also uncertainty associated with the particular times that these cycles occur, as age dating (e.g., via radiocarbon dating) has not been performed in the Great Salt Lake area. Most studies simply examine the degree of lake salinity using fossil records, and are associated with cores that are in or near the Great Salt Lake. For example, Balch et al. (2005; Fig. 6) estimated that there were six "saline/hypersaline" (i.e., shallow to intermediate) lake cycles that occurred between the Lake Bonneville and Little Valley cycles, and approximately that same number between the Little Valley cycle and the maximum age evaluated (300 ky). However, this work does not inform the question of whether these lakes may have reached the elevation of Clive, nor does similar work such as Davis (1998). Assumptions used in modeling are documented in Section 6.2."

127. INTERROGATORY CR R313-25-8(4)(D)-127/1: CARBONATE SEDIMENTATION

Provide additional rationale for the assumption that carbonate sedimentation will not occur in intermediate lakes, based on the limnology literature.

EnergySolutions' Response*:* The intent of the cited sections is not to exclude carbonate deposition in intermediate lakes (see for example the second paragraph of section 6.2 that references carbonate oolitic deposition in intermediate lakes). The primary emphasis of the descriptions in section 3.3 is on the sediment depositional rates of intermediate versus large lakes not on the presence or absence of carbonate deposition. A key assumption for the deep time assessment is the observation, based on core sediment studies, that the net depositional rate of deep lakes is lower than the sediment depositional rate for intermediate lakes. The conceptual basis for this assumption is sedimentation rates are dependent on basin location, presence or absence of fluvial deposition, wave dynamics, availability of local sediment sources, slope, water chemistry and biological activity. Carbonate deposition is likely to occur under a wide range of lake conditions but the ratio of carbonate deposition to clastic sedimentation will increase as the lake deepens because of the reduction in sedimentary influx with increased distance from shoreline processes and decreased wave activity.

There are recognized trends in carbonate mineralogy that can be correlated with lake volume and indirectly lake depth (for example, Oviatt, 2002; Oviatt et al., 1994; Benson et al., 2011). The transitions from low-magnesium calcite to high-magnesium calcite to aragonite generally reflect increasing lake salinity and increasing magnesium concentration which occur with decreasing lake volume. Similarly, for a hydrologically closed pluvial lake system, the relative concentration of total inorganic carbon should decrease as lake size increases. The δ18O of deposited carbonate can be correlated with rising lake levels because of the interplay between the δ18O value of river discharge entering a lake and the δ18O value of water vapor exiting the system via evaporation (Benson et al. 2011). The mineralogy and isotopic composition of carbonate composition can be obtained from sediment cores. However, interpretations of the data are complicated by multiple processes including local groundwater discharge, introduction of glacial rock flour, and reworking of lake sediments during transgressive and regressive lake cycles.

The model parameters used in the deep time assessment are sensitive to lake duration and sedimentation rates but are not dependent on the dynamics of carbonate deposition. Radionuclides in sediment will partition between the lake water and solid phase dependent on element-specific solubility and assigned sorption properties. Radionuclides remaining in the pore water can diffuse into the lake water. Some radionuclide species may bind with carbonate ions in the lake water and precipitate as carbonate. However, the deep time assessment assumes all waste is precipitated into local sediments during lake recession. Additional detail on lake dynamics/circulation and processes of radionuclide partitioning in lake carbonate and evaporite deposits during lake recession is being added.

128. INTERROGATORY CR R313-25-8(4)(D)-128/1: LAKE SEDIMENTATION

Use the information in existing journal literature on sedimentation rates to update statements in the Deep Time Assessment report. Emphasize how the core data and sedimentation rates for those locations are relevant to the Clive site given the paleodepositional facies involved.

EnergySolutions' Response*:* The heuristic model for the glacial lake cycles in the deep time assessment is not designed to match the depositional record of the Clive site. Instead the model represents the long-term variability in climate and glacial-lake cycles for the next 2.1 million years. Probability distribution functions are sampled in the model simulations for sedimentation rates for large and intermediate glacial lakes (Table 1, Appendix 13 Deep Time Assessment). The selected distributions represent potential variability in lake sedimentation for a wide range of conditions spanning multiple glacial cycles. Section 3.4 describes sediment accumulation rates determined from studies of sediment cores and pit exposures at a range of sites in the Lake Bonneville basin and including unpublished data from the Clive site. The model design does not necessarily require matching the sedimentation rates to the specific depositional facies at the Clive site.

While inclusion of rate data from published literature from as many sites as possible is always a consideration, the added data would only be important if it modifies the distribution parameters used to represent lake sedimentation during future glacial cycles. Moreover, the sedimentation rates are not key parameters affecting the deep time model results (lake and sediment concentrations). The model results are strongly dependent on assumptions of embankment erosion and incorporation of DU waste in lake sediments, radionuclide recycling between sediment and lake water, and remixing of waste/sediment mixtures during successive glacial lake cycles. Additionally, the model results are more dependent on the parameter distribution used to represent site dispersal area of waste during lake erosion intervals (see the model parameter list in Table 1, Appendix 13 Deep Time Assessment) than the parameters for lake sedimentation rates.

No changes are needed in the text.

Note that the model is heuristic, capturing the concepts of large and intermediate lake formation, and sedimentation through each glacial cycle (which includes aerial deposition, lake/wave scouring and lake deposition).

129. INTERROGATORY CR R313-25-8(4)(D)-129/1: LAKE EROSION

Provide a reference to support the assumption that a lake is large enough to obliterate a relatively soft pile. Explain why such obliteration will not be cause for ongoing active maintenance.

EnergySolutions' Response: The assumption of complete erosion of the embankment during the first lake return to the Clive site is considered a simplifying assumption. Figure 13 in the Clive DU PA model and the accompanying text show that the U-238 concentration in sediments is driven by the first lake event, with decreasing sediment concentrations in successive lakes. If the embankment is not completely eroded, there will be less waste mixed in the sediments, and lower sediment concentrations of U-238 in the first and all successive lake sediments. Consequently, this simple assumption is probably conservative for the endpoints of U-238 concentrations in sediment and lake water.

The concept is that subsequent to obliteration by a lake, there will no longer be a disposal site that needs to be maintained. Assuming the waste is dispersed through wave action and lake dynamics, and that the waste is no longer containerized in this environment, any exposed waste will be dispersed with other material in the mound and with other material being moved with the returning lake. There will be nothing left to maintain if the whole site is obliterated.

Aerial deposition is being addressed as part of evaluating erosion of the ET cover. Aerial deposition rates suggest that greater stability will be provided for the site over time, so that only the upper portions of the site might be dispersed. The DU, disposed below grade, could stay buried. This is being evaluated further in the next model revision.

The degree of erosion will be strongly dependent on local lake conditions as well as the dynamics and duration of wave action and shoreline processes. If documentation is required for the conservative assumption of complete erosion of the waste embankment, a preferred approach would be examination of natural analogues of erosion processes and erosion effects in the Lake Bonneville basin. See the response to Interrogatory #131 for a discussion of possible natural analogue studies that could potentially be applied to model revisions and/or supporting studies of the lake erosion part of the deep time model.

Also, note that there is no expectation or requirement of active maintenance of a low-level waste disposal system for time periods of 10,000 years or longer.

Refer to R313-25-22*: The disposal facility shall be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.*

130. INTERROGATORY CR R313-25-8(4)(D)-130/1: LAKE GEOCHEMISTRY

Provide references to support statements concerning the geochemisty of uranium in the carbonate system and adsorption behavior on clays, iron oxides, and ferrihydrites and revise the statements as needed to reflect the literature.

EnergySolutions*' *Response: Section 4.0, page 13, of the Deep Time Assessment report states the following:

> "*While the lake is present, some waste in the water column will bind with carbonate ions and precipitate out into oolitic sediments, while the remaining waste will fall out with the sediment as the lake eventually recedes.*"

This section (Section 4.0, page 13) of the Deep Time Assessment documentation is referring to precipitation of radionuclides with soluble carbonate ions to form carbonate minerals. It is not discussing adsorption onto clays or carbonates. This statement is elaborated on in Section 6.5.2. Text is being added to Section 4.0, page 13 after the quote above to reference Section 6.5.2 for more details.

The K_ds for U and the other elements are the same in the Deep Time model as in the original model. The only change to U geochemistry in the Deep Time model is the solubility, which decreases for the reasons described in Section 6.5.2.

Interrogatory #147 asks to justify high U K_ds that are associated with ferrihydrites and clay. See the response to Interrogatory #147 for more discussion on U adsorption.

131. INTERROGATORY CR R313-25-8(4)(D)-131/1: POTENTIAL WAVE ENERGY

Provide support and references for the assumption that shallow lakes have low wave energy.

EnergySolutions' Response*:* Waves in small lakes could be destructive and potentially erode the waste embankment. As noted in the response to Interrogatory 129, the deep time model makes the conservative assumption that the embankment is completely eroded during the return of the first lake cycle to the elevation of the Clive site. Note also that the model revision includes an ET cover and will also address aerial deposition prior to when the first lake arrives. Aerial deposition rates in the area are at least 0.1 mm/yr, which covers and increases stabilization of the disposal system, and complete cover of the disposal system is also possible if the first lake does not arrive in the current climate cycle.

Examination of the literature on erosion of engineered features of coastal shorelines is a possible approach to evaluating lake erosion. However, the approach would be difficult to apply to the dynamics of transgressive and regressive stages of glacial lakes. A potentially more useful approach would be analogue studies examining erosional features of preserved shorelines in the Lake Bonneville basin. Two approaches could be considered. The first is examination of erosional features of the regressive-phase Provo shorelines (Sack, 1999) in the Clive vicinity. Field measurement could be made on the erosion depth/height of preserved shorelines and used to develop a distribution of erosion depths for use in parameters developed for a more physically realistic erosion model (an alternative to complete erosion of the embankment and release of disposed DU). Additionally, the surficial expression of shorelines could be used to refine the SiteDispersalArea parameter in the deep time GoldSim model (Table 1, Appendix 13, Deep Time Assessment). Both parameters would be significant in model evaluations of radionuclide concentrations in lake sediments.

A second approach would be systematic examination of erosional features of volcanic landforms modified by post-Provo shoreline erosion in the Black Rock

Desert volcanic field (Nash, 1990). The advantages of this approach are two-fold. First, volcanic landforms have distinctive shapes (scoria cones, tuff cones, tuff rings) allowing reconstruction of erosional modification of their original shape/geometry (see attached Figures below). Second, volcanic landforms exhibit a range of resistance to lake erosion varying from poorly consolidated scoria cones (easily eroded), indurated tuff cones and tuff rings from palagonization (the process of alteration of hydrated basaltic glass to form palagonite), and highly resistant lava flows with distinctive flow structure (pahoehoe and aa lava flows). The physical properties of this range of volcanic landforms would be analogous to the physical properties of closure cover designs.

These analogue studies would only be considered if model revisions are required to reduce the conservatism of the assumption of complete erosion of the waste embankment in the first return of a glacial lake.

Figure 2-131/1, Google Earth Depiction of Volcanic Landforms

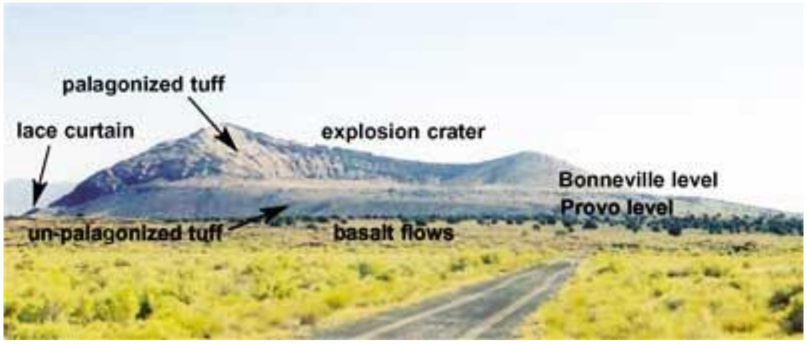

Figure 2-131/2, Bonneville Volcanic Landforms

Google Earth photograph of the Pahvant Butte in the Black Rock Desert, a 16,000 BP tuff cone (crater diameter is 3 km for scale); oblique view of the crater from photograph on the WWW with identification of the Bonneville and Provo shoreline benches.

132. INTERROGATORY CR R313-25-8(4)(D)-132/1: SEDIMENTATION MODEL

Provide more detail on the sedimentation model as it relates to the text.

EnergySolutions' Response*:* The data in Figure 9 represent a time history, in which case a time series technique is appropriate. The data in Figure 9 show a range in elevation of about 5 m for the roughly 150 year period. The model incorporates the time history curve, so that it preserves the elevation range over time. A serial correlation is also assumed, which is evident from Figure 9 (if not, all data points would look random across the plot, instead of showing upward and downward trends for shorter period of time). An autoregressive model achieves variability across time, but in a correlated fashion that allows the elevation of the lake to increase for short periods and then decrease for short periods.

It was further assumed that, in the transgressive phase of the development of a lake, the lake elevation would increase. So, the model for the transgressive phase has an increasing function so that the elevation of the lake is increasing with time, but subject to shorter term variability modeled with a time series function that allows lakes to expand for a while and then shrink for a while (as evidenced by the data presented in Figure 9).

The underlying conceptual model is that as the climate cycle continues beyond the inter-glacial period, the elevation of the lake will rise in general, but include "stops and starts" along the way. The 150 year data record was used to model the "stops and starts" with the autoregressive time series model, whereas the general trend (upwards during the transgressive phase) was modeled as a transgressive and then regressive curve. The text description is being expanded to include more information on the modeling, in particular the transgressive and then regressive curve that underlies the process.

However, it is important to note that the intent of the deep time model is to allow large lakes to return periodically, and to allow intermediate lakes to appear during the transgressive and regressive phases. The number of lakes that return is not nearly as important as the process that allows at least some lakes to return.

More information can be provided about the processes affecting lake sedimentation. Sedimentation happens through three basic mechanisms. The first is aerial deposition of wind-blown deposits that happens predominantly during the inter-glacial period. The second is sediment that is physically moved by lake action (and related water action – for example, once the lake returns there will be more above lake and below lake "rivers" that will move sediment – lake action will scour sediment, hence the benches that are seen around the Bonneville basin). The third is lake precipitation or oolitic sedimentation.

The historical record consists of data that represent seven or eight 100 ky cycles. Our analysis of the different cores (Burmester, Knolls, and the borrow pit wall at the Clive site), suggest roughly 15-20 m of sediment per cycle, whether or not a large lake returns. Note that these sediments are often mixed so that the differentiation between aerial deposition, alluvial sediment, and lake sediment (oolitics) is difficult. But, it appears that all processes contribute to the overall lake sedimentation cycles, with more aerial deposition in some cycles, and more lake sediment in other cycles, etc. The mixing of sediment occurs when a lake returns and churns the aerial deposition, and then lake sediments; both overly and mix with other sediments (depending on the duration of the lake cycle and the maximum lake depth, both of which affect lake sedimentation rates).

These interacting processes are being described in greater detail in the revised report. In addition, supplemental research is being performed using analogue features in the Lake Bonneville basin to better constrain processes of sedimentation and embankment erosion, as well as how the disposal mound might be partially covered by the time a lake returns.

133. INTERROGATORY CR R313-25-8(4)(D)-133/1: CALCULATIONS OF RADIOACTIVITY IN WATER AND SEDIMENT

Provide context for the equations and variables presented for calculating radioactivity in water and sediment.

EnergySolutions' Response*:* A scenario considering occurrence of an intermediate lake, the resulting destruction of the Energy*Solutions* waste embankment, and dispersal of the waste is modeled. The activity per unit volume of sediment following the dispersal of the waste is estimated using equation 13 on page 31 of the Deep Time Assessment report:

$$C_{sediment} = \frac{R_{above\ grade}}{V_{material\ above\ grade} + V_{sediment}}$$

In this equation $C_{sediment}$ is the activity per unit volume of the sediment, $R_{above\ grade}$ is the activity of the waste in the above grade portion of the embankment, $V_{material\ above\ grade}$ is the volume of material in the above grade portion of the embankment, and $V_{sediment}$ is the additional sediment transported to the dispersal location due to lake formation. $V_{sediment}$ is estimated as the depth of sediment due to lake processes times the area over which the waste is dispersed.

The calculation of the activity diffusing from the sediments into the water during a time period is described on pages 31 and 32 of the Deep Time Assessment report.

As radionuclides associated with the sediments dissolve into the pore water, they diffuse into the lake water using a constant flux model based on Fick's first law, with the following assumptions:

- There is an interface boundary layer of 0.1 m above the sediment, above which the water has a radionuclide concentration of 0. In fact, there will be some buildup of concentration as a radionuclide migrates into the water, but it will diffuse into the lake. It is conservative to assume a zero concentration, which results in the highest possible flux.

- The concentration in sediment remains constant over the deep time period. The sediment concentration should in fact diminish over time if enough mass is migrated into the water, but for simplicity, the sediment concentrations are kept constant across time steps.

Fick's law for this case estimates the activity diffusing from a given area of sediment into the lake with time. The activity per area per time is the flux. Fick's law states that this flux is given by the change in activity with distance multiplied by a free-water diffusion coefficient. The calculation assumes that there is a stagnant interface boundary layer of water between the sediment and the open water that is 0.1 m thick. The assumption is also made that the activity concentration is zero in the open water. The difference in concentration across the stagnant layer is then the concentration in the sediment Cv minus the concentration in the open water or Cv - 0. Fick's law would be written as:

$$Activity\ Flux = \frac{R}{\Delta t\ A} = D_m \frac{C_v - 0}{0.1}$$

Where:

R is the activity,
Δt is the length of the time period,
A is the area of the sediment that contains the waste, and
D_m is the diffusion coefficient for the radionuclide in water.

Multiplying both sides of the equation by Δt A gives equation 14 in the Deep Time Assessment report.

The activity concentration in the lake water is then calculated by dividing the total activity, A, by the volume of lake water. The volume of lake water is the product of the lake depth and the dispersal area. The above equations are implemented in the GoldSim model to provide qualitative assessments of deep time concentrations in lake water and lake sediment following the return of a lake in the Bonneville Basin large enough to demolish the CAS embankment. The text in the Deep Time Assessment report is being revised to provide context for the equations and variables presented.

134. INTERROGATORY CR R313-25-8(4)(D)-134/1: FUTURE LAKE LEVEL ELEVATIONS

Provide further discussion on the potential rise of the lake level with respect to the proposed facility and more specific definitions of the depth of "intermediate" and "deep" lakes.

EnergySolutions' Response: Please also see the response to Interrogatory CR R313-25-8(4)(d)-126/1 with regard to distinctions between "*shallow*", "*intermediate*", and "*deep*" lake definitions as germane to modeling. Text has been added following the paragraph below:

> *"For modeling purposes, a distinction is made between shallow, intermediate and large lakes. Large lakes are assumed to be similar to Lake Bonneville, occurring no more than once per 100 ky glacial cycle. Intermediate lakes are assumed to be smaller lakes that reach and exceed the altitude of Clive, but are not large enough that carbonate sedimentation can occur. The Gilbert shoreline of Lake Bonneville is an example of a lake that attained the elevation of Clive (Currey et al 1984). Shallow lakes are assumed to exist at all other times. The current Great Salt Lake is an example. For the purpose of modeling, the depths of these lakes are not as important as the altitude attained. Under current climate conditions, it is assumed that intermediate lakes will not occur. Under future climate conditions, some glacial cycles will produce a large lake in*

the Bonneville Basin, and intermediate lakes will occur during the transgressive and regressive phases of a large lake, or during glacial cycles that do not exhibit a large lake."

"It is also possible that intermediate lakes could occur and thus reach the elevation of Clive under unusual conditions. The areal extent of lakes is not only determined by elevation, but by local topography, precipitation, temperature, characteristics of inflow and outflow sources, and other factors. For instance, the Great Salt Lake 'spilled' over a 1285 m (4217 ft) topographic barrier to the west of the present lake into the area of the present Great Salt Desert as recently as the 1700s (Currey et al., 1984). This expanded lake was about 15 m lower than the Clive site. Precise dating of shorelines for the Great Salt Lake and variants is unfortunately lacking. Radiocarbon dating for the Pyramid Lake area in Nevada indicates that this lake's levels have lowered approximately 35 m from the late Holocene (3.5 to 2.0 ky) to today (Briggs et al. 2005). Radiocarbon and tree-ring dating to determine lake levels in the Carson Sink area in Nevada indicates that lake elevations have risen approximately 20 m twice in the last 2000 years (Adams 2003). It is not possible at this time to interpolate from these studies to the Great Salt Lake area. However, given that there is lack of empirical evidence that under present climate conditions that an intermediate lake would reach the Clive site, this condition is not addressed. Future intermediate lake assumptions are described in Section 4.1.1.1."

135. INTERROGATORY CR R313-25-19-135/1: EXPOSURE TO GROUNDWATER

Provide a calculation of the doses to an individual who pumps, processes, and uses the groundwater from a well located near the Clive facility to ensure that exposures are below the levels specified in R313-25-19. Examine how byproducts of future desalination processes that might rely on radio-contaminated groundwater at Clive will need to be managed to protect public health and the environment, incorporating additional dose to a member of the public if needed.

EnergySolutions' Response*:* Please see the response to Interrogatory CR R313-25-7(2)-91/1.

136. INTERROGATORY CR R313-25-7(1)-136/1: IRON (HYDRO)OXIDE FORMATION

Clarify whether the formation of iron (hydro)oxides derived from the waste containers was considered in predicting sorption.

Energy**Solutions' *Response***: In the Clive DU PA model, the K_ds of the waste are assumed as those for Sand. No credit is taken for degradation of the steel to form iron (hydr)oxide or the subsequent sorption by radionuclides to these solids. Taking credit for the iron present in the waste is appropriate and is more realistic for the transport of radionuclides, slowing down the movement of radionuclides out of the waste.

Text is being added to Section 2.0 of the Geochemical Modeling report to clarify that no credit was taken for adsorption onto the steel drums in the development of K_ds for the waste materials.

137. INTERROGATORY CR R313-25-7(1)-137/1: TOTAL DISSOLVED CARBONATE CONCENTRATIONS AND OTHER GEOCHEMICAL DATA

1. Reassess the total dissolved carbonate concentrations to determine whether they were underestimated, leading to the underestimation of uranium sorption in subsurface earth materials.
2. Explain and justify why the geochemical data from the seven wells listed in Tables 5 and 6 of the Geochemical Modeling report are representative of the shallow aquifer at Clive, especially in light of the presence of 78 compliance monitoring wells now found in Section 32.
3. Describe what hydrostratigraphic units the water table occupies below the Class A South cell, including in terms of groundwater mounding that exists near GW-19A.
4. Explain and justify the range of TDS quoted for the shallow aquifer at Clive.

EnergySolutions' Response:

1. The underestimation of soluble carbonates leads to an overestimation of U sorption. As stated in reply to other interrogatories (#140, #142, #148), the carbonate assumptions are being clarified, including the applicability of the references used for K_d distribution development to the Clive site, especially with respect to the high carbonates expected at Clive.

2. The monitoring well data is being revisited and clarified in Table 5, further demonstrating the representativeness of these 7 wells for the shallow aquifer of the Federal Cell. If applicable, data from compliance monitoring wells is being included in the Geochemical Modeling report in Table 5 or an

additional table to encompass the range of geochemical parameters expected at Clive.

3. The Geochemistry Modeling report is being revised and describes what units the water table occupies below the Federal Cell, including groundwater mounding at the southwestern margin of the Federal Cell (e.g., near GW-19A).

4. The TDS values in Table 5 range from about 20 parts per thousand to 70 parts per thousand. Data from Energy*Solutions* (2013) were not available when the original Geochemical Modeling report was written. With a minimum of 10.4 parts per thousand, these data appear to be fairly consistent with Table 5 TDS values. The Energy*Solutions* (2013) data is being incorporated into the Geochemical Modeling report.

138. INTERROGATORY CR R313-25-26(1)-138/1: MONITORING WELL COMPLETION ZONES

Clarify from which completion zones the wells are sampled.

EnergySolutions' Response: Completion zones and screen depths (and associated groundwater concentrations) are reported annually to the Division for Energy*Solutions'* point of compliance monitoring wells (Energy*Solutions*, 2014b). However, the text in question only discusses the shallow aquifer data, as evidenced by the statement that

> "*All wells are completed within the upper unconfined aquifer…*".

The text is being changed to the following:

> "*The Clive Facility has a large number of monitoring wells with completion zones in the shallow aquifer and monitoring data are currently collected from these wells on at least an annual basis.*"

139. INTERROGATORY CR R313-25-7(1)-139/1: ION CHARGE BALANCE

Clarify the ion charge balance.

***Energy*Solutions' *Response*:** The table below is being added to Section 2.2 of the Geochemical Modeling report, as a revised Table 6, along with the modified text below.

"Sodium and chloride are clearly the dominant ions with slightly alkaline pH. Excellent charge balance is obtained using these data, indicating all major ions are being accounted for. Note that the dominance of Na and Cl in the charge balance (86% and 92%) obscures many of the other ion contributions."

Table 2-139/1 (6): Ion Concentrations from GW Wells Surrounding the Waste Cell. Negative and positive percent charge balance contributions are given on a molar basis.

GW Well	Br– (mg/L)	F– (mg/L)	Cl– (mg/L)	NO3 – (mg/L)	SO4 2– (mg/L)	Ca2+ (mg/L)	Mg2+ (mg/L)	K+ (mg/L)	Na+ (mg/L)
GW-16R	22	3.8	22,914	1.4	1,769	354	486	476	14,263
GW-25	23	8.8	25,783	1.1	4,420	527	853	565	16,465
GW-19A	0	0	37,800	0	0	1,028	1,580	616	23,800
GW-57	18	8.5	23,110	1.9	4,652	707	844	530	14,398
GW-100	26	1.8	20,254	1.1	2,911	496	683	457	12,993
GW-110	17	1.5	17,989	2.1	2,226	322	469	432	11,400
GW-125	16	0.9	20,813		2,494	427	637	488	12,813
Average (mg/L)	20	4.2	24,094	1.5	3,079	552	793	509	15,162
Average (mol/L)	2.2E-04	1.9E-04	6.8E-01	1.8E-05	2.7E-02	1.4E-02	3.3E-02	1.3E-02	6.6E-01
percent of charge balance	0.03%	0.03%	92 %	0.002%	7.5 %	3.6 %	8.5 %	1.7 %	86 %

140. INTERROGATORY CR R313-25-7(1)-140/1: DETERMINATION OF K_D VALUES

1. Provide a more detailed description of the determination of K_d values used in the recent PA modeling.
2. For those elements/nuclides that are redox sensitive, describe the redox condition assumed in selecting appropriate K_d values and compare this assumption with all aquifer redox data collected from the shallow Clive aquifer to date.
3. Add a summary table to Section 4.1 of the Geochemical Modeling report that provides more detail on inputs to the model.
4. Compare the site-specific K_d values determined by Adrian Brown Consultants (1997) with the PA model's K_d descriptive statistics and explain and justify any similarities or differences in light of the local geologic conditions and geochemistry and the depositional environment that created the pluvial lake deposits occupied by the Clive vadose zone and shallow aquifer.

***EnergySolutions' Response**:*

1. Clarification is being added to the text to describe how K_d values were selected from references (EPA, 1999) and used for the Clive DU PA model, especially for Cs and Pa with respect to the effects of TDS on sorption and the applicability of the references.

2. The redox assumptions are being clarified for the elements that are redox sensitive and the role redox plays in selection of K_d ranges. The assumptions of redox conditions for Clive and comparison to the aquifer redox data is being discussed.

3. A summary table is being added to the Geochemical Modeling report to include:
   - Element simulated in the GoldSim model
   - K_d distribution type used in the model (normal or log-uniform)
   - Defining values of the distribution (mean and variance, or min and max, respectively for normal or log-uniform)
   - Range of K_d inputs used to develop distributions (as in the Response to Interrogatory #146)
   - The corresponding laboratory-determined K_d, using Clive soils and Clive groundwater, reported by Adrian Brown Consultants (1997)

4. A discussion of the K_d values from Adrian Brown Consultants (1997) and their applicability to the Clive DU PA model and how they were used in K_d distribution development is being included in the Geochemical Modeling report.

141. INTERROGATORY CR R313-25-7(1)-141/1: PH AND K_D VALUES AND SERNE (2007)

Consider pH values when estimating K_d values and provide more detail on the "*non-groundwater scenario*" used in Serne (2007).

EnergySolutions' Response*:* The intention of citing the Serne (2007) report is to use it primarily as a secondary reference for comparison purposes for K_ds. The sites are somewhat similar, although there are differences.

For example, the Clive soils have a pH range of 7 to 8. The pH of the soils in Serne (2007) are 6.2 to 7.8. Since pH is an important contributor to K_d, it should be noted that K_ds from Serne may have a wider distribution than would be expected at Clive. As part of the analysis of the Serne (2007) K_d ranges, it should be noted that the Clive K_ds are slightly broader ranges that to include slightly higher pH values of the Clive soils.

Text is being added to say,

"*Of note is that the Hanford soils are slightly acidic (pH 6.2 to 7.8), ….*"

The total organic carbon content referenced in Serne (2007) of 0.5% to 1.5% is the total organic carbon content in the sediments along the river banks. So this is the carbon content of the solid phase rather than the groundwater. According to the NRCS Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm), Clive soils are slightly lower in organic matter, with ranges at Clive from approximately 0.3% to 1%. These slight differences will not make much difference in the K_d estimations.

Text is being added to say

> *"…with organic content of 0.5 to 1.5% organic carbon, slightly different from the Clive location with organic carbon contents of approximately 0.3% to 1%.*"

Text is being added to clarify the non-groundwater scenarios as

> "*scenarios that do not involve direct ingestion of contaminated well water by humans or animals,"* as in Serne (2007).

142. INTERROGATORY CR R313-25-7(1)-142/1: REFERENCES FOR K_D DISCUSSION

Provide additional references to support the discussion of K_d values. Alternatively, either (1) select conservatively low K_d values or (2) collect Clive soil and groundwater samples and perform independent laboratory testing to determine a site-specific empirical value(s).

EnergySolutions' Response*:* The expected chemical species of each ion is presented based primarily on EPA (1999) and EPA (2004). Detailed chemical modeling is not needed, in general, for the initial Clive DU PA model, except, perhaps, for certain elements of interest, such as uranium. If necessary, the probabilistic model will demonstrate, through sensitivity analysis, whether or not more detailed modeling is needed to reduce uncertainty in sensitive parameters. The text is being modified to clarify the references that provide a basis for the speciation of each chemical element.

The discussion of chemical speciation is relevant only in that it provides justification for selecting K_d values from some references versus other references. The applicability of each reference depends in part on the chemical speciation. The text is being modified to clarify the chemical speciation of the element in the reference, along with a discussion of the applicability of the reference for K_d distribution development at the Clive site.

The solid phase composition of sites is being compared if possible and if applicable. The emphasis for the level of detail needed for justification of the applicability of a reference should be on demonstrating that the most appropriate data were used. Carbonate concentrations and pH may be more important factors than solid phase composition, although clay and iron oxide contents are also important.

Clarification is being added to the Geochemical Modeling report to justify the K_d distributions from the literature so that site-specific data are not needed. Conservatively low K_d values are not easily interpretable and will not be used, in general. With the complexity of performance assessment models, it is difficult to identify what a "conservative" assumption means because of the non-linearity of the model and because of multiple endpoints. An assumption might be conservative for one endpoint, but that same assumption might not be conservative for a different endpoint. It is better to create wider distributions where there is uncertainty in the solubility than it is to be "conservative."

143. INTERROGATORY CR R313-25-7(1)-143/1: NEPTUNIUM SPECIATION

Correct a reference to Np(VI) and provide citations. Alternatively, either (1) select conservatively low K_d values or (2) collect Clive soil and groundwater samples and perform independent laboratory testing to determine a site-specific empirical value(s).

<u>EnergySolutions' Response</u>: The graphs presented from the Geochemist's Workbench provide some insight into aqueous speciation of Np. However, these diagrams show only the dominant species at each point in the diagram. In solution multiple different solution species can be present, even though only one is dominant. That is why it is also helpful to look at different types of diagrams, such as activity vs. pH diagrams.

For example, see Figure 5.8 below, taken from EPA (2004). This figure shows that for Np(V), carbonate complexes begin to form at pH 7, where dissolved carbonate concentrations are 57 mg/L. So, while Np carbonate complexes do not dominate Np speciation, there could be 10 20% (or more, depending on redox and carbonate concentrations) of soluble Np complexed with carbonates for the Clive range of pH values.

That said, there is very little research on Np carbonate complex sorption and a limited number of K_d studies for Np. So, the effects of carbonate solution complexation on K_d are not evaluated for Np.

The text is being corrected to add the EPA (2004) reference to Figure 5.8, illustrating the formation of carbonate complexes above pH 7. The text will also change to refer to "Np(V)" carbonate complexes instead of "Np(VI)" carbonate complexes, since Np(V) is the most likely redox state of Np for the conditions at the Clive site.

This interrogatory is being addressed as a text change. There is no need to either select conservatively low K_d values or derive site-specific empirical K_d value(s).

Figure 5.8. Calculated aqueous speciation for Np(V) as a function of pH. [Neptunium(V) aqueous speciation was calculated based on a total concentration of dissolved neptunium of 1×10^{-8} mol/l, the water composition in Table 5.1, and thermodynamic constants from Lemire *et al*. (1984).]

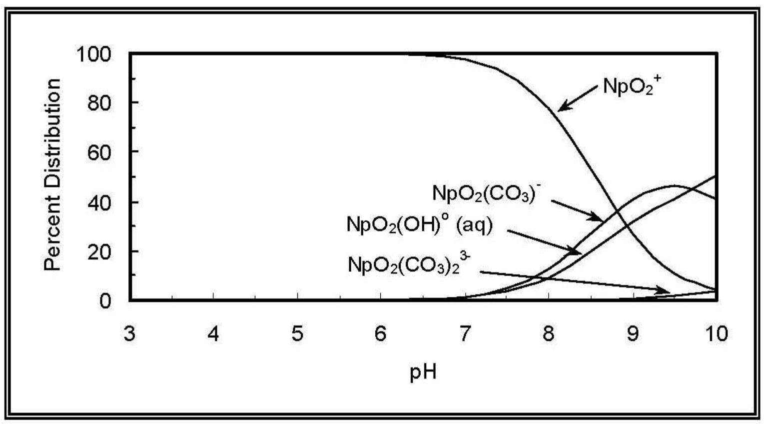

Figure 2-143/1, Aqueous Speciation for Np(V)

144. INTERROGATORY CR R313-25-7(1)-144/1: PLUTONIUM SPECIATION

Provide additional information to support the assumptions with respect to plutonium speciation.

EnergySolutions' Response*:* It is assumed that discussion of neptunium in the Interrogatory text is a typo and should have been plutonium. As such, it is recognized that Pu(IV) could also be present in the Clive system because of slightly reducing conditions in the saturated zone and in localized areas of the disposal system. The groundwater chemistry data in Table 5 of the Geochemical Modeling report may be biased towards slightly reducing conditions. In the unsaturated zone, oxidizing conditions are generally expected. However, Pu(IV) may be an important form of Pu to consider for Clive geochemistry.

EPA (1999) indicates that soil redox conditions are not as important as ligand presence and concentration, as well as carbonate ion concentrations (Section

5.6.6.1). There is some discrepancy between EPA (1999) Figure 5.3, which indicates Pu(OH)2(CO3)2- would be the dominant Pu solution species, and the figures above, generated using Geochemist Workbench.

The range of the K_d distributions for Pu at Clive encompasses the contributions of Pu(IV) on K_d values. Bechtel SAIC (2004) (e.g., pp. A-39 to A-42) demonstrate that Pu(IV) species tend to have higher K_d values associated with them than Pu(V) and Pu(VI) species, where Pu(IV) K_ds are predicted to be on the order of 103 ml/g, which is the upper range of the Clive DU PA model K_d values. Including Pu(IV) in the K_d distribution development should not change the Pu K_d distributions recommended for the Clive DU PA.

Text in Section 4.1.6 is being changed to acknowledge the likely presence of Pu(IV).

145. INTERROGATORY CR R313-25-7(1)-145/1: SORPTION REVERSIBILITY AND GLOVER ET AL. (1976) DATASET

Provide further explanation for the potential impact of reversibility of sorption on the PA and the relevance of the Glover et al. (1976) dataset.

EnergySolutions' Response*:* A fundamental assumption of the adsorption modeled in the Clive DU PA is that the adsorption is reversible. The sentence

> "*Some studies indicate the sorption is non-reversible*"

does not refer to critical knowledge about sorption of Pu in the Clive system. That sentence is being removed from the Geochemical Modeling report.

The references to Glover et al. (1976) in the Geochemical Modeling report (Section 4.1.7) are intended to highlight the use of the Glover et al. (1976) data in the EPA report to develop the Look-up Table (Table 5.11, EPA 1999) for Pu sorption coefficients. Glover et al. (1976) measured many different soil parameters along with sorption of Pu and Am. Regression equations were developed from Glover et al. (1976) to get the Look-up Table that separate levels of carbonate concentrations and clay content, making this data applicable to the Clive DU PA. However, the Look-up Table has lower maximum K_ds than the other references for Pu K_ds investigated in the Geochemical Modeling report. To incorporate the uncertainty that these other references might include potential K_d values, a slightly higher range was chosen than that which is given in the Glover-derived Look-up Tables.

The text of Section 4.1.7 is being modified to clarify the role Glover et al. (1976) played in the K_d range development for Pu for the Clive DU PA model. Text is also being added to clarify that the higher range that was chosen as consistent with other references for Pu solubility.

146. INTERROGATORY CR R313-25-7(1)-146/1: DETERMINATION OF K_D VALUES

Provide further explanation on how the K_d values for each radionuclide were selected. Elaborate on how the soil textures listed in Table 1 of the Geochemical Modeling report, or any other factors, were used to determine the Clive K_d ranges for the respective nuclides. Provide a summary table of actual K_d values used for each element/nuclide.

EnergySolutions*' *Response: The Geochemical Modeling report is being revised to include a table of the ranges of K_d values for the three soil textures (sand, silt, clay) for each element in the model, and relate them to the literature references as described in the subsections of the report. Providing these ranges will make the distribution development more transparent. It will clarify the values chosen from the literature and how they were used to develop probability distributions as described in Section 3.0. These changes are being made concurrently with changes made per the Response to Interrogatory #140 CR R313-25-7(1)-140/1.

147. INTERROGATORY CR R313-25-7(1)-147/1: DETERMINATION OF K_D VALUE FOR URANIUM

Provide support for assumptions regarding the derivation of the partition coefficient for uranium with regard to the results of an increase in ionic strength and the potential bias of high K_d values for ferrihydrite and kaolinite.

EnergySolutions*' *Response: The sentence,

> "*As the ionic strength increases, other cations will displace the uranyl (UO2)2+ ion*"

is from EPA (1999). The text is being changed to

> "*As the ionic strength increases, other cations, such as Ca2+, will displace the uranyl (UO22+) ion (EPA, 1999).*"

The sentence

> "*These very high K_d values are considered potentially biased by one order of magnitude*"

reflects conclusions from EPA (1999) that some of these high K_d values correspond to experiments where precipitation of U occurred in addition to adsorption.

The Geochemical Modeling report is being modified to clarify assumptions and derivations of geochemical parameters, as discussed in other interrogatories, such as Interrogatory CR R313-25-7(1)-140/1.

148. INTERROGATORY CR R313-25-7(1)-148/1: INFLUENCE OF CARBONATE ON URANIUM SPECIATION

Resolve contradictory statements regarding uranium sorption and focus the discussion on the influence of carbonate on uranium speciation.

EnergySolutions' Response*:* The intention of the text and of the K_d distribution development for U in this section is to discuss general geochemistry knowledge about U sorption, site specific considerations for U sorption and then other references and how their results apply to Clive DU PA modeling. The text in Section 4.1.13 will be revised to focus on the effects of carbonate and pH on U sorption. The carbonate assumptions for the Clive site will be clarified as to the applicability of the references used for K_d distribution development to the Clive site, especially with respect to the high carbonates expected at Clive.

As stated in the Response to Interrogatory CR R313-25-7(1)-140/1, more detailed documentation of how these distributions were developed is being provided in a revised Geochemical Modeling report.

149. INTERROGATORY CR R313-25-7(1)-149/1: AMERICIUM SORPTION

Provide additional justification for the assumptions made regarding americium sorption and for the preferred range of values in light of the elevated TDS content of shallow Clive groundwater and the competing ion effect.

EnergySolutions' Response*:* Section 5.1.2 of the Geochemical Modeling Report refers to americium solubility, not sorption. Elevated TDS and the competing ion effect apply more to sorption than solubility.

As per the request in Interrogatory CR R313-25-8(4)(a)-64/1, a more recent Yucca Mountain study (SNL, 2007) was used to review the solubility distributions for all elements in the Clive DU PA model. The range of americium solubility values from SNL (2007) were examined for pH values of 7 to 8 and pCO_2 values of 3.5 to 1.5. The pCO_2 range was chosen based on the assumption that atmospheric CO_2 partial pressures (pCO_2 of 3.5) to slightly elevated CO_2 partial pressures (pCO2 of 2.5) will be most likely, as described in Section 2.0, page 3 of the Geochemical Modeling Report. A maximum pCO_2 value of 1.5 is likely slightly high but was chosen to encompass the range of possible CO_2 partial pressures and equivalent dissolved carbonates at the Clive site.

Given these assumptions, the range of Am solubilities in SNL (2007), Table 6.9-2 are from 6.6×10^{8} mol/L to 4.6×10^{-6} mol/L. With these values, the maximum of 10^{6} M in the original reference does not seem unrealistic. This range is close to the range in the original Clive DU PA and so no changes are recommended for the Am solubility range at this time.

With probabilistic modeling, whether or not a parameter distribution is "unnecessarily broad" is being decided in part in a sensitivity analysis. If the parameter is a sensitive parameter, the uncertainty in that parameter's input distribution may be unacceptably large in the context that it leads to too much uncertainty in the result. If that is the case then further investigation may be desired to refine the input distribution so that the range is not "unnecessarily broad." However, if the parameter is not sensitive, then there is less need to refine the distribution.

150. INTERROGATORY CR R313-25-7(2)-150/1: PLANT GROWTH AND COVER PERFORMANCE

Clarify the nature and degree to which plant growth might impact future system performance. Justify the use of the selected root penetration value and discuss the potential for deep plant rooting.

EnergySolutions' Response: Detailed analysis conducted by SCWA demonstrating negligible degradation of the Evapotranspirative Cover's radon barrier from animal borrow has previously been conducted (Energy*Solutions*, 2013d). As a result of their analysis, SWCA concluded,

> "*The proposed biointrusion barrier and capillary breaks in the [Evapotranspirative] cover have been demonstrated to effectively deter or limit penetration by deep rooting plants [native to Clive] into protective [clay] layers"* (pg 45).

Plant growth is being accounted for in the GoldSim model of ET cover performance.

Root Depth

At this site, the water table is about 9 m below ground surface, and the cover mound is 13.7 m in height, so the water table is almost 23 m below the surface of the cover. Greasewood is known to occur down to water tables as deep as 19 m. However, the vegetative survey of the Clive site found that the majority of greasewood plants are less than one meter tall, and studies have found that greasewood of that size tend not to produce taproots (Robertson, 1983).

Additionally, the root excavation of greasewood at the Clive site found that the deepest roots of these smaller plants ranged from 40-70 cm (SWCA 2011).

However, given the known ability of phreatophytes to form deep tap roots and the fact that larger plants do occupy parts of the Clive site, especially where precipitation runoff is concentrated, and these plants may extend taproots to exploit deeper water, the model should take into account the possibility of tap roots somewhere on the site. For the purposes of the model the greasewood root depth was limited to the more modest amount of 5.7 m (as opposed to 19 m) because 1) the aboveground plant biomass at the site do not support the idea of tap roots deeper than this and 2) it is thought that the roots would not penetrate the radon barriers (thick clay layers).

The depth of 5.7 m also represents an estimate of what Groeneveld (1989) terms "maximum effective root depth" noting that isolated roots may grow well below this depth under special circumstances of water availability and aeration. As an example, Groeneveld cites the observation by Robinson (1958) of greasewood roots penetrating the roof of a mine tunnel approximately 19 m below the ground surface, suggesting that the 19 m maximum depth for greasewood is an artifact of preferential pathways created by the mining activities. These preferential pathways are not expected to occur in the constructed cover.

This barrier consists of two 1-ft thick layers of clay, with 3.5 ft of soils and cobble above. In this model the roots grow out horizontally across the top of the radon barrier, rather than developing deep taproots. The assumption of the current model is that the plants cannot penetrate the cover system. In the previous model a riprap cover was used but this is being replaced with an ET cover. The ET cover dries out the system more and includes two layers of clay. Based on previous work at the site, rooting depths were shallower than expected and plant roots were found to spread out horizontally and the deepest root excavated was 70 cm (Table 6, Figure 7, SWCA 2011). Based on this work, the phreatophytes at this site do not form deep taproots.

It may be possible for the species that occur at the site to create deep taproots at other sites, but there is no evidence that the conditions are right at this site to develop deep taproots. The model did not include deeper roots because it was assumed that the plants would grow out instead of down and based on the survey of the aboveground vegetation and root excavations at the site it does not appear that greasewood form deep taproots.

The above explanation will apply to the ET cover that is currently being modeled as a replacement for the riprap cover. Text is being modified as necessary to address the ET cover effects on plant roots.

Forage

The interrogatory claims the PA denies the possibility of forage at the site. It is not clear to what this comment is referring. A consideration of forage exposure is included in the Cattle and Game radionuclide uptake exposure factors that are provided on p. 8 of the Dose Assessment white paper.

Plant Uptake

The interrogatory also mentions that the PA denies the potential for plant uptake. Again, it is not clear to what this is referring and what additional changes are sought. Plant uptake is detailed in Section 3.6 Estimation of Plant Uptake.

151. INTERROGATORY CR R313-25-8(4)(A)-151/1: RADON BARRIER ATTENUATION

Describe the role performed by the design of the radon barrier in demonstrating that the exposures to humans from the release of radon will not exceed the limits in R313-25-19. Include the value of any diffusion coefficients used (and justification for their selection) and the basis for any radon attenuation calculated. If either of the diffusion coefficients or attenuation is different for the DU PA model from what were used for other facilities at the Clive site (e.g., the LLRW and 11e.(2) disposal facilities), provide justification for those differences.

EnergySolutions' Response: The role of the radon barrier in attenuating the release of generated radon into the environment for the evapotranspirative cover system is currently being modeled by Neptune and is being documented in their subsequent Modeling Report.

The calculations of radon migration in the Clive DU PA Model are based on a few straightforward concepts and values. The origin of radon anywhere in the model is from decay of parents (e.g. Ra-226 decaying to Rn-222) but its introduction into the environment wherein it would be subject to migration is attenuated by the escape/production ratio (E/P ratio, also known as the radon emanation factor). In the DU waste, the E/P ratio is defined by a distribution: beta(mean = 0.290, std. dev. = 0.156, min=0, max=1).

Elsewhere in the model, it is defined as 1, meaning that all radon produced is immediately available for transport. Anywhere that radon exists in the model, it is free to partition between air and water (according to its Henry's Law constant (\Materials\Air_Properties\Kh_Rn), which is about 4.6. It is also free to diffuse in air and water, according to its free air diffusivity (\Materials\AirDiffusivities\Da_Rn) of 0.11 cm^2/s, and the molecular diffusivity in water (\Materials\Water_Properties\Dm), with a mean value of 3×10^{6} cm^2/s.

Diffusion in porous media in the model is calculated internally by GoldSim, according to accepted mathematical approaches. Diffusion is a basic Fickian process, driven by spatial concentration gradients and moderated by diffusion coefficients. When building definitions of diffusive flux between modeling cells in unsaturated porous media in GoldSim, the programmer must explicitly account for phasic tortuosity (τ_{air} or τ_{water}) and for the effects of saturation on the diffusive area. Once these connections are properly constructed, GoldSim does the rest, evaluating diffusion in concert with advection, biotic transport, and radioactive decay and ingrowth. To study the effects of diffusion in isolation, it is necessary to remove these coupled effects using the Diagnostics dashboard, accessible from the Control Panel.

In other words, there is no special diffusivity for radon, in either air or water, assigned to any given porous medium in the model. Effective diffusivities is being different in each porous medium, and indeed in the same medium under different conditions of water content. This results from having different tortuosities and saturations present in different places in the model. The diffusion of radon (and other species, for that matter) is thereby built up from first principles, in a manner of speaking, and GoldSim simply “does the math” to determine the result.

Unless other coupled processes (e.g. water advection, biotic processes, and even radioactive decay and ingrowth) are disabled, it is not possible to study the effects of diffusion in isolation, and the results may be confusing or even misleading. Consider, for example, the simple process of radioactive decay, wherein Rn-222 is generated by Ra-226. If radium is able to migrate through a “radon barrier” clay, then it provides a source for radon on the other side. This “stealth” radon migration, as the radium parent, can circumvent the effectiveness of a radon barrier, at least to some degree. Biotic effects complicate matters more, since animals will move bulk materials containing radon and its parents, and plants will move specific radionuclides preferentially. Predicting the outcome of all these coupled processes is fraught with potentially counterintuitive effects, which is why it is important to couple the processes in a model, like GoldSim.

152. INTERROGATORY CR R313-25-8(5)(A)-152/1: GOLDSIM INPUT PARAMETERS

Provide documentation and justification for the radon correction factors (RnDiffusivityCorrection) used in the GoldSim DU PA Model.

EnergySolutions*' *Response: See response to Interrogatory CR R313-25-7(3)-60/1. The radon correction factors are not model inputs, which is why they do not appear in the Parameters Document. These are model calibration factors, set by the user as part of the radon calibration routine. As such, it is informative to run the radon calibration in order to gain an appreciation of where these values come from. To run this calibration, follow these instructions:

1. In the Control Panel, set the model duration to 10,000 years with the checkbox and input field on the upper left.

2. Go to the container \Disposal\ClassASouthCell\TopSlope and set the value of the AirDiffCalib_Switch near the bottom right of the page to "true".

3. Enter the RnCalibCalcs container above it.

4. Take note of the values in the RnDiffCorrection_* data elements and run the model.

5. Dismiss any warnings about aborting calculations at 10,000 years.

6. Examine the result elements *_Comparisons, and look for agreement between the radon flux calculations using coarse cells (red dashed line) and fine cells (green dotted line).

7. If the red line is too high, reduce the value of the corresponding RnDiffCorrection_* factor a bit. If the red line is too low, increase the value.

8. Repeat steps 4 through 7, iterating on the values of the RnDiffCorrection_* until satisfied that the lines lie atop each other.

Note that each layer containing a different material requires its own correction factor. This is because the material properties and tortuosities are so different between the layers. It is recommended that the above procedure be performed by first calibrating the lowermost layer (waste), then the radon barrier clays, and finally the cap layers.

This radon calibration procedure need be performed only after making changes to the model that involve layer thicknesses, porous medium material properties, moisture contents, E/P ratio, diffusivity definitions—in short, any parameter that might affect the behavior of radon migration. Once the calibration is complete, be sure to set the AirDiffCalib_Switch to "false" so that these detailed calculations do not continue to use up computer cycles.

It is recognized that this was not documented in the model report, since it is not something that a user would typically do. It is more a tool for the model programmers to calibrate this part of the model. However, documentation is being added in the next version.

153. INTERROGATORY CR R313-25-8(4)(D)-153/1: IMPACT OF PEDOGENIC PROCESS ON THE RADON BARRIER

Demonstrate that the impact of pedogenic processes has been included in embankment cover performance, particularly with respect to effects on hydraulic conductivity.

EnergySolutions' Response: The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

A revised model of the engineered cover is being developed, based on an ET cover design.

With regard to the influence of biointrusion on model parameters, also refer to the response to Interrogatory CR R313-25-8(4)(A)-108/1 on biointrusion.

Also see the following three paragraphs from the response to Interrogatory CR R313-25-7(2)-05/1 on Radon Barriers:

A compromised radon barrier is being modeled. It is not considered necessary at this time because the ET Cover design will limit infiltration down to the radon barrier. With no infiltration down to that level, the naturalization of the radon barrier will have no effect on performance. However, for completeness, this issue is being addressed.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of the radon barrier and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility.

Confidence in the assessment of radon barrier performance can be enhanced through sensitivity and uncertainty analyses of the models. Modeling the uncertainty in cover performance involves alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty). Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling.

There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. To provide a more comprehensive sensitivity analysis for infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

154. INTERROGATORY CR R313-25-8(4)(D)-154/1: USE OF FIELD DATA TO VALIDATE DISPOSAL CELL COVER PERFORMANCE

Document the extent to which field data were used to validate the performance of the proposed Federal Cell cover design; include consideration of information from DOE disposal sites.

EnergySolutions' Response: In development of the new evapotranspirative (ET) cover design, Energy*Solutions* examined the performance of other similar cover systems in use in the arid west (Appendix D of Energy*Solutions*, 2013b). Energy*Solutions* also examined natural localized plateaus and land features in the Clive area similar in shape, surface soil type, and slope to that proposed for the Federal Cell (Appendix D of Energy*Solutions*, 2013b). Furthermore, Energy*Solutions* used as input to the models site-specific meteorological data obtain at their Clive meteorological station since 1993 (MSI, 2014).

Additionally, Energy*Solutions* has historically been required to consider bounding input and overly conservative assumptions in its various performance assessments. These in turn have always predicted infiltration at rates orders of magnitude higher than anything observed onsite via collection lysimeter and Cover Test Cell performance.

The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

With respect to unsaturated zone flow models one approach is comparison with analog sites. However, due to the complexity of the interaction of characteristics and processes in the vadose zone and the atmospheric boundary layer, true analog sites are scarce and any comparison of performance between sites must be done with care.

However, site-specific data help build confidence in model predictions. Data have been collected from scaled structures located at the disposal sites such as the lysimeters described in this Interrogatory and the Test Cell at Clive. This approach avoids the problems of differences in climate, vegetation, and material characteristics and can provide valuable information for model calibration and verification but can be vulnerable to issues resulting from differences in scale.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of cover design components and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility.

Confidence in flow model predictions can also be enhanced through sensitivity and uncertainty analyses of the models. Modeling the uncertainty in cover performance involves alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty).

Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling. There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. To provide a more comprehensive sensitivity analysis for infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

System models such as the Clive DU PA model simulate numerous interacting processes. Confidence can be built in system model predictions through documenting the testing of single processes in the system model by comparison with results from other simulation codes.

155. INTERROGATORY CR R313-25-8(4)(D)-155/1: COVER PERFORMANCE FOR 10,000 YEARS

Document how expected climate changes and other FEPs that may degrade cell performance over 10,000 years have been factored into the cover cell design. Also discuss historical analogs of similar structures and how they have functioned over long periods of time.

EnergySolutions' Response*:* Energy*Solutions* currently plans to use an evapotranspiration (ET) cover design rather than the design requiring rip rap specified in the Clive DU PA model. In this ET design the rip rap and filter layers are being replaced with native soil that will be re-vegetated. With this design there are no longer issues concerning the effect of rock degradation on cover performance. The upper layers of the ET cover will resemble native conditions not requiring active maintenance at the time of successful completion of the re-vegetation program.

The long-term integrity of the clay radon barriers below the frost protection layer has been investigated in detailed biological surveys conducted at the site. These analyses indicate that penetration by deep rooting plants or biointrusion by small mammals will be minimized or eliminated in these layers. More discussion on the results of these surveys including references is provided in the response to Interrogatory CR R313-25-7(2)-05/1: Radon Barrier. Other evidence on the effect of animal burrowing on subsurface moisture content comes from a field experiment at the Hanford Site conducted by Landeen (1994). Over the course of five testing periods, three during the summer and two during the winter soil moisture measurements showed no influence of burrowing activities on long-term water storage.

Additional site-specific analyses of the effectiveness of the frost protection layer have been conducted. These analyses concluded that calculated frost depths were consistent with the thicknesses proposed for the ET cover design. More discussion on the results of these analyses including references is provided in the response to Interrogatory CR R313-25-7(3)-60/1: Modeled Radon Barriers.

A compromised radon barrier is being modeled under the PA Maintenance program. It is not considered necessary at this time because the ET Cover design will limit infiltration down to the radon barrier. With no infiltration down to that level, the naturalization of the radon barrier has no effect on performance. However, for completeness, this issue will be addressed under PA Maintenance.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of the radon barrier and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility. The Benson et al. (2011) reference is a credible report that emphasizes cover properties in general, not the specific cover types and materials proposed for the Clive site and the local climatic setting. The recommendations from the report, by itself, are not sufficient justification to require redesigning the cover system.

Confidence in the assessment of radon barrier performance can be enhanced through sensitivity and uncertainty analyses of the models. Modeling the uncertainty in cover performance involves alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty). Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling. There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. To provide a more comprehensive sensitivity analysis for infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

The potential influence of erosion on cover performance must be considered in the context of all sediment transport processes occurring at the site. Erosion modeling using the SIBERIA landscape evolution model has been performed on a borrow pit at the site, the results of which will be abstracted and adapted to the disposal mound in the upcoming model of the ET Cover. Because of the slope differences, this will over-estimate sediment transport offsite, and will over-estimate depth of gullies formed but will provide some insight into the response of an embankment to water erosion processes that include both hillslope erosion and channel growth. This will be included in the next version of the model and the report. Note that under the scenario that the DU waste is disposed below grade, the erosion consequences are likely to be minimized. This is evident in the current model results by comparing the three pairs of scenarios.

Another sediment transport process that should be considered is the complicating but potentially advantageous feature of the Clive site; the aggrading depositional environment. The site is located on the east edge of Lake Bonneville, a dry playa lake. Depositional rates of windblown sand and silt (loess) has been shown to be significant near dry playa lakes of the arid southwest United States (> 0.1 mm/yr). We are considering studying well dated volcanic landforms in the Black Rock Desert volcanic field located in the southern Utah within the former footprint of Lake Bonneville (39.0 degrees N, 112.5 degrees W). A series of basaltic volcanic centers with associated lava flows in the volcanic field (Pavant Butte, Ice Springs and the Tabernacle volcanoes) range in age from 16,000 to 800 years BP (before present). The lava and scoria cone/tuff rings provide unique landforms that can be examined to establish benchmarks for the operation of erosional and depositional process that would likely effect a waste embankment at the Clive site. Data can be gathered to assess whether aeolian depositional rates are sufficient to blanket and/or protect a closure cover. The properties of the aeolian cover/soils can be examined to evaluate erosional and biological processes affecting materials comparable to closure covers providing information on the long-term stability of the disposal site.

156. INTERROGATORY CR R313-25-26(2–3)-156/1: SEPARATION OF WASTES IN FEDERAL CELL

Since the Federal Cell will have no isolation barrier or groundwater monitoring system, explain how the DU waste and 11e.(2) waste will be isolated from each other and how groundwater passing beneath the DU will be monitored before site closure and for 100 years after site closure so as to meet Utah rules and protect the public from undue radiation exposure during the time before DOE takes stewardship of the Federal Cell.

EnergySolutions' Response: The interrogatory inaccurately states that the Federal Cell will have no isolation barrier or groundwater monitoring system. This statement is assumed to refer to the clay barrier between Class A and 11e.(2) wastes under the former Class A South cell design; and to groundwater monitoring proposed to occur beneath that barrier.

The former Class A South cell design was subjected to these additional buffer zone and monitoring requirements due to long-term stewardship being split between the State of Utah and DOE. The Federal Cell will be entirely within DOE stewardship and there will be no requirement to segregate Class A LLRW from 11e.(2) wastes; therefore, the additional requirements will not apply.

Nonetheless, the Federal Cell will have a radon barrier and ET cover system to isolate wastes from the environment; and the existing perimeter groundwater monitoring system will remain in place subject to Ground Water Quality Discharge Permit #UGW450005.

157. INTERROGATORY CR R313-25-8(5)(A)-157/1: INCLUSION OF DU AND OTHER WASTES IN PA

Provide documentation that the PA includes the total quantities of DU and other wastes.

EnergySolutions' Response: When the DEIS was prepared for Part 61, DU was considered, just not the large volumes stored by DOE. Contained in that analysis is a default value for DU disposal, which is manifested in R313-25-8(5)(c): "For purposes of this R313-25-8(5) only, "concentrated depleted uranium" means waste with depleted uranium concentrations greater than 5 percent by weight."

See the response to Interrogatory CR R313-25-7(9)-89/1 for documentation that DU disposed at the time R313-25-8(5)(a) went into effect was less than this 5 percent criteria.

In 2008, NRC noted that while,

> "*The licensing of new uranium enrichment facilities in the United States has brought DU to the forefront of low-level waste (LLW) disposal issues. The DU waste stream is unique; the relatively high concentrations and large quantities of DU that are generated by enrichment facilities were not considered in the Final Environmental Impact Statement (FEIS) supporting the development of 10 CFR Part 61. When the FEIS was issued in 1982, there were no commercial facilities generating large amounts of*

DU waste, therefore, the FEIS considered only the types of uranium-bearing waste streams being typically disposed of by U.S. Nuclear Regulatory Commission (NRC) licensees at the time, (NRC, 1982). The NRC concluded that those waste streams posed an insufficient hazard to warrant establishing a concentration limit for uranium in the waste classification tables in 10 CFR 61 . . . Part 61 DEIS assumed 17 Curies (Ci) of ^{238}U and 3 Ci of ^{235}U would be disposed of in 1 million m^3 of waste over a 20-year generic LLW site operating life (NRC, 1981)," (NRC, 2008).

Bulk Class A LLRW will be placed above the DU. Performance assessment for these nuclides is addressed via the ET cover performance assessment currently undergoing DRC review (Energy*Solutions*, 2013d). As such, the condition of the disposal of other Class A low-level radioactive bulk wastes within the Federal Cell is a modeled condition. Therefore, it is unnecessary to repeat this analysis in this Depleted Uranium Performance Assessment.

The Clive DU PA Model v1.0 addresses only certain proposed disposals of large quantities of depleted uranium waste. It does not address previously-disposed DU waste.

158. INTERROGATORY CR R313-15-1009(2)(B)(I)-158/1: WASTE PACKAGING

Address in the PA the use of soft-sided containers for the disposal of DU oxides, including how well these containers would survive long-distance transportation to and handling at the Clive low-level waste facility, how full of DU oxides each container would be and how much headspace would remain, the weight of the contents of each container, and the nature of the materials constituting the container.

EnergySolutions' Response*:* The PA takes no credit for container type in terms of contaminant fate and transport; thus, the transportation container is irrelevant. Prior to acceptance at the Clive facility, transportation of radioactive materials is governed by the specific waste generator's license and U.S. Department of Transportation (DOT) regulations.

DOT regulations ensure that the container selected for any hazardous material is appropriate for surviving long-distance transportation, considering the physical, chemical, and radiological characteristics of the material. There are no unique characteristics of the depleted uranium wastes or associated packages considered within this Performance Assessment that vary from those commonly being managed during Energy*Solutions*' 25 year history. In fact, existing waste placement controls have successfully been applied in disposal of the current DU inventory placed in the LARW, Class A, and Mixed Waste cells prior to the 2010 rulemaking.

Current Construction Quality Assurance/Quality Control (CQA/QC) specifications for waste placement require that headspace void be eliminated at disposal, regardless of the package type. This is accomplished through compaction and testing for uncontainerized wastes, and through use of a flowable grout (Controlled Low-Strength Material, or CLSM) for waste disposed in containers. In fact, similar soft-sided containers to those referenced in the Basis for this interrogatory from the DOE Fernald site have been disposed using CLSM in the 11e.(2) waste portion of the Federal Cell. Therefore, continued disposal of depleted uranium does not create an unanalyzed condition regarding the type of container or procedures required to safely manage and dispose of them.

159. INTERROGATORY CR R313-25-8(4)(D)-159/1: EMBANKMENT DAMAGE BY LAKE FORMATION

Explain how radon releases will be controlled when the embankment is destroyed by wave action and the intruding waters subsequently recede to levels below the current ground surface.

EnergySolutions' Response*:* There are two components to this response. The first is the timing of a lake return with erosion of the embankment and the second is the interplay between sedimentation and erosion – the two components are interrelated.

The first 10,000 year stage of the PA model assumes the lake will not return. The closure cover will degrade/erode but the radon barrier will remain. Moreover, the cover is likely to be partially buried over 10,000 years by aeolian deposition of silt and sand (loess). Depositional rates of aeolian deposits have not been measured at the Clive site but information is available on loess accumulation rates adjacent to playa lakes at multiple sites in the arid southwest United States. Accumulation rates can be highly variable but are likely to be > 0.1 mm/yr (1 meter per thousand years) during interpluvial conditions. The expected case for these conditions is progressive burial of the waste embankment by aeolian deposition until the return of the first lake.

The following events are expected during the return of the first glacial lake to the Clive elevation. Wave action at the lake shoreline will rework the loess deposits, erode the embankment and intermix DU waste with the lake sediments. The deep-time assessment makes the conservative assumption that the above grade embankment is completely eroded and all the DU waste is intermixed with sediments. The reality is that the degree of erosion and release of DU waste will be dependent on the timing of the arrival of the first lake (the longer the interval the deeper the aeolian cover) and the dynamics and duration of lakeshore processes at the Clive elevation.

The latter topic was not examined in the deep-time model and instead the above-grade embankment was assumed to be completely eroded, (see the responses to interrogatories CR R313-25-8(4)(d)-129/1 Lake Erosion and CR R313-25-8(4)(d)-131/1 Potential Wave Energy). Subsequent lake cycles will affect the Clive site but the net result will be burial of the site through combined aeolian and lake sedimentation. The largest increase in radionuclide concentrations will be as a consequence of the first lake event, with concentrations decreasing as the sediment thickness increases (see Section 6.52 and Figure 13 of the Appendix 1 Clive DU PA Model Version 1.0 Final Report).

According to UAC regulations, quantitative assessments of radon flux are not required for the time frame following 10,000 years, when the analysis is expected to be qualitative. The deep time model assumption of sediment/waste mixing will spread and dilute DU waste (see the SiteDispersalArea parameter in Table 1 of the Appendix 13 Deep Time Assessment) and the sediment/waste mixture will be buried progressively with continuing lake cycles. The time of greatest radon flux/potential dose will be during the first lake return but it is difficult to identify a credible dose exposure scenario for a lake/shoreline at 10,000 years plus into the future.

160. INTERROGATORY CR R313-25-7(2)-160/1: COMPARISON OF CLASS A WEST AND FEDERAL CELL DESIGNS

Address the significant differences between the Class A West embankment and Federal Cell designs in order to justify why the existing Class A West design would suffice for the Federal Cell.

EnergySolutions*' *Response: The depleted uranium Performance Assessment is being revised to reflect the construction of an evapotranspirative cover over the proposed Federal Cell. As such, this Interrogatory is no longer applicable.

161. INTERROGATORY CR R313-25-7(2–3)-161/1: INCONSISTENT INFORMATION ON WASTE EMPLACEMENT

Resolve the conflicting statements about available thickness in the embankment for waste emplacement and emplacement depths. Explain and justify the plans given in the text of the PA given the information in Figure 1.2 and revise as necessary.

EnergySolutions*' *Response: Figure 1.2 has been clarified to reflect Energy*Solutions'* commitment that only a volume of depleted uranium that can be disposed of below grade in the Federal Cell will be managed. Because

Energy*Solutions* has committed to dispose of significant quantities of depleted uranium only below grade in the Federal Cell, the noted discrepancies in model scenarios for above-grade disposal need not be revised within the model.

162. INTERROGATORY CR R313-25-22-162/1: DISPOSAL CELL STABILITY

Address factors affecting stability, including wave-cutting erosion, gully erosion, catastrophic storms, differential settling driven by canister disintegration and cover rock degradation in greater detail to demonstrate long-term disposal system stability.

EnergySolutions' Response: Each of the subject topics is addressed in turn below.

Erosion by wave-cutting of embankment materials
Interrogatory CR R313-25-8(4)(d)-159/1 describes the lake erosion model of the embankment used in the deep time assessment (Appendix 13) and the effect on radon. To briefly summarize, lake erosion is not expected at the Clive site until after 10,000 years which is beyond the period of required dose calculations. The impact on the site is dependent on the time and dynamics of lake return, coverage of the site by aeolian deposits, and sediment/waste mixing and dispersal during lake erosion. The largest increase in radionuclide concentrations will be as a consequence of the first lake event, with concentrations decreasing as the sediment thickness increases (see Section 6.52 and Figure 13 of the Appendix 1 Clive DU PA Model Version 1.0 Final Report). The net result of multiple glacial cycles will be natural burial of the site through combined aeolian and lake sedimentation. This burial process does not require mitigation of lake erosion through design features of the disposal site.

Gully erosion
Other modeling options for gully erosion include the SIBERIA program for executing landform evolution studies of the embankment under PA maintenance. Results of this model provide estimates of the timing and extent of erosion.

Destruction of embankments by catastrophic storms
While tornados could initiate erosion of the embankment, they are low frequency events in Utah (see the response to Interrogatory CR R313-25-7(1)-46/1); the probability of a tornado strike at a specific point in Tooele County is extremely low.

Damage to the cover system from differential settlement
As discussed in the DUF_6 Waste Management Plan (UDS 2009), the U_3O_8 product of the deconversion process will be roll-compacted to a density of 2.4 to 2.7 g/cm^3 before introduction to the 48 Y cylinders through a rotary valve

metering device. During the filling operation, the cylinder is held vertically and is vibrated to promote settling and compaction. Energy*Solutions* describes their current Construction Quality Assurance/Quality Control (CQA/QC) specifications for waste placement as requiring that headspace void be eliminated at disposal, regardless of the package type. This is accomplished through compaction and testing for uncontainerized wastes, and through use of a flowable grout (Controlled Low-Strength Material, or CLSM) for waste disposed in containers. For more detail see the response to Interrogatory CR R313-25-22-166/1.

Cover-system rock degradation
Partly in response to the documented weathering of certain facies of rocks used for rip rap on the Vitro UMT pile, the Federal Cell will adopt a different technology for cover design. The new design is an evpotranspirative (ET) cover that does not involve the use of rip rap from the source used for the Vitro pile. The PA Model is being rebuilt with this new design, so the question of the extent of weathering of rip rap is not applicable.

163. INTERROGATORY CR R313-25-8(5)(A)-163/1: GROUNDWATER COMPLIANCE FOR 10,000 YEARS

Include results describing groundwater concentrations for a minimum of 10,000 years and indicate whether a dose standard of 4 mrem/yr TEDE is met for the compliance period.

EnergySolutions*' *Response: *S*ee the response provided for Interrogatory CR R313-25--7(2)-91/1.

164. INTERROGATORY CR R313-15-1009-164/1: INCORRECT RULE CITATION

Correct the indicated rule citation.

EnergySolutions*' *Response: Section 4.2.2 of the Conceptual Site Model report is being corrected.

The Conceptual Site Model white paper is being corrected as follows:

[Conceptual Site Model white paper, Section 4.2.2, page 18, first sentence:]

> "*Rule R313-15 contains section R313-15-1009 Classification and Characteristics of Low-Level Radioactive Waste.*"

[Conceptual Site Model white paper, Section 4.2.2, page 18, caption to Figure 5:]

> **Figure 5. Waste classification Table I from R313-15-1009**

165. INTERROGATORY CR R313-15-1009(1)(C)(I)-165/1: INCORRECT CITATION OF RA-226 LIMIT

Ensure that the DU PA model and associated text use the correct limit for Ra-226 and that all other model input parameters correctly interpret the concentrations in Table 1 of R313-15-1009.

EnergySolutions*' *Response: Section 4.2.2 of the Conceptual Site Model report is being corrected to reflect the Class A waste concentration limit of 10nCi/g for Ra-226. As is reported in Table 6 of Appendix 4, "*Waste Inventory*," the mean Ra-226 concentration of 316.8 pCi/g (with standard error of 19.1) was included in the GoldSim analysis (which is a small fraction of the limited promulgated in Table 1, R313-15-1009). The correction does not affect model input parameters or results.

The text on page 18 of the Conceptual Site Model report is being revised to the following:

> "*Rule R313-15 contains section R313-15-1009 Classification and Characteristics of Low-Level Radioactive Waste. The definitions in this section are essentially identical to those in 10 CFR 61.55, with one exception: Utah adds Ra-226 to the list of long-lived radionuclides in the regulations' Table I (see Figure 5), with a concentration of 100 nCi/g (Utah, 2010).*"

The mean concentration of Ra-226 in the SRS DU waste is 317 pCi/g, or 0.317 nCi/g, with a standard deviation of 0.019 nCi/g. As such it is well within the Class A limit (which is 0.1 × 100 nCi/g = 10 nCi/g). Note that the Clive DU PA Model does not explicitly consider waste classifications—rather, it performs calculations based on whatever inventories are provided.

166. INTERROGATORY CR R313-25-22-166/1: STABILITY OF WASTE

Analyze stability conditions as compaction of disintegrating drums and cylinders occurs. Consider the presence of any headspace in the waste containers and include a statement that the waste is **not** uncontainerized but rather is emplaced in drums and cylinders.

***EnergySolutions*' *Response*:** There are no unique characteristics of the depleted uranium wastes or associated packages considered within this Performance Assessment that vary from those commonly being managed during Energy*Solutions'* 25 year history. In fact, existing waste placement controls have successfully been applied in disposal of the current DU inventory placed in the LARW, Class A, and Mixed Waste cells prior to the 2010 rulemaking.

Current Construction Quality Assurance/Quality Control (CQA/QC) specifications for waste placement require that headspace void be eliminated at disposal, regardless of the package type. This is accomplished through compaction and testing for uncontainerized wastes, and through use of a flowable grout (Controlled Low-Strength Material, or CLSM) for waste disposed in containers. In fact, similar soft-sided containers from the DOE Fernald site have been disposed using CLSM in the 11e.(2) waste portion of the Federal Cell.

Therefore, continued disposal of depleted uranium does not create an unanalyzed condition regarding the type of container or procedures required to safely manage and dispose of them.

167. INTERROGATORY CR R313-15-1009(2)(A)(VII)-167/1: PYROPHORICITY OF DUO2

Address the pyrophoric tendencies of DUO_2. Either provide for the exclusion of uranium dioxide (UO_2) from the waste or justify the disposal of waste container UO_2 at the site. Consider development of finely divided particles and possible pyrophorism during physical transport by rail or road, placement in an embankment, or geochemical modification subsequent to burial.

EnergySolutions' Response*:* The risk from pyrophoricity of UO2 is minimal.

While it is true that finely-divided UO_2 can be pyrophoric, the waste form being produced by the deconversion plants in Piketon (Portsmouth), OH and Paducah, KY contains "very minor" amounts of UO_2, especially in consideration of the "high-volume pneumatic transfer" used in bulk materials operations, which would tend to further oxidize the uranium oxides (personal communication from Jack Zimmerman, Babcock & Wilcox Conversion Services, to John Tauxe, Neptune and Company, Inc., 28 Mar 2014).

Disposal of the GDP DU is to occur using the same 48 Y DU cylinders that the waste was placed in at the deconversion plant. The cylinders are welded shut, and so their contents have no contact with atmospheric oxygen outside the container. Even if particles of UO_2 were to spontaneously ignite, they would quickly use up any available oxygen in the container, producing U_3O_8. In the disposed environment, Energy*Solutions* operators will infill and cover the cylinders with grout or flowable concrete, further sealing them from the elements. Subsequently, the DU would be buried under other low-level waste, and the isolation of the DU would be such that no contact with the atmosphere would occur.

The Savannah River Site DU is all UO_3, according to the shipping manifests, so UO_2 pyrophoricity is not an issue with that population.

No products from International Isotopes Fluorine Products have been reviewed or considered for this PA.

168. INTERROGATORY CR R313-25-7(2)-168/1: RIP RAP SIZING

Resolve the discrepancy in descriptions of the side slope in the Erosion Modeling report and the 2013 Compliance Report, Revision 1.

***EnergySolutions*' *Response**:* Since the depleted uranium Performance Assessment is under revision to model the proposed Federal Cell with an evapotranspirative cover, Interrogatory CR R313-25-7(2)-168/1 is no longer applicable.

Section 3.0, page 2, of the Erosion Modeling report could be modified to include the information on rip rap sizes for the top and side slopes. Energy*Solutions,* however currently plans to use an evapotranspiration (ET) cover design rather than the design requiring rip rap specified in the Clive DU PA model. Given the change in design, description of rip rap characteristics is no longer applicable.

169. INTERROGATORY CR R313-25-7(9)-169/1: CLARIFICATION OF STATISTICAL TREATMENT OF CHEMICAL AND ISOTOPIC ASSAYS

Clarify issues related to the statistical treatment of uranium chemical and isotopic assays as presented in the Waste Inventory report.

***EnergySolutions*' *Response**:*

1. The data used came from a Waste Profile Record file that is labeled Waste Profile Record SRS DU 9021-33_r0.pdf, as referenced in the Waste Inventory report. It is an Energy*Solutions* radioactive waste profile record that is signed by a DOE representative (Glenn Siry). The DOE signature is dated November, 2009. It is clear in this Waste Profile Record that the original 33 samples were used to characterize most radionuclides, and that the same (six) samples were used for the atom% data. However, it is not clear why Sample #8 is missing from the atom% table (listed as Attachment 2 in the Waste Profile Record), or why there are duplicate results presented for each of the six samples that are included.

2. The U-233 atomic% values were treated as non-detects. Since they were reported as 0.000000at%, an assumption was made that the actual value is less than 0.0000005at%. Further explanation is being added to the Report.

3. These documents are being included with the next submittal.

4. These references are being included in the next submittal.

5. The appropriate reference is:

   Fussell, G.M, and D. L. McWhorter, 2002. Project Plan for the Disposition of the SRS Depleted, Natural, and Low-Enriched Uranium Materials. WSRC-RP-2002-00459, Washington Savannah River Site, November 21, 2002.

6. Clarification is being included in the Report. The units are pCi/g of DU waste.

170. INTERROGATORY CR R313-25-7-170/1: DU WASTE FORM RELEASE MECHANISMS AND RATES

Provide a detailed description of the conceptual mechanisms, equations, and assumptions used in the model to determine the rate of release of contaminants from the DU waste material (solid phase) to infiltrating waters (liquid phase).

EnergySolutions' Response: The Clive DU PA model does not take into account waste containers (largely because it is assumed that the containers will rust in the very saline environment in a relatively short time frame compared to the time frame of the PA – see CSM, Section 8.1 p.44, and Geochem WP, section 2.0). The waste release rate would depend on the solubility of the element in the waste layer. The Geochemical Modeling report, Section 2.0, page 3, describes in some detail the assumptions of the waste and its release to the environment. The waste is assumed to be homogenized with the sand / alluvial fill material so that the properties of the waste layer are approximately the same as the sand.

This topic is indirectly mentioned in FRV1, Section 4.1.2.5, page 30, where the report says that the waste leaving the waste cell initially starts off as solubility-limited. As time goes on and more radionuclides dissolve, Kds may control the release of radionuclides from the waste layer.

Clarification can be added to FRV1 on the release of waste from the waste. Thermodynamically, U_3O_8 is much less soluble (and more stable) than UO_3. Over time, it is apparent that U_3O_8 is immobile, whereas the UO_3 would be more mobile and thus more likely to leave the system.

More clarification can be added to the Deep Time report to clarify the question of how and why the soluble U (UO_3) leaves the system within 50,000 years.

171. INTERROGATORY CR R313-25-7-171/1: ADEQUACY OF DU CELL BUFFER ZONE

Describe the location, dimensions, and attributes of the buffer zone at the proposed DU disposal cell, and explain and justify how it will be adequate for environmental monitoring and future mitigative actions, if needed.

EnergySolutions' Response: The location, dimensions, and attributes of the buffer zone for the proposed Federal Cell are detailed in Section 1.2.2.2 of the License Amendment Request for the Class A West Embankment (Energy*Solutions* 2012). Note that this discussion speaks of the 11e.(2) cell, i.e., the footprint for the proposed Federal Cell. This buffer zone was approved by DRC with approval of the Class A West Embankment on November 26, 2012.

Note that the former Class A South cell design was subjected to additional buffer zone and monitoring requirements due to long-term stewardship being split between the State of Utah and DOE. The Federal Cell will be entirely within DOE stewardship; therefore, the additional requirements of Morton, 2008, do not apply.

172. INTERROGATORY CR R313-25-20-172/1: INADVERTENT INTRUDER PROTECTION

Provide a comprehensive analysis of possible inadvertent human intrusion scenarios.

EnergySolutions' Response*:* See the response to Interrogatory CR R313-25-8(4)(B)-07/1.

The response to Interrogatory #7 covers the local site conditions and regulatory basis for selection of inadvertent human intrusion scenarios. The response also cites guidance from the Performance Assessment Work Group (PAWG) of the NRC that recommends against excessive speculation about future events. The first scenario identified in the basis for interrogatory is a statement about erosion and embankment stability associated with future sand and gravel operations – it is not an intruder scenario. The second scenario is concerned with buildings that may or may not remain after site maintenance and long-term closure activities. However, these buildings are outside of the buffer zone and therefore any activities are by definition public rather than intruder scenarios.

173. INTERROGATORY CR R313-25-7(2)-173/1: STABILITY OF EMBANKMENT

Demonstrate that the loading created by the high-density DU waste form will not result in subsidence in the disposal embankment that will compromise the performance of the cover/radon barrier system.

EnergySolutions' Response: Section 5 provides a loading calculation demonstrating that the DU waste form meets existing criteria for waste liner loading. This criterion encompasses scenarios considering in prior embankment settlement evaluations, thus confirming there is not an unanalyzed condition for embankment stability.

174. INTERROGATORY CR R313-25-7(6)-174/1: WASTE EMPLACEMENT IN CLASS A SOUTH DISPOSAL CELL

Provide a more detailed description of the manner in which waste is emplaced in the Class A South disposal cell:

1. Define the terms “clean uranium” in waste layers 13–26 (and layer WasteOut) and “contaminated uranium” in waste layers 7–12.
2. Elaborate on what type of native soil will be used in the “no waste” section (layers 1–6) of the embankment profile or cross-reference where this information can be found. If non-DU waste is to be placed at these intervals, explain and justify why the waste will not contain any nuclides known to be in the SRS or GDP DU waste streams. As an alternative, explain how the model adequately accounted for SRS and GDP radionuclides in these layers as a part of the waste source term or inventory in the PA model.
3. Describe how incoming DU shipments will be controlled and managed to ensure that construction honors the analyzed condition.

EnergySolutions’ Response:

1. Energy*Solutions* has committed to dispose of significant quantities of depleted uranium only below grade, regardless of whether it is “contaminated” or “clean”. Therefore, the distinction is irrelevant.

   These terms “clean uranium” in waste layers 13–26 (and layer WasteOut) and “contaminated uranium” in waste layers 7–12 are defined in the Waste Inventory white paper. Simply defined, “clean uranium” refers to depleted uranium oxide that has no contaminants that get introduced from the processing of reactor returns. That is, it consists only of uranium isotopes and their progeny.

   “Contaminated uranium”, on the other hand, contains some amount of fission products (e.g. Tc-99) and transuranics (e.g. Np-237, Am-241, Pu-X) resulting from the processing of reactor returns. While the inventory of DUF6 to be converted to oxides at the Piketon (Portsmouth) site are believed to be largely clean, a small fraction of the Paducah inventory is contaminated, and all the SRS DU is contaminated.

   It is noted that the Interrogatory refers to Figure 9, page 13, of the Conceptual Site Model for the figure showing waste layers, but this figure is from the Embankment Modeling white paper.

2. The “no waste” designation in the model refers to Class A LLRW and native soils other than significant quantities of depleted uranium. Since the waste is Class A, it could in fact contain of nuclides in the SRS or GDP DU waste streams; but it will not contain significant quantities of depleted uranium. Performance assessment for these nuclides is addressed via the ET cover performance assessment currently undergoing DRC review.

   If the model dashboard option of “No Waste” is selected in the specification of the layering of the waste cell, Unit 3 soils are assumed to occupy the space. If generic “Class A Low-Level Waste” is selected, then the material “Generic_Waste” is modeled. Until such time as this waste is better defined, this generic waste is assigned the properties of Unit 3 soil as well, and has no inventory of radionuclides currently assigned. Therefore, the end effect of selecting either of these choices is the same. No radionuclide inventory is assigned to Generic_Waste, since this PA Model is focused on the assessment of future risks from the proposed disposals of DU waste, without regard to wastes already disposed, or non-DU wastes proposed to be disposed.

To account for SRS and GDP DU wastes in the model, the user selects the layering of the various waste types, using the Waste Layer dashboard (accessible through the Control Panel). A check is made to assure that the total volume of the various types of DU wastes proposed for disposal is less than the cumulative volume of the layers selected for the disposal of each type. The inventory of each type of DU is then distributed evenly throughout the total volume of the layers selected by the user. As it turns out, the entire SRS DU inventory will fit into a single layer, as will the entire contaminated GDP DU inventory. The clean GDP DU inventory requires at least four layers be assigned to hold it.

Energy*Solutions* has committed to dispose of significant quantities of depleted uranium only below grade, regardless of whether it is “contaminated” or “clean”. Therefore, additional controls on placement elevation are not needed.

3. Energy*Solutions* has committed to dispose of significant quantities of depleted uranium only below grade, regardless of whether it is “contaminated” or “clean”. Therefore, additional controls on placement elevation are not needed.

175. INTERROGATORY CR R313-25-7(2)-175/1: INFILTRATION RATES FOR THE FEDERAL CELL VERSUS THE CLASS A WEST CELL

Justify that the Federal Cell infiltration rates are comparable to those predicted for the Class A West cell.

<u>EnergySolutions' Response</u>: Since the depleted uranium Performance Assessment is under revision to model infiltration into the proposed Federal Cell with an evapotranspirative cover, Interrogatory CR R313-25-7(2)-175/1 is no longer applicable.

176. INTERROGATORY CR R313-25-8(5)(A)-176/1: REPRESENTATIVE HYDRAULIC CONDUCTIVITY RATES

Model the migration of DU and other associated wastes, including bulk Class A waste components, assuming corrected hydraulic conductivity values provided in NRC guidance (NUREG/CR-7028).

<u>EnergySolutions' Response</u>: The sensitivity of cover infiltration to changes in radon barrier integrity has been evaluated (Energy*Solutions*, 2014) for the ET cover design. These analyses demonstrated that an increase of 3 orders of magnitude in radon barrier hydraulic conductivity resulted in no increase in infiltration. Therefore, no further assessment of the impact of a compromised radon barrier is necessary in the model.

Note that these sensitivity cases have not historically been applied to the frost-protected radon barrier under the traditional rock armor mulch design. The ET cover design reduces predicted infiltration by two order of magnitude compared with the rock armor mulch. Any further degradation of radon barrier for the rock armor mulch design would only further reduce its performance relative to an ET cover.

The Benson et al. (2011) reference emphasizes cover properties in general, not the specific cover types and materials proposed for the Clive site and the local climatic setting. The recommendations from Benson (2011), by itself, are not sufficient justification to require redesigning the cover system nor is it contradictory with the steady state infiltration rates developed from the HELP modeling.

The topic of cover performance is complex with a wide range of research and programmatic applications (for example, ongoing work in the NRC, DOE, CERCLA/RCRA and international communities). Any modifications in data and model assumptions used for cover properties and cover performance should be based on information from multiple referenced sources. More importantly, the long-term performance and changes in cover performance over time are strongly dependent on the type of closure cover (for example, engineered, ET cover) and the climate setting for the cover application. An expanded assessment of cover design components and assigned physical properties in models of cover performance must be carefully designed for applicability to the climate and hydrogeological setting of the Clive disposal facility.

This interrogatory spans two topics: alternative assignments of initial cover properties (parameter or knowledge uncertainty) and alternative approaches to degradation models for changes in cover properties over time (conceptual uncertainty). Enhanced investigations of these components of uncertainty require both different approaches in the structure of the modeling studies and application of methods of global sensitivity and uncertainty using probabilistic modeling. There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. If a more comprehensive sensitivity analysis is needed for the infiltration modeling, it should not be based on selective and non-systematic changes in physical properties of cover materials. Instead what is required would be refined modeling of closure cover performance using probabilistic cover parameters and multiple model simulations designed so that the output from the multiple simulations can be abstracted into the probabilistic performance assessment model.

177. INTERROGATORY CR R313-25-8(5)(A)-177/1: DOSE FROM PLANT UPTAKE

Include a quantitative analysis of dose resulting from plant uptake through "other wastes" in addition to DU.

EnergySolutions' Response: The PA is specific to depleted uranium and does not encompass "other wastes"; i.e., other wastes were not included in the scope of the PA. Therefore, this response focuses on the final statement of the Basis for Interrogatory,

> "*The plant pathway needs to receive full consideration within the PA model and text.*"

The discussion of black greasewood, shadscale saltbush, and four-wing saltbush in the Basis for Interrogatory is presumed to relate to the cited Compliance Report text (Section 3.1.5, page 3-4) which states that:

> "*…deep-rooted native plants present in the site vicinity do not have root depths sufficient to penetrate the Division-approved cover systems, overlying wastes, and into the depth at which depleted uranium is modeled for disposal (i.e., greater than 5 meters below the base of the cover).*"

The identification of plant groups for modeling root uptake of radionuclides as a transport mechanism is discussed in Section 3.2 of Appendix 9 of the Final Report (Biological Modeling). Black greasewood and shadscale saltbush are specifically identified in Table 3 of Biological Modeling as species identified at Clive and were the basis for naming two of the three present-day vegetative associations (Black Greasewood and Shadscale – Gray Molly) used to support parameterization of the plant transport component of the PA computer model. Additionally, black greasewood and shadscale saltbrush at Clive were among the plant species excavated to obtain root profile measurements (Biological Modeling; page 8) used in the PA computer model.

In addition to serving as a contaminant transport pathway for vertical migration of radionuclides, plants are assumed to serve as browse for cattle and game and therefore contribute to meat ingestion dose for receptors in the Ranching and Recreation exposure scenarios. This is described in Section 4.2 of Appendix 11 of the Final Report (Dose Assessment). Sheep are not considered, as there is no evidence that sheep are currently or have been routinely grazed in the area in the past. Therefore, the plant transport pathway has been fully considered in the PA.

178. INTERROGATORY CR R313-25-8(5)(A)-178/1: SURFACE WATER PATHWAY

Analyze potential doses to humans through the surface water exposure pathway.

EnergySolutions' Response*:* The Clive facility is sited in an area of extremely low topographic relief, and surface water features such as stream channels are rare. The ancestral lake bed is quite flat, so there is little in the way of land surface gradients which might drive surface water flow. Most if not all meteoric water that lands on the ground is assumed to be returned to the atmosphere by evapotranspiration, and essentially none is abstracted by runoff except on the rip rap covers. The embankment cells on the waste disposal site have significant relief, and surface water runoff should be expected from these structures. The runoff and associated sediment transport will be local, and is likely to remain in the vicinity of the site.

The interrogatory describes an historical event when a large storm resulted in an overflow condition for a retention pond. This is water that flowed from surface and intermediate layers of the cover system without contacting the waste. When cover maintenance ceases, radionuclide concentrations can increase at the cover surface due to burrowing and translocation by plants. Runoff events under these conditions could lead to movement of contaminated sediment. However, given the lack of topographic relief and few stream channels, even the impacts of rare large runoff events are likely to remain local.

The retention pond is an operational feature that will be replaced with a dispersion ditch transition to general overland flow as part of site closure. See detail J on drawing 14004-V5, which carries forward the design currently approved by DRC on drawing 9407-5, rev. I (Table 2A of the Ground Water Quality Discharge Permit). Therefore, there will be no standing bodies of surface water except immediately following storm events.

179. INTERROGATORY CR R313-25-7(2)-179/1: RIP RAP

Clarify the thickness, source, and availability of the rip rap.

***EnergySolutions*' Response**: Since the depleted uranium performance assessment is under revision to model the proposed Federal Cell with an evapotranspirative cover, Interrogatory CR R313-25-7(2)-179/1 is no longer applicable.

180. INTERROGATORY CR UGW450005 PART I.D.1-180/1: COMPLIANCE PERIOD

Indicate how pertinent performance standards will be met for groundwater for a compliance period of at least 10,000 years, or justify why those standards do not need to be met. Correct the discussion of the type of analysis needed to comply with UAC R313-25-8(5)(a).

***EnergySolutions*' Response:** See response to Interrogatory CR R313-25-7(2)-91/1.

181. INTERROGATORY CR R313-25-19-181/1: GROUNDWATER MORTALITY

Provide more detailed justification, including more specific references, for the risk factors and the calculated mortalities presented in Table 3-2 of the 2013 Compliance Report, Revision 1.

***EnergySolutions*' Response**: Projection of mortality from the ingestion of Clive's natural groundwater is estimated using the average concentrations from up-gradient well GW-19A, as reported in EnergySolutions, (2012). Mortality slope factors for the ingestion of non-radioactive constituents were obtained from EPA's IRIS database EPA (2013). Mortality slope factors for the ingestion of radioactive constituents were obtained from EPA (1999). As such, it is clear that Clive's natural groundwater as unpotable (meaning that doses from its ingestion are inconsistent with current practices at Clive and beyond the intent of the U.S. nuclear Regulatory Commission performance assessment guidance) as discussed in the response to Interrogatory CR R313-25-7(2)-91/1.

182. INTERROGATORY CR R313-25-19-182/1: GROUNDWATER EXPOSURE PATHWAYS

Expand the discussion in Section 1.3.1, page 1-9, of the 2013 Compliance Report, Revision 1, to include other pathways in addition to ingestion and explain whether or not these additional pathways can significantly contribute to doses.

EnergySolutions' Response*:* See responses to Interrogatory CR R313-25-8(4)(A)-96/1 and Interrogatory CR R313-25-7(2)-91/1.

3. REFERENCES

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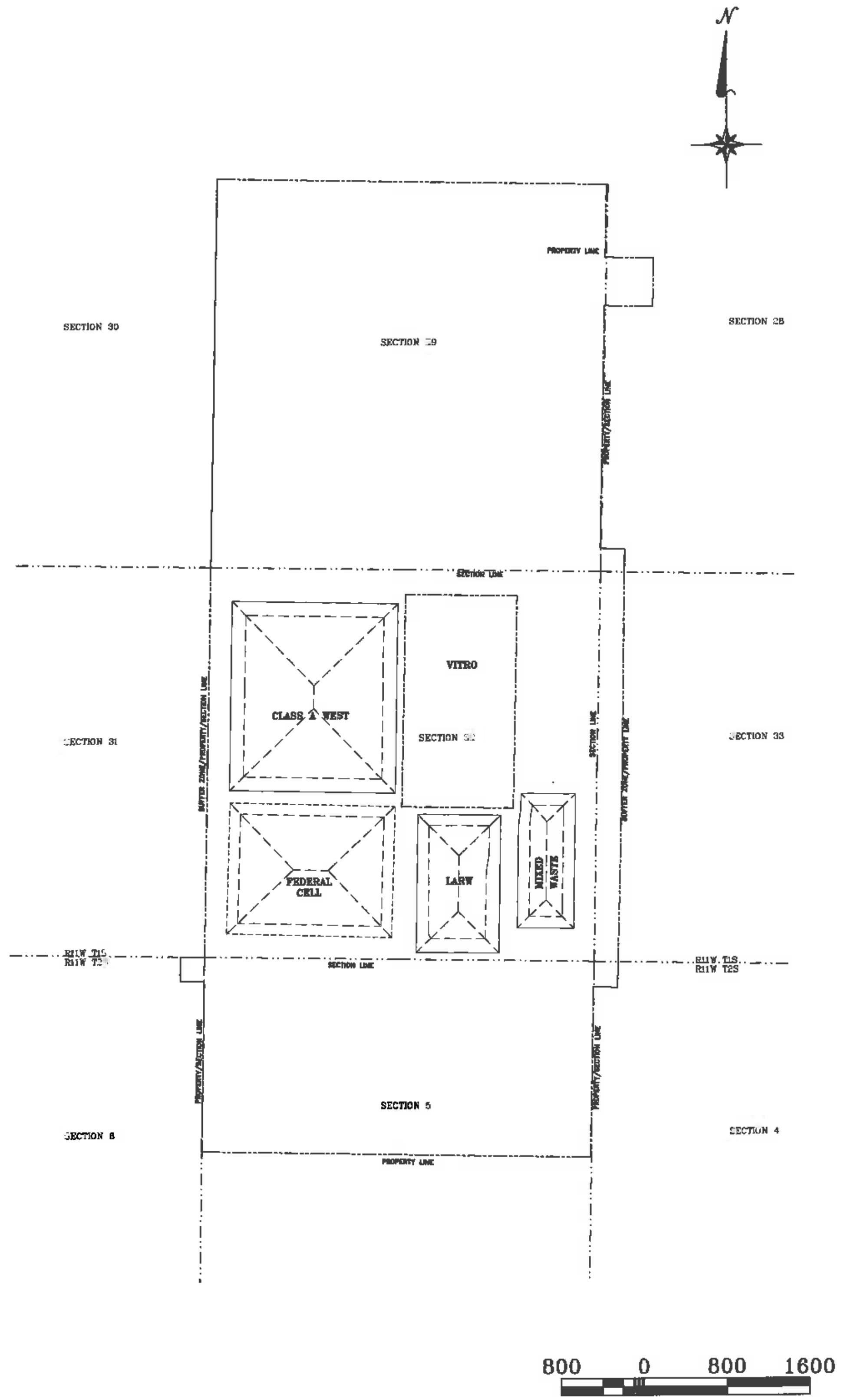
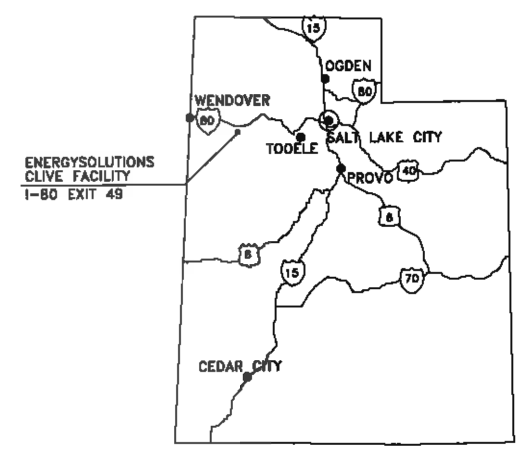
4. FEDERAL CELL PRELIMINARY DRAWING PACKAGE



FEDERAL WASTE DISPOSAL CELL

DWG. NO.	DESCRIPTION
14004-G1	PROJECT TITLE SHEET
14004-U1	DISPOSAL CELL BUFFER ZONE
14004-U2	DISPOSAL CELL WASTE LIMITS-LATITUDES & LONGITUDES
14004-U3	DISPOSAL CELL ENVIRONMENTAL MONITORING
14004-V1	CELL LAYOUT
14004-V2	CELL COVER LAYOUT
14004-V3	CELL CROSS SECTIONS 1 OF 2
14004-V4	CELL CROSS SECTIONS 2 OF 2
14004-V5	CELL CONSTRUCTION DETAILS 1 OF 2
14004-V6	CELL CONSTRUCTION DETAILS 2 OF 2
14004-V7	COVER CROSS SECTIONS AND GRADATIONS
14004-L1	CONCEPTUAL DU DISPOSAL PLAN



UTAH VICINITY MAP

LICENSED PROFESSIONAL ENGINEER
No. 189500
DAVID F BOOTH
3/31/14
STATE OF UTAH

1	3/31/14	DFB	PRELIMINARY
	DATE	BY	DESCRIPTION OF CHANGE

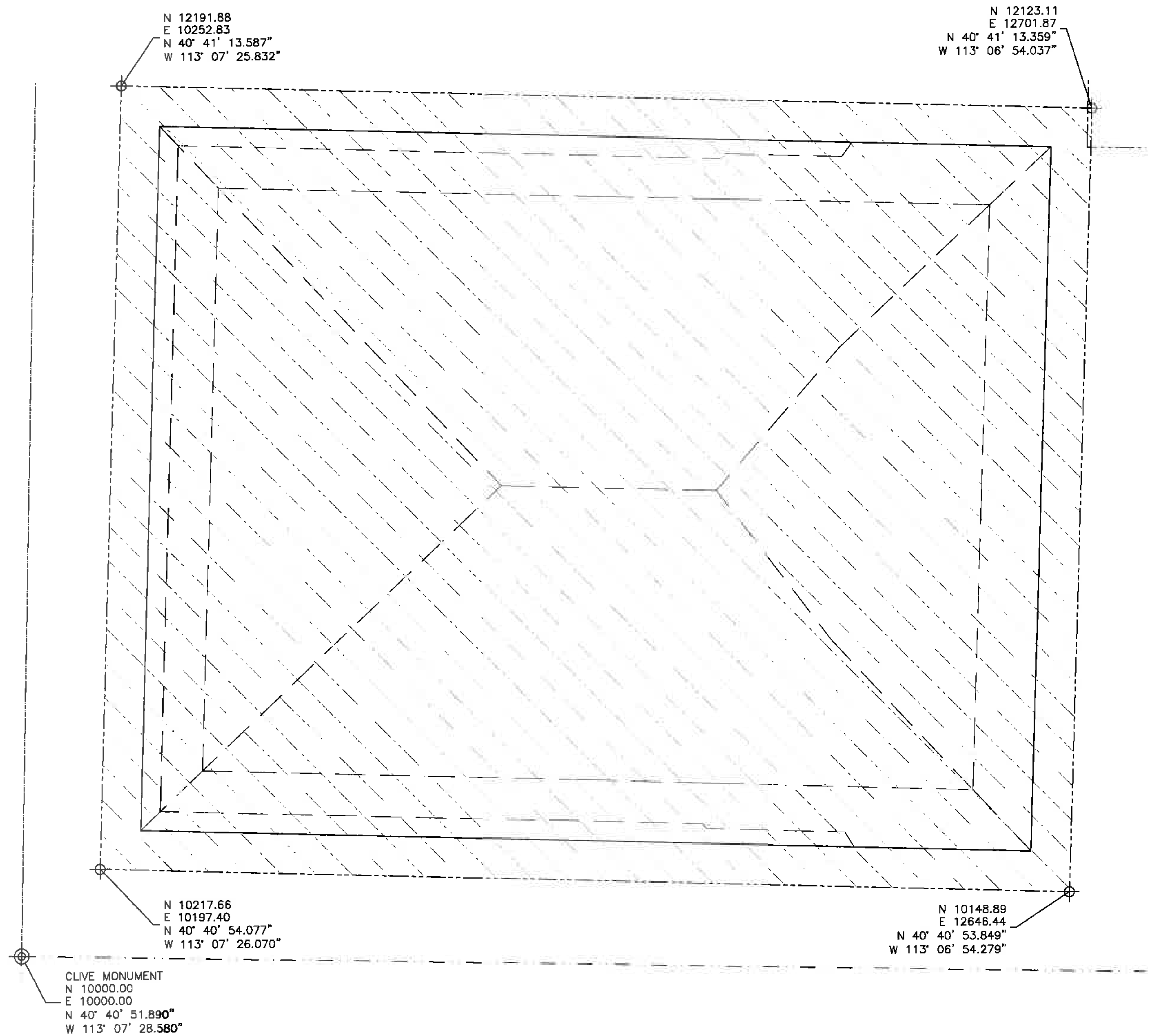
ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
PROJECT TITLE SHEET
CLIVE, UTAH

PRELIMINARY

DRAFTED BY D.BOOTH
REVIEWED BY G.DUTSON
APPROVED BY D.BOOTH
SCALE AS NOTED | 03/28/14 | REV. 1

DRAWING NO. 14004 G1



N

LEGEND

- BUFFER ZONE LIMITS
- SECTION LINE
- PROPERTY LINE
- PERMITTED WASTE LIMITS
- DISPOSAL CELL BREAK LINES
- BUFFER ZONE

500 0 500 1000

1	3/31/14	DFB	PRELIMINARY
	DATE	BY	DESCRIPTION OF CHANGE

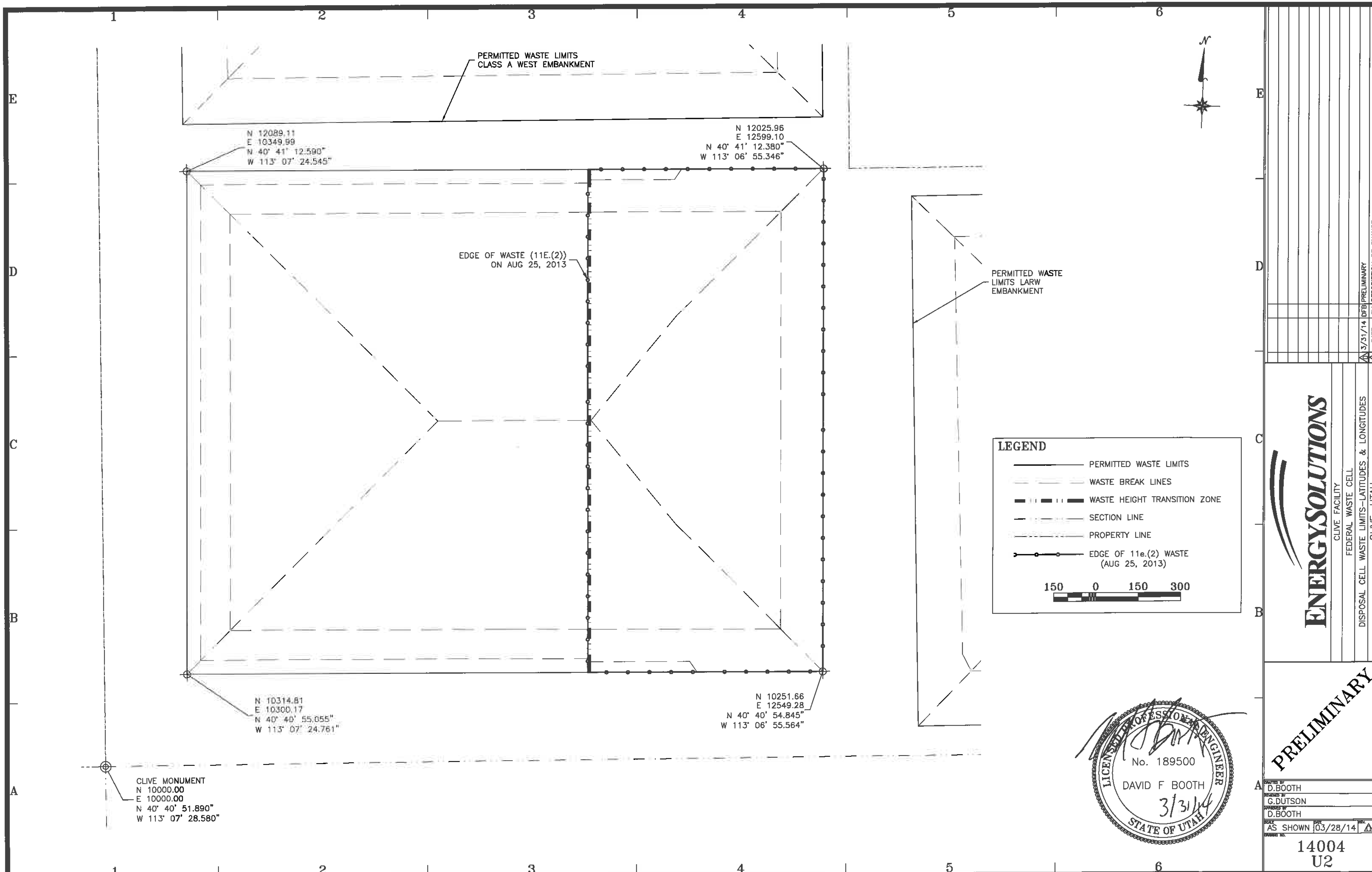
ENERGYSOLUTIONS

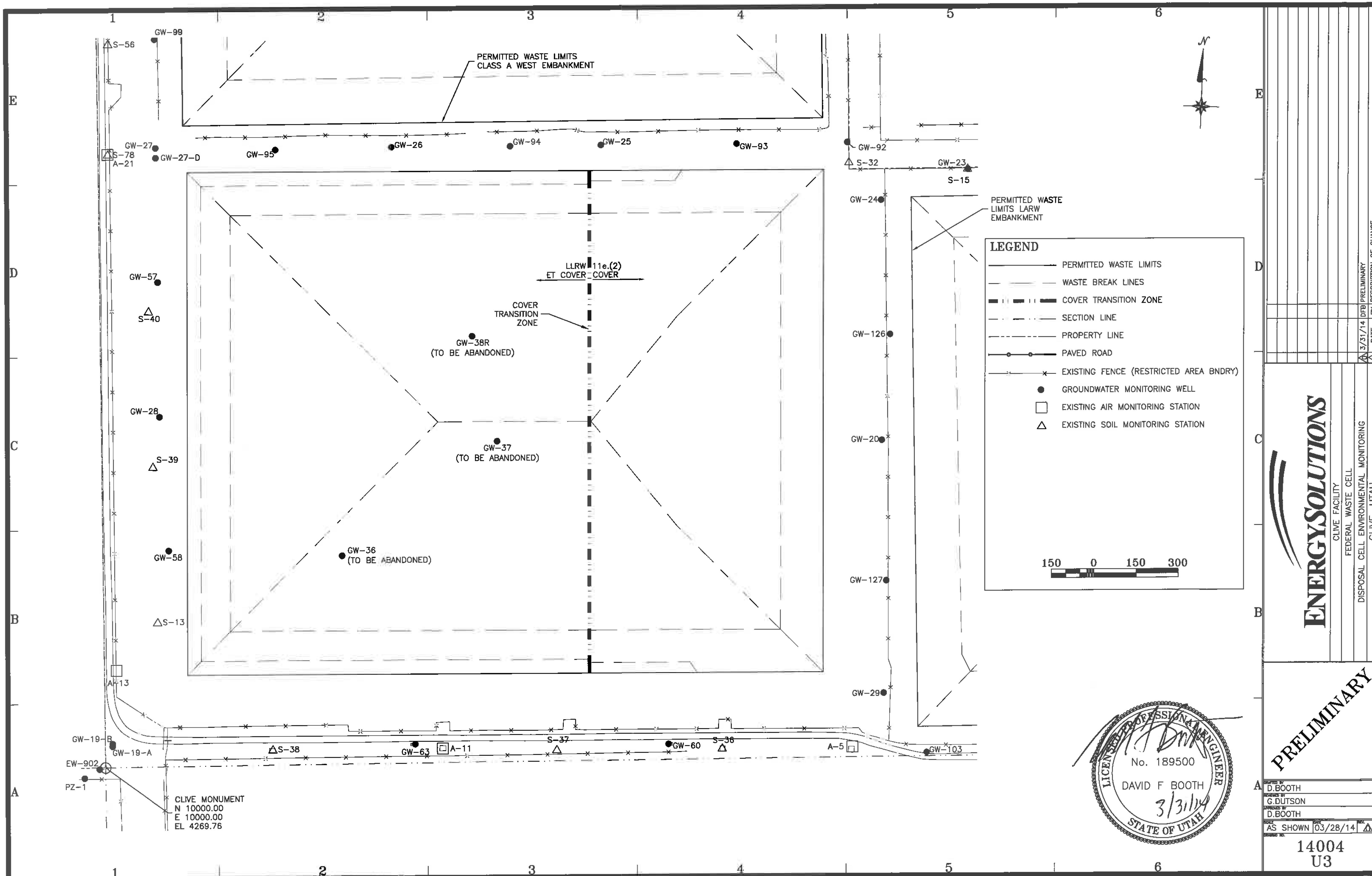
CLIVE FACILITY
FEDERAL WASTE CELL
DISPOSAL CELL BUFFER ZONE
CLIVE, UTAH

PRELIMINARY

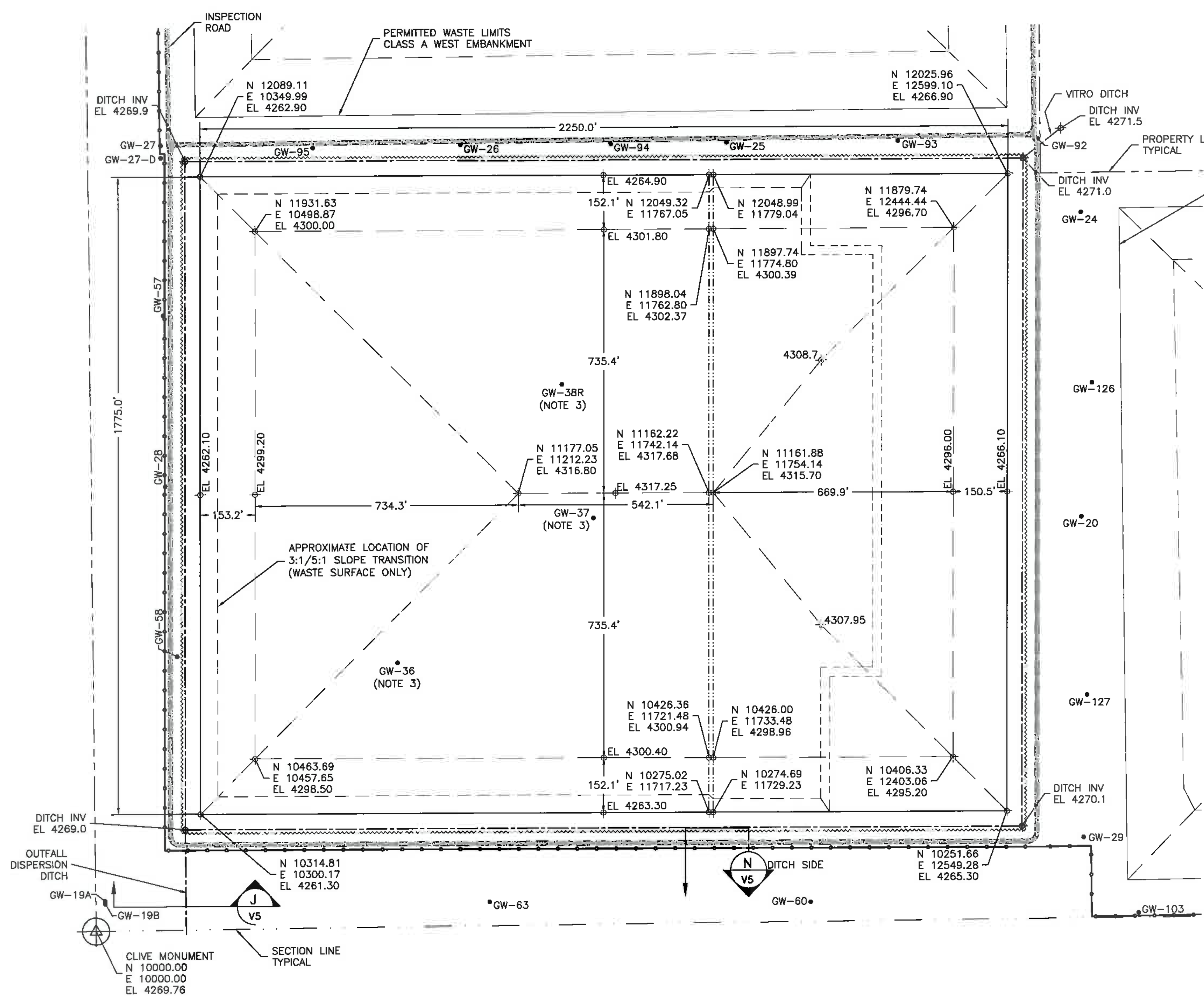
LICENSED PROFESSIONAL ENGINEER
No. 189500
DAVID F BOOTH
3/31/14
STATE OF UTAH

DRAFTED BY: D.BOOTH
REVIEWED BY: G.DUTSON
APPROVED BY: D.BOOTH
SCALE: AS NOTED | 03/28/14 | REV. 1
DRAWING NO.: 14004 U1


PERMITTED WASTE LIMITS
CLASS A WEST EMBANKMENT
N 12089.11
E 10349.99
N 40° 41' 12.590"
W 113° 07' 24.545"
N 12025.96
E 12599.10
N 40° 41' 12.380"
W 113° 06' 55.346"
EDGE OF WASTE (11E.(2))
ON AUG 25, 2013
PERMITTED WASTE
LIMITS LARW
EMBANKMENT
N 10314.81
E 10300.17
N 40° 40' 55.055"
W 113° 07' 24.761"
N 10251.66
E 12549.28
N 40° 40' 54.845"
W 113° 06' 55.564"
CLIVE MONUMENT
N 10000.00
E 10000.00
N 40° 40' 51.890"
W 113° 07' 28.580"
LEGEND
PERMITTED WASTE LIMITS
WASTE BREAK LINES
WASTE HEIGHT TRANSITION ZONE
SECTION LINE
PROPERTY LINE
EDGE OF 11e.(2) WASTE
(AUG 25, 2013)
150 0 150 300
No. 189500
DAVID F BOOTH
3/31/14
LICENSED PROFESSIONAL ENGINEER
STATE OF UTAH
3/31/14 DFB PRELIMINARY
DATE BY DESCRIPTION OF CHANGE
ENERGYSOLUTIONS
CLIVE FACILITY
FEDERAL WASTE CELL
DISPOSAL CELL WASTE LIMITS-LATITUDES & LONGITUDES
CLIVE, UTAH
PRELIMINARY
D.BOOTH
G.DUTSON
D.BOOTH
AS SHOWN
03/28/14
14004
U2



PERMITTED WASTE LIMITS CLASS A WEST EMBANKMENT
PERMITTED WASTE LIMITS LARW EMBANKMENT
LLRW ET COVER
11e.(2) COVER
COVER TRANSITION ZONE
GW-38R (TO BE ABANDONED)
GW-37 (TO BE ABANDONED)
GW-36 (TO BE ABANDONED)
S-56
GW-99
GW-27
GW-27-D
S-78
A-21
GW-95
GW-26
GW-94
GW-25
GW-93
GW-92
S-32
GW-23
S-15
GW-24
GW-126
GW-20
GW-127
GW-29
GW-57
S-40
GW-28
S-39
GW-58
S-13
A-13
GW-19-B
GW-19-A
EW-902
PZ-1
S-38
GW-63
A-11
S-37
GW-60
S-36
A-5
GW-103
CLIVE MONUMENT
N 10000.00
E 10000.00
EL 4269.76
LEGEND
PERMITTED WASTE LIMITS
WASTE BREAK LINES
COVER TRANSITION ZONE
SECTION LINE
PROPERTY LINE
PAVED ROAD
EXISTING FENCE (RESTRICTED AREA BNDRY)
GROUNDWATER MONITORING WELL
EXISTING AIR MONITORING STATION
EXISTING SOIL MONITORING STATION
150 0 150 300
N
No. 189500
DAVID F BOOTH
3/31/14
STATE OF UTAH
ENERGYSOLUTIONS
CLIVE FACILITY
FEDERAL WASTE CELL
DISPOSAL CELL ENVIRONMENTAL MONITORING
CLIVE, UTAH
3/31/14 DFB PRELIMINARY
DATE BY DESCRIPTION OF CHANGE
PRELIMINARY
D.BOOTH
G.DUTSON
D.BOOTH
AS SHOWN 03/28/14
14004
U3



LEGEND

- PERMITTED WASTE LIMITS
- WASTE HEIGHT TRANSITION ZONE
- INSPECTION ROAD
- WASTE BREAK LINES
- LINER LIMITS (MINIMUM)
- DRAINAGE DITCH CENTERLINE
- 11e.(2) COVER TRANSITION
- RUNON BERM CENTERLINE
- SECTION LINE
- PROPERTY LINE
- CLOSURE FENCE
- GROUNDWATER MONITORING WELL

150 0 150 300

NOTES

1. ALL ELEVATIONS SHOWN ARE FOR TOP OF WASTE UNLESS OTHERWISE NOTED.
2. COORDINATES ARE BASED ON THE CLIVE MONUMENT.
3. THESE WELLS WILL BE ABANDONED PRIOR TO CONSTRUCTION OF CELL LINER.
4. INSPECTION ROAD AND DITCH CENTERLINE TO BE DETERMINED AT TIME OF COVER CONSTRUCTION.
5. LAST FOOT OF WASTE IS SUBSTITUTED WITH TEMPORARY COVER.

LICENSED PROFESSIONAL ENGINEER No. 189500 DAVID F BOOTH 3/31/14 STATE OF UTAH

DATE	BY	DESCRIPTION OF CHANGE
3/31/14	DFB	PRELIMINARY

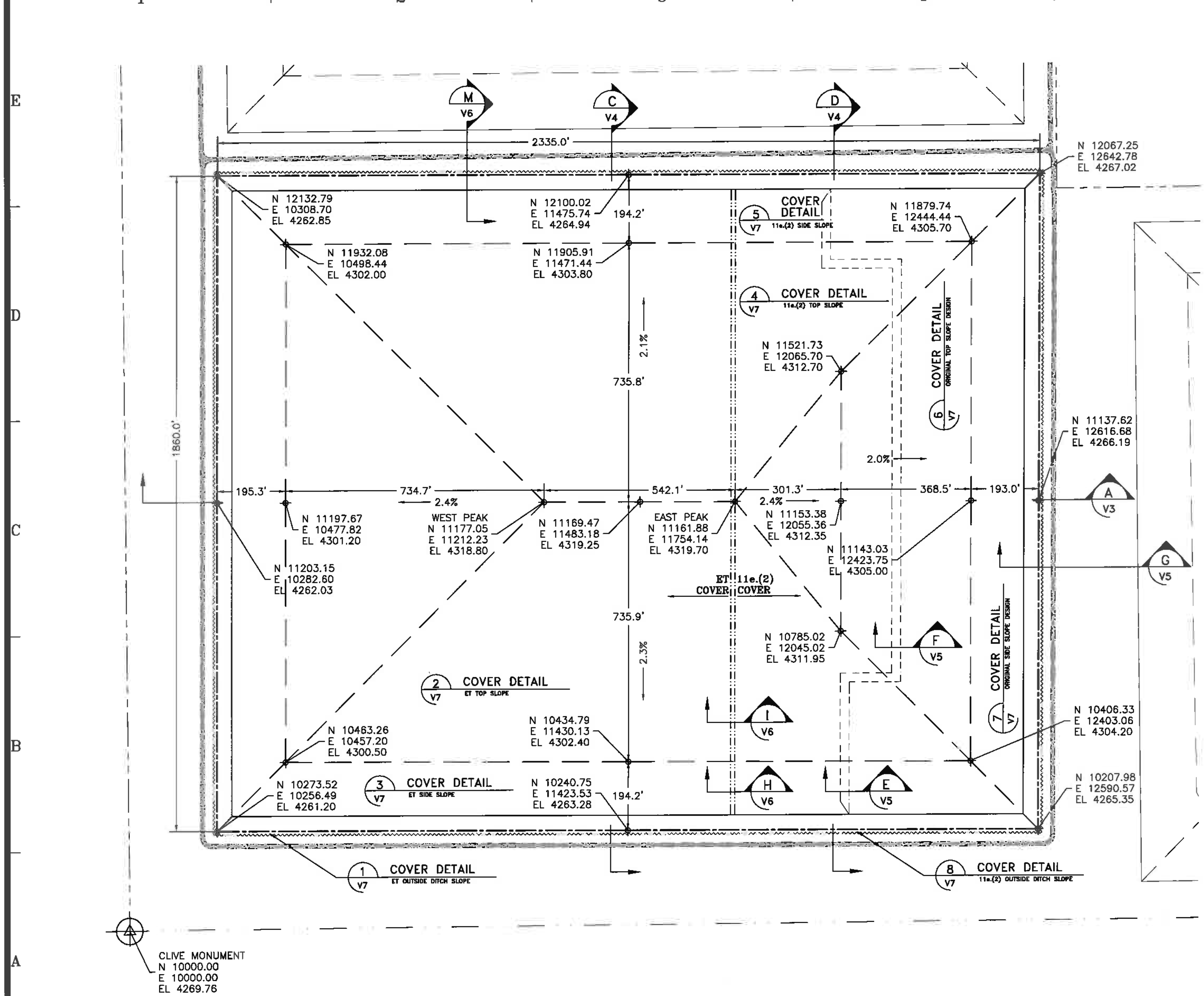
ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL LAYOUT
CLIVE, UTAH

PRELIMINARY

D.BOOTH
G.DUTSON
D.BOOTH
AS NOTED 03/28/14

14004
V1



LEGEND

- PERMITTED WASTE LIMITS
- RADON BARRIER LIMITS
- WASTE HEIGHT TRANSITION ZONE
- INSPECTION ROAD
- RADON BARRIER BREAK LINES
- LINER LIMITS (MINIMUM)
- 11e.(2) COVER TRANSITION
- SECTION LINE
- PROPERTY LINE

150 0 150 300

NOTES

1. ELEVATIONS SHOWN ARE FOR TOP OF RADON BARRIER (5x10−8 CM/SEC) LAYER UNLESS OTHERWISE NOTED.
2. COORDINATES ARE BASED ON THE CLIVE MONUMENT.

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DATE	BY	DESCRIPTION OF CHANGE
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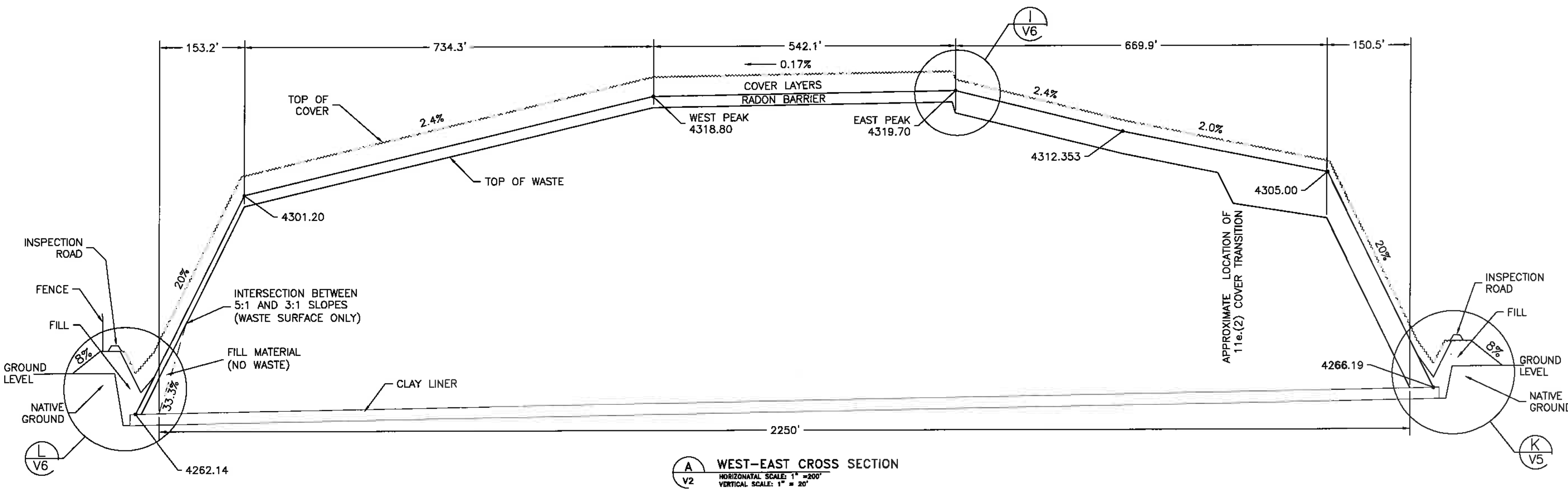
ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL COVER LAYOUT
CLIVE, UTAH

PRELIMINARY

DRAFTED BY D.BOOTH
CHECKED BY G.DUTSON
APPROVED BY D.BOOTH
SCALE AS NOTED DATE 03/28/14

14004
V2



A V2 WEST-EAST CROSS SECTION
HORIZONATAL SCALE: 1" =200'
VERTICAL SCALE: 1" = 20'

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ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL CROSS SECTIONS 1 OF 2
CLIVE, UTAH

PRELIMINARY

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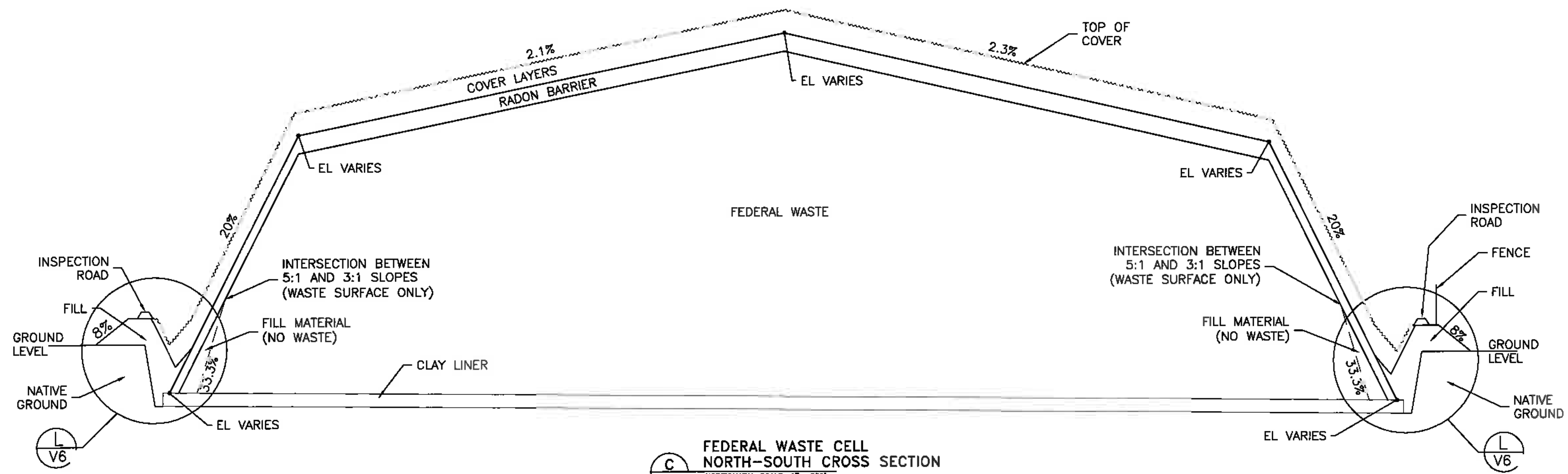
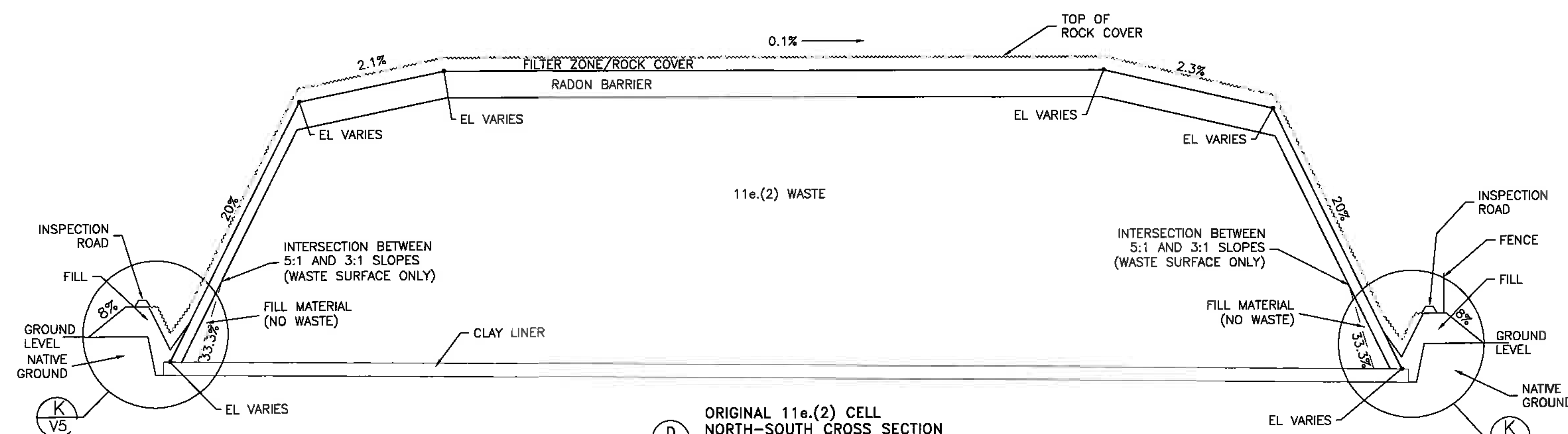
APPROVED BY: D.BOOTH
SCALE: NTS DATE: 03/28/14 REV: 0
DRAWING NO. 14004 V3



C V2 FEDERAL WASTE CELL NORTH–SOUTH CROSS SECTION
HORIZONATAL SCALE: 1" =200'
VERTICAL SCALE: 1" = 20'



D V2 ORIGINAL 11e.(2) CELL NORTH–SOUTH CROSS SECTION
HORIZONATAL SCALE: 1" =200'
VERTICAL SCALE: 1" = 20'

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ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL CROSS SECTIONS 2 OF 2
CLIVE, UTAH

PRELIMINARY

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DATE 03/28/14
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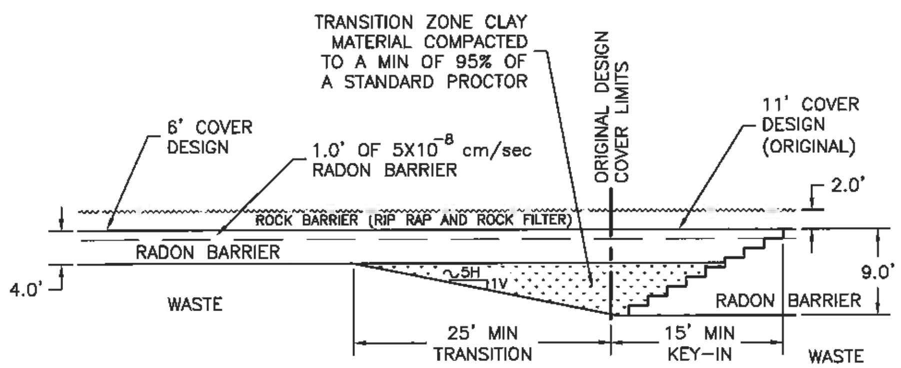
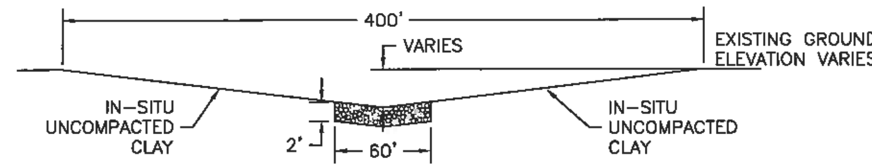
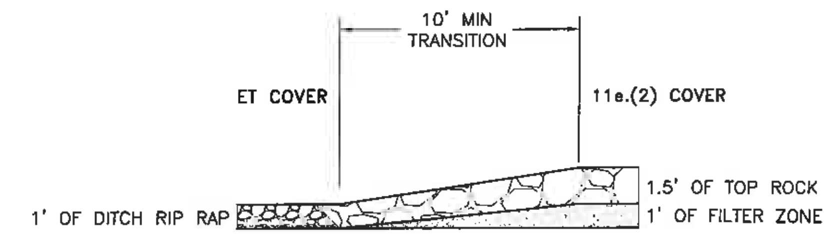


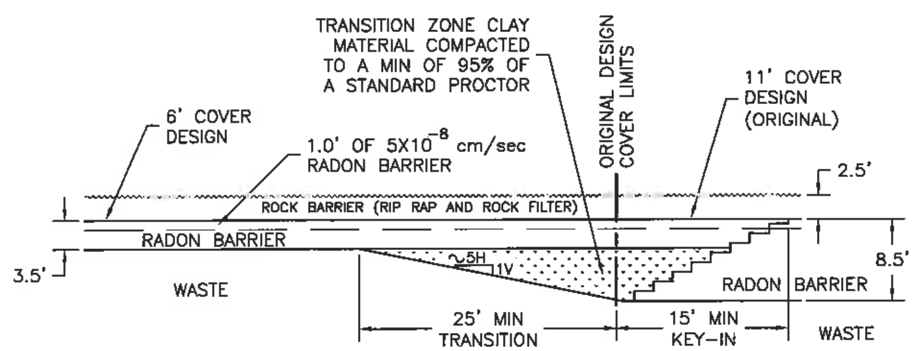
F V2 11e.(2) TOP SLOPE COVER TRANSITION
NOT TO SCALE



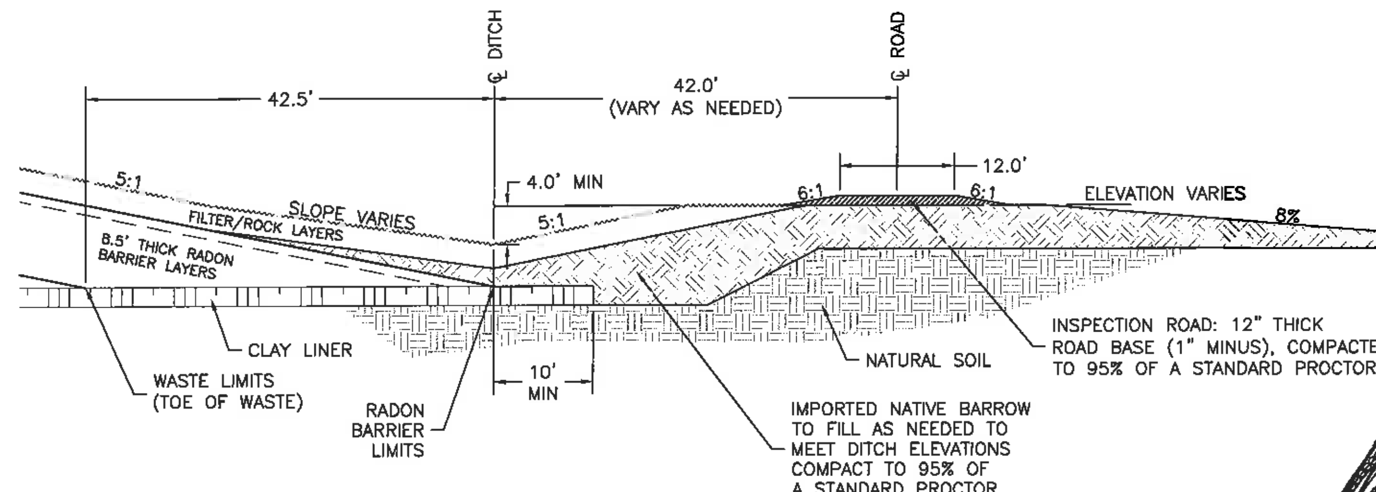
J V1 DISPERSION DITCH CROSS SECTION
HORIZONTAL SCALE: 1" = 120'
VERTICAL SCALE: 1" = 20'



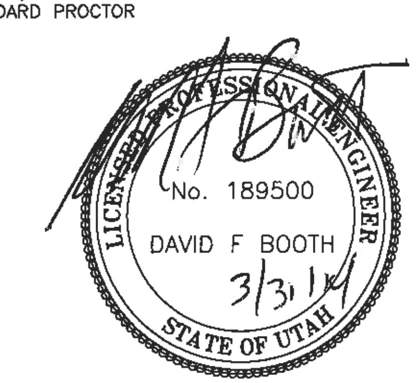
N V1 DITCH SIDE SLOPE TRANSITION OUTSIDE OF CENTERLINE
HORIZONATAL SCALE: 1" = 8'

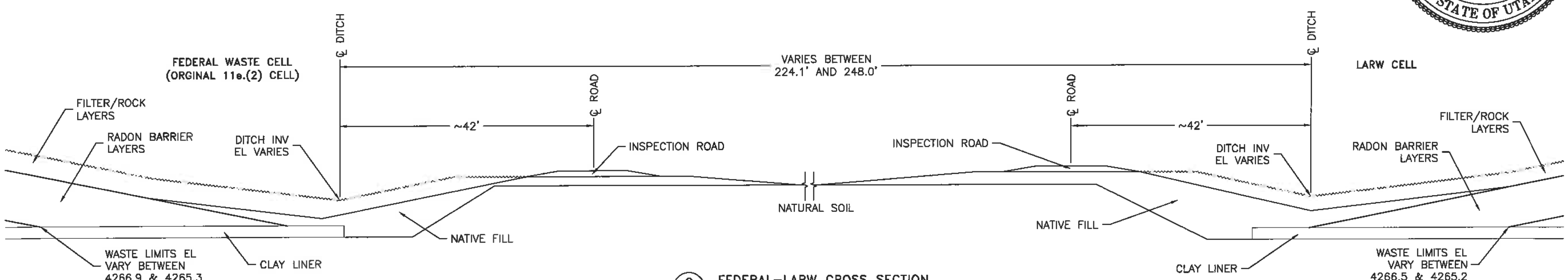


E V2 11e.(2) SIDE SLOPE COVER TRANSITION
NOT TO SCALE



K V3 ORIGINAL DITCH CROSS SECTION
10 0 10 20





G V2 FEDERAL-LARW CROSS SECTION
10 0 10 20

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ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL CONSTRUCTION DETAILS 1 OF 2
CLIVE, UTAH

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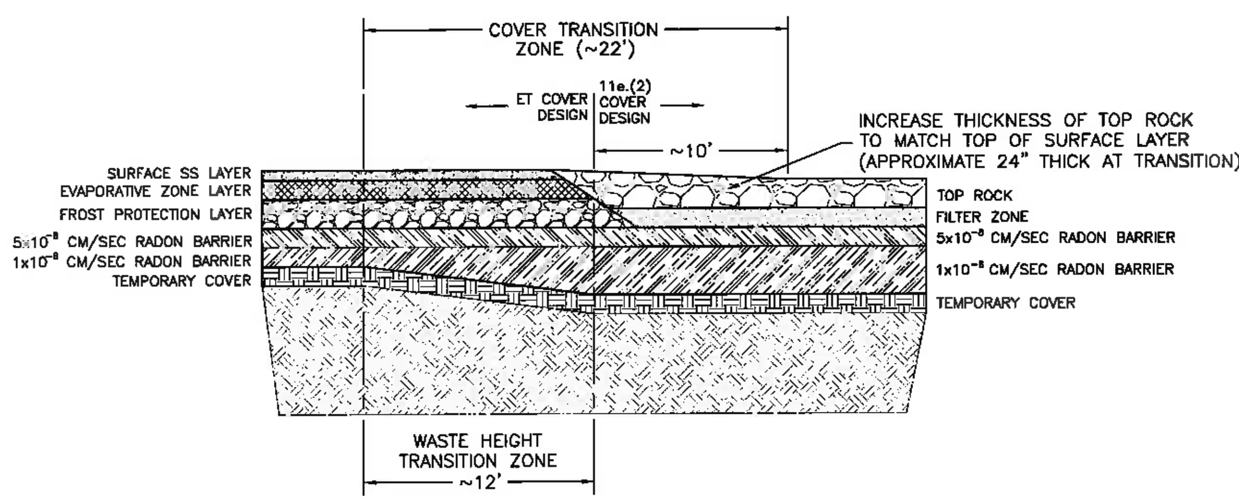
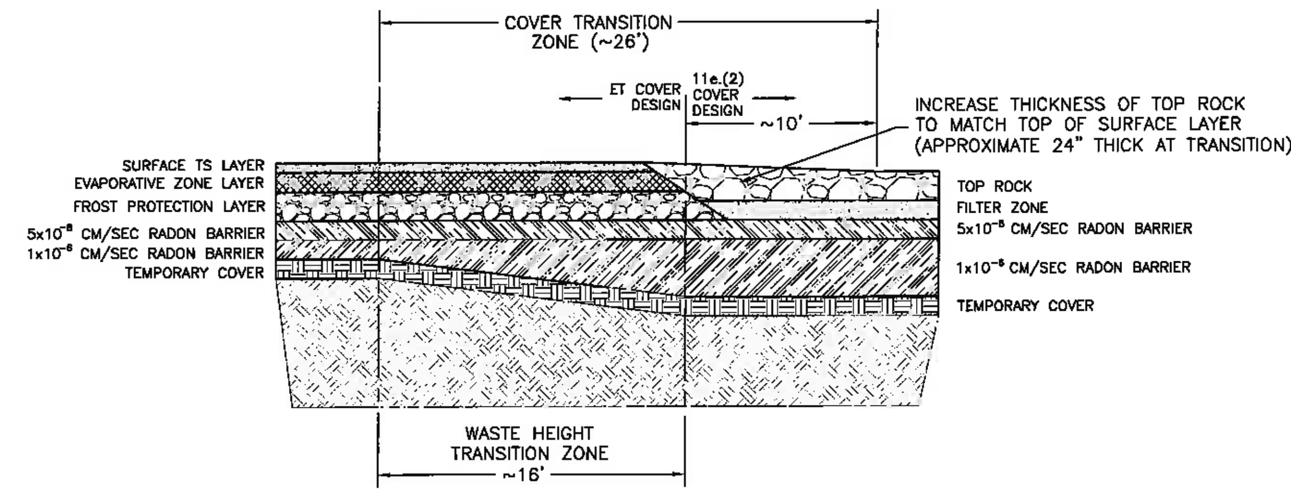
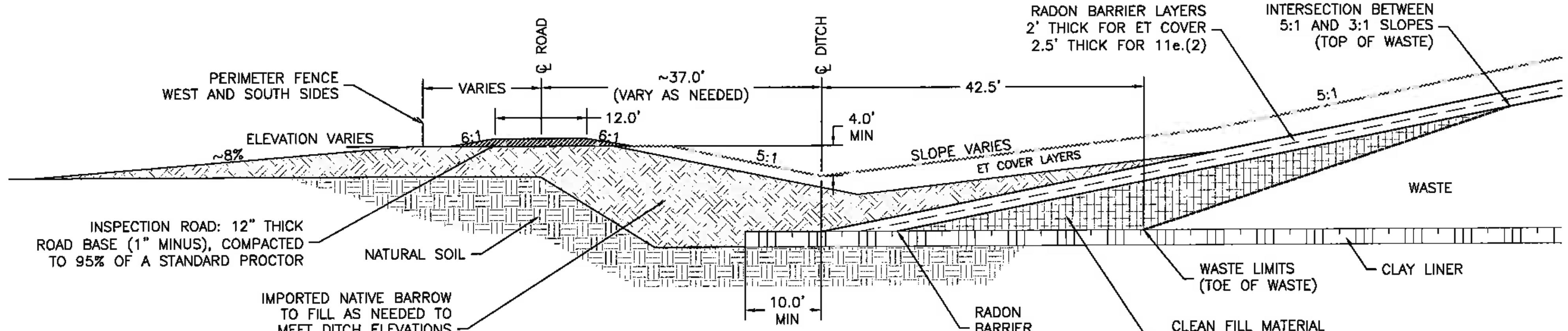


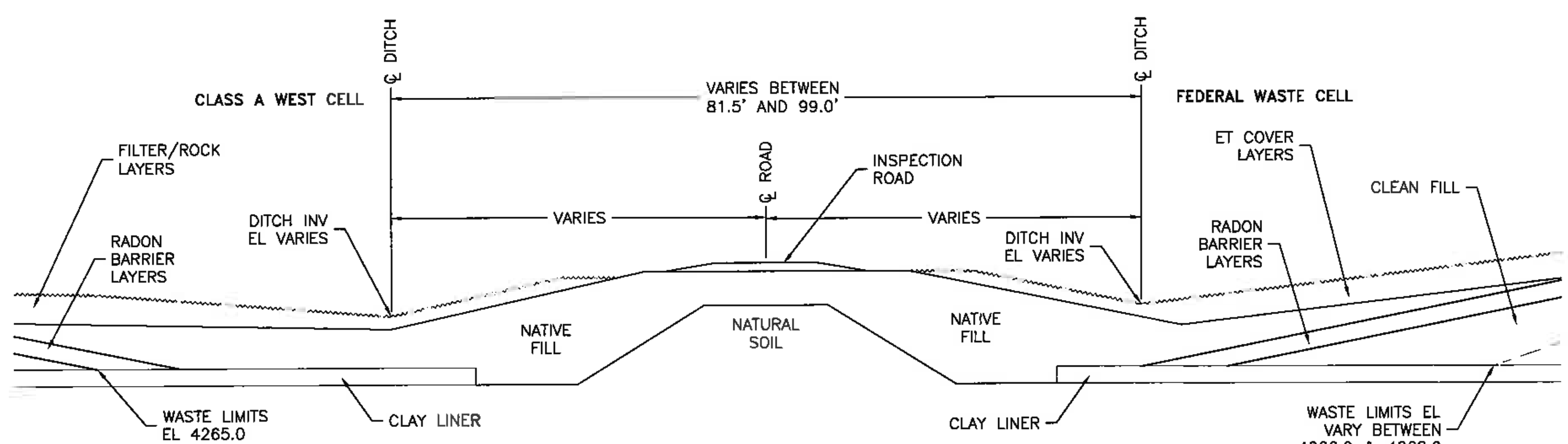
H V2 SIDE SLOPE COVER COVER TRANSITION ZONE
SCALE: 1" =10'



I V2 TOP SLOPE COVER COVER TRANSITION ZONE
SCALE: 1" =10'



L V3 DITCH CROSS SECTION



M V2 CLASS A WEST–FEDERAL CROSS SECTION

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ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CELL CONSTRUCTION DETAILS 2 OF 2
CLIVE, UTAH

PRELIMINARY

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APPROVED BY D.BOOTH
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DATE 03/27/14
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ORIGINAL 11e.(2) CELL COVER DESIGNS

ROCK
12" THICK TOP ROCK
12" THICK FILTER ZONE
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
CLAY
3' OF 1 X 10^{-6} CM/SEC RADON BARRIER

4/V2 11e.(2) TOP SLOPES

ROCK
18" THICK SIDE ROCK
12" THICK FILTER ZONE
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
CLAY
2.5' OF 1 X 10^{-6} CM/SEC RADON BARRIER

5/V2 11e.(2) SIDE SLOPES

ROCK
12" THICK TOP ROCK
12" THICK FILTER ZONE
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
CLAY
8' OF 1 X 10^{-6} CM/SEC RADON BARRIER

6/V2 11e.(2) TOP SLOPES
ORIGINAL DESIGN

ROCK
18" THICK SIDE ROCK
12" THICK FILTER ZONE
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
CLAY
7.5' OF 1 X 10^{-6} CM/SEC RADON BARRIER

7/V2 11e.(2) SIDE SLOPES
ORIGINAL DESIGN

ROCK
18" THICK SIDE ROCK
12" THICK FILTER ZONE
NATURAL GROUND OR IMPORTED NATIVE BARROW MATERIAL

8/V2 PERIMETER DITCH
OUTSIDE SLOPE ONLY

GRADATIONS – ASTM C-136

TOP ROCK
D_{100} 2-1/2 TO 4-1/2 INCHES
D_{50} 1-1/8 TO 3 INCHES
D_{15} 3/4 TO 1-1/2 INCHES

SIDE ROCK
D_{100} 12 TO 16 INCHES
D_{85} 8 TO 12 INCHES
D_{50} 4-1/2 TO 8 INCHES
D_{15} 2 TO 4 INCHES

FILTER ZONE
D_{100} = 1.5 TO 3. 0 INCHES
D_{85} = 1.0 TO 2.5 INCHES
D_{50} = 0.75 TO 2.0 INCHES
D_{15} = 0.3.125 TO 0.625 INCHES
D_{10} >= #10 SIEVE (2.0 mm)
D_{5} >= #200 SEIVE (0.074 mm)

FEDERAL WASTE CELL COVER DESIGNS

ROCK
12" THICK DITCH RIPRAP
BORROW MATERIA OR EVAPORATIVE ZONE MATERIAL

1/V2 PERIMETER DITCH
OUTSIDE SLOPE ONLY

COVER
6" THICK SURFACE TS LAYER (15% GRAVEL/85% CLAY)
12" THICK EVAPORATIVE ZONE LAYER
18" THICK FROST PROTECTION LAYER
CLAY
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
12" OF 1 X 10^{-6} CM/SEC RADON BARRIER

2/V2 ET COVER TOP SLOPES

COVER
6" THICK SURFACE SS LAYER (50% GRAVEL/50% CLAY)
12" THICK EVAPORATIVE ZONE LAYER
18" THICK FROST PROTECTION LAYER
CLAY
12" OF 5 X 10^{-8} CM/SEC RADON BARRIER
12" OF 1 X 10^{-6} CM/SEC RADON BARRIER

3/V2 ET COVER SIDE SLOPES

ET COVER MATERIAL SPECIFICATIONS

SURFACE LAYER, SIDE SLOPE (SS):
50% UNIT 4 MATERIAL AMENDED WITH 50% (±3%), BY VOLUME, GRAVEL. REFER TO NOTE 2.

SURFACE LAYER, TOP SLOPE (TS):
85% UNIT 4 MATERIAL AMENDED WITH 15% (±3%), BY VOLUME, GRAVEL. REFER TO NOTE 2.

EVAPORATIVE ZONE LAYER:
UNIT 4 MATERIAL (CLAY). REFER TO NOTE 2.

FROST PROTECTION LAYER:
16" MINUS BANK RUN COBBLE/GRAVEL/SOIL MATERIAL. REFER TO NOTE 2.

DITCH RIPRAP:
FINE GRADED ROCK WITH A D_{50} OF 6". SEE NOTE 2.

NOTES:

1. EXTEND THE SIDE SLOPE SURFACE LAYER ONTO THE TOP SLOPE A MINIMUM OF 3 FT PAST THE BREAK OVER BETWEEN THE TOP AND SIDE SLOPES.

2. REFER TO THE CURRENT APPROVED LLRW/11e.(2) CQA/QC MANUAL FOR ADDITIONAL MATERIAL SPECIFICATIONS, GRADATIONS, CONSTRUCTION AND TESTING REQUIREMENTS.

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ENERGYSOLUTIONS
CLIVE FACILITY
FEDERAL WASTE CELL
COVER CROSS SECTIONS AND GRADATIONS
CLIVE, UTAH

PRELIMINARY

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APPROVED BY: D.BOOTH
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14004
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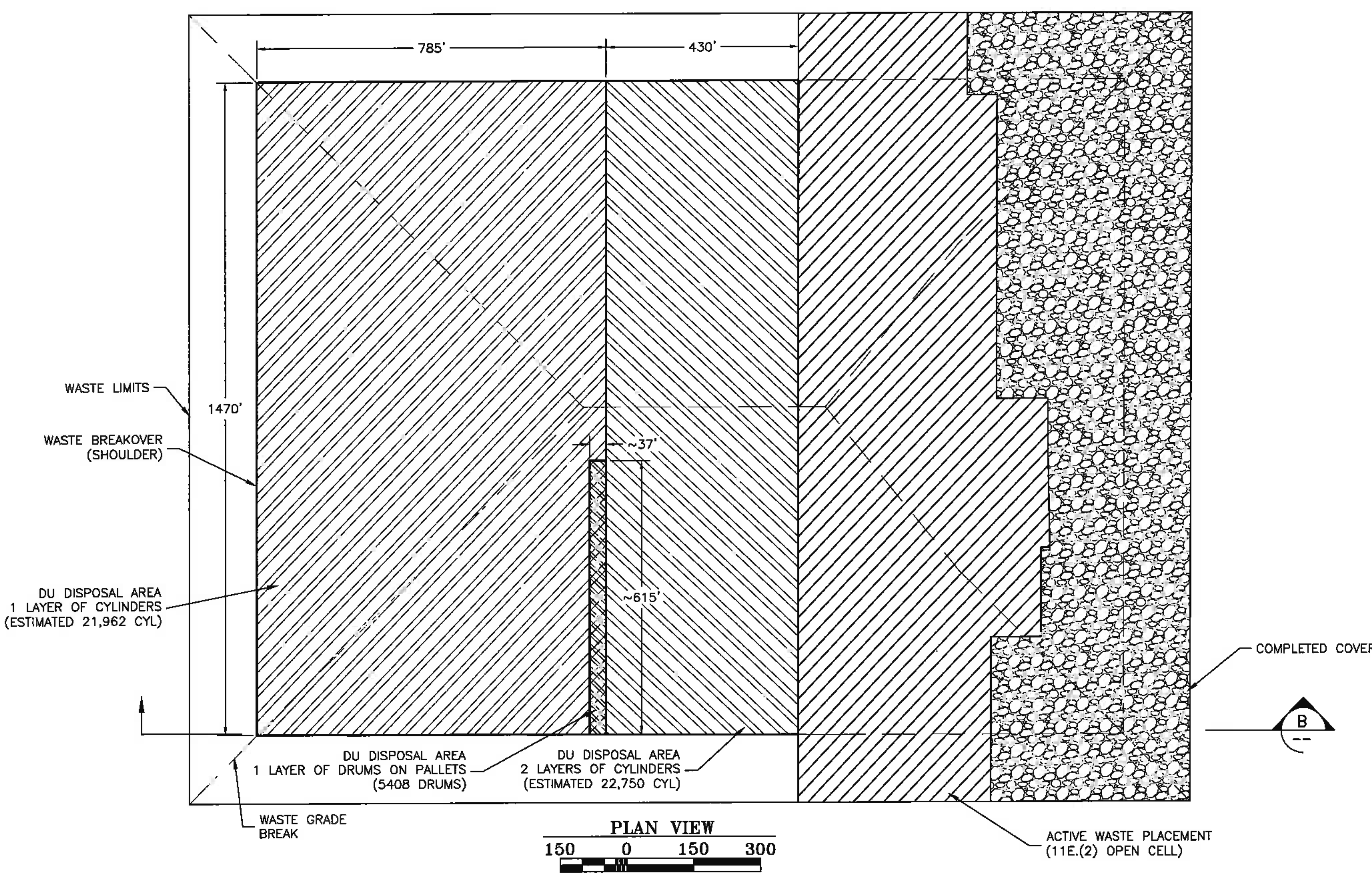
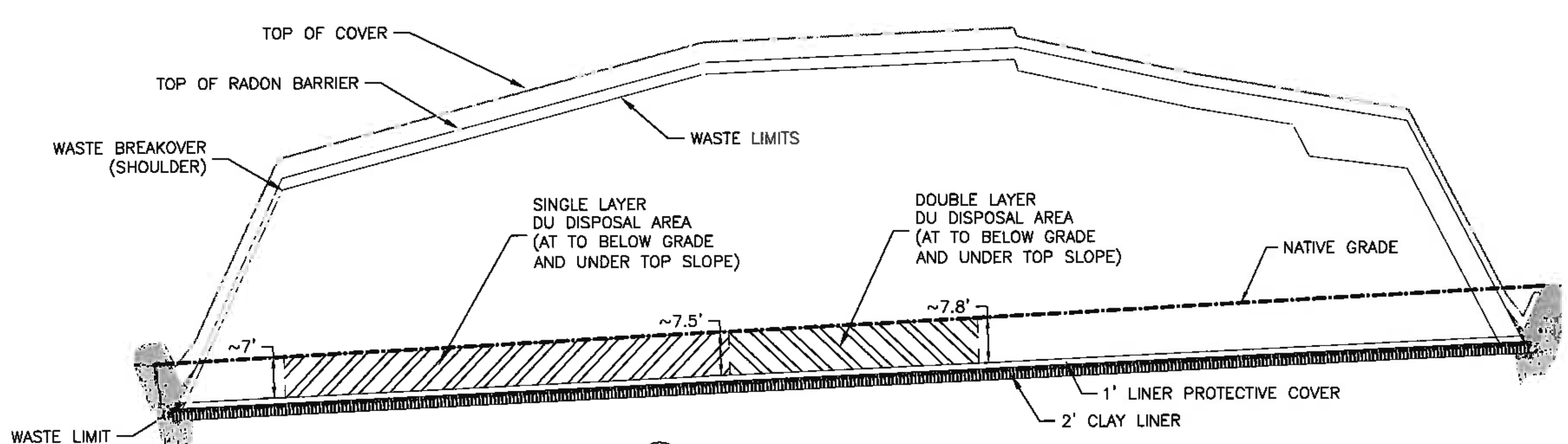
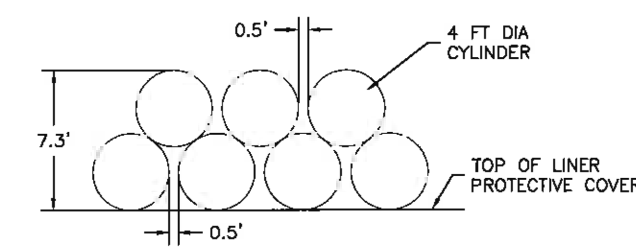




B WEST–EAST CROSS SECTION
HORIZONATAL SCALE:VERTICAL SCALE = 1:10



CONCEPTUAL DOUBLE STACK CONFIGURATION
NOT TO SCALE

NOTES

1. LIMITS FOR SINGLE AND DOUBLE LAYER DISPOSAL ARE CONCEPTUAL ONLY, BASED ON CONSERVATIVE ASSUMPTIONS FOR NATIVE GRADE, CYLINDER SIZES, SPACING, AND STACKING CONFIGURATION.
2. ESTIMATED NUMBER OF CYLINDERS ASSUMES THAT ALL CYLINDERS ARE 12–Mg CYLINDERS (12' LONG X 4' DIA), AND ASSUMES THE FOLLOWING PLACED SPACING.
   SINGLE LAYER: CYLINDERS ARE SPACED 0.2 FT END–TO–END AND SIDE–TO–SIDE, AND DRUMS ARE PLACED ON 4'X4' PALLETS SPACED AT 0.1 FT.
   DOUBLE LAYER: CYLINDERS ARE SPACED 0.2 FT END–TO–END AND 0.5 FT SIDE TO SIDE, BOTH LAYERS.

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ENERGYSOLUTIONS

CLIVE FACILITY
FEDERAL WASTE CELL
CONCEPTUAL DU DISPOSAL PLAN
CLIVE, UTAH

PRELIMINARY

DRAFTED BY: D.BOOTH
REVIEWED BY: G.DUTSON
APPROVED BY: D.BOOTH
SCALE: AS NOTED | DATE: 03/28/14

14004
L1

5. DU WASTE FORM LINER LOADING CALCULATIONS

DU Drum Bearing Capacity Calculations 31-Mar-14

Bearing Weight Limit **3000** psf

Find the bearing pressure of a DU drum weight in Double Stack DU Drum Configuration to verify compliance with the 3,000 psf allowable bearing pressure.
Details of DU Drum(s):

Assume DU Drum is 12' long x 4' diameter, made of 3/8" thick steel: assume cylinder weight of 2500 lbs.

Assuming the the particle density of U3O8 is 8.3 g/cm3 (Wikipedia 2014) from the Interrogatory:

Waste weight: 8.3 gm/cm3 = 518.086 lb/cf

Assume a drum placed in the lower tier and center of the area supports the weight of 1/2 of two upper tier drums: so calculate the bearing capacity using the weight of two 100% filled drums.

Size of Drum:	Length (ft)	Diameter (ft)	Volume (cf)	Area (sf)	Weight (lbs)
Maximum DU Drum total waste weight (doubled)	12.0	4.0	150.7	48.00	**158,672**

Soil Cover:	Thickness		Unit Weight	
Soil Protective Cover	1	feet	125	pcf

Calculations:

Use Westergaard Theory (Fig. 8.26) to determine loading at level of Clay Liner. Center controls.

m value	2.00
n value	6.00
I-sigma value from Fig 8.26	0.193

Bearing Pressure of Component: 2,677 psf < 3,000 psf allowable

Assumptions:

Assume worst case scenario: Drums in double stack orientation at base of Federal Cell over one foot of protective cover over clay liner.

Single Drum orientation will impart a lower bearing pressure to the clay liner than will the double stack orientation.

weight of drum				
density of DU	8.3	gm/cm3	518.086	pcf
weight of drum			78085.922	lbs

assume 2500 lbs cylinders… 100% full… du… wt cylinder…

1/4 thick steel…	10.2	psf
3/8 thick steel	15.38	psf

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2:1 try spread value…
one on one….

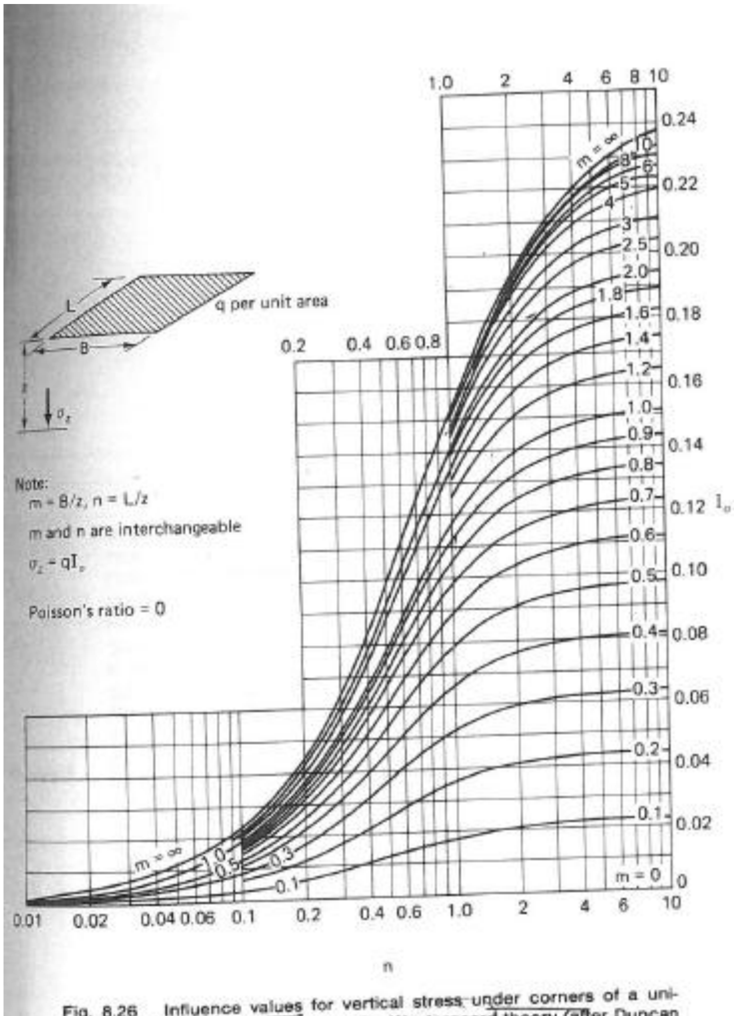

Fig. 8.26 Influence values for vertical stress under corners of a uniformly loaded rectangular area for the Westergaard theory (after Duncan and Buchignani, 1976).