State of Utah
GARY R. HERBERT
Governor
GREG BELL
Lieutenant Governor

Department of
Environmental Quality
Amanda Smith
Executive Director
DIVISION OF RADIATION CONTROL
Rusty Lundberg
Director

June 7, 2013

Sean McCandless
Director of Compliance and Permitting
EnergySolutions
423 West 300 South, Suite 200
Salt Lake City, UT 84101

Subject: Round 1 Request for Information regarding Updated Site-Specific Performance Assessment, dated October 8, 2012. Radioactive Material License (RML) UT2300249

Dear Mr. McCandless:

This cover letter introduces the attached Interrogatory – Round 1 request for information (RFI) from the Utah Division of Radiation Control (DRC) to Energy*Solutions* (the Licensee) regarding the Licensee's Updated Site-Specific Performance Assessment (PA), dated October 8, 2012. This RFI specifically addresses DRC concerns with a newly proposed cover system for the Class A Waste (CAW) Embankment at the Clive facility as well as the processed cation-exchange resin waste proposed to be transported to, and disposed of within the CAW embankment. The RFI focuses on a number of issues that must be addressed before the results of the PA can be fully evaluated.

Among other concerns, the DRC seeks to ensure that, in accordance with Utah's performance assessment rule [UAC R313-25-8(1)], low-level radioactive waste (LLW) not previously analyzed by the U.S. Nuclear Regulatory Commission (U.S. NRC) in 10 CFR Part 61 is evaluated with respect to potential impacts to the environment or to human health or safety prior to its disposal at the Energy*Solutions*' Clive Disposal Facility.

One type of LLW not previously analyzed when 10 CFR Part 61 and R313-25-8 were formulated is cation-exhange resin waste processed and packaged during large-scale blending and processing operations currently performed at the Studsvik facility in Erwin, Tennessee. It is noted that the Utah Board of Radiation has determined that the Licensee must conduct a new PA and that this PA must be approved by the DRC Director (Director) before the Licensee can dispose of additional waste beyond the 40,000 cubic feet per year authorized in DRC letter dated December 12, 2011. The PA must follow up-to-date U.S. NRC guidance (e.g., that found in NUREG 1573). The Licensee is acknowledged as having submitted an initial version of the PA in an effort to meet this requirement. The attached DRC RFI (i) reviews and comments on selected portions of the PA, (ii) provides relevant regulatory, rule-based and scientific and engineering references, and (iii) requests the Licensee to provide additional information and changes in the modeling that will be needed prior to final approval of the PA by the Director.

In addition to an evaluation of performance in connection with receipt and storage of large quantities of processed LLW from Studsvik facility, this RFI also evaluates portions of the PA dealing with the newly proposed CAW embankment evapotranspirative cover system, described for the first time by ES in the submitted PA. This cover system differs in substantive ways from the rip-rap cover system previously approved by the DRC for the CAW embankment.

This RFI specifically comments on and requests additional information for the following topics:

- codes, regulations and law
- waste and source term
- erosion
- biointrusion by mammals
- plant cover, model plant parameters, and biointrusion by plant roots
- transpiration
- evaporation
- freezing of the radon barrier
- capillary barrier
- hydraulic conductivity, infiltration and flow
- air exposures
- other modeling issues
- inadvertent intruder analysis
- miscellaneous topics

Based on the impacted this PA submittal, review and approval has on the license renewal application submitted in October, 2012, the DRC recommends the Licensee respond to this RFI within 90 days from the date of receipt. If after reviewing the RFI the Licensee would like additional time, please let me know. If there are other questions, please contact either myself or David Edwards at (801) 536-4250.

Sincerely,

John Hultquist

John Hultquist, LLW Licensing Manager
Division of Radiation Control

JH/DAE:dae

Enclosure

UTAH DIVISION OF RADIATION CONTROL

ENERGY*SOLUTIONS*, LLC.
CLIVE, UTAH
LOW-LEVEL RADIOACTIVE MATERIAL LICENSE (RML UT2300249)
UPDATED SITE-SPECIFIC PERFORMANCE ASSESSMENT
OCTOBER 8, 2012

REQUEST FOR INFORMATION

JUNE 7, 2013

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

^{137}Cs	Cesium-137
^{60}Co	Cobalt-60
1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
ALARA	As low as reasonably achievable
amsl	Above mean sea-level
BLM	U.S. Department of Interior Bureau of Land Management
Bq	Becquerel
C	Celsius
CAW	Class A West embankment
CEC	Cation exchange capacity
CFR	Code of Federal Regulations
Ci	Curie(s)
cm	Centimeter(s)
Cr	Coefficient of runoff, or runoff coefficient
Cs-137	Cesium-137
CTC	Cover Test Cell
CWR	Containerized waste facility
DOE	U.S. Department of Energy
DRC	Utah Division of Radiation Control
EPA	U.S. Environmental Protection Agency
ES	Energy*Solutions*
E_p	Fraction of potential evapotranspiration (PET) attributable to transpiration (Ritchie, 1972)
E_p	Fraction of potential evapotranspiration (PET) attributable to evaporation (Šimůnek et al., 2009)
E_o	Potential evapotranspiration (PET) (Ritchie, 1972)
ET	Evapotranspiration
EZD	Evaporative zone depth
F	Fahrenheit
ft	Feet
ft^3	Cubic feet
g	Grams
GBq	GigaBecquerel = 1,000,000,000 Bq
GWQS	Groundwater quality standards
H-3	Tritium (hydrogen-3)
HELP	A quasi-two-dimensional Hydrologic Evaluation of Landfill Performance model for conducting water balance analyses of landfills, cover systems, and other systems involving containment of solid waste
HYDRUS	Suite of modeling software used on the Windows platform for analysis of flow of water as well as of heat and solute transport in variably saturated porous media

i	hydraulic gradient
in	Inch(es)
ISL	In-situ leaching
K	Temperature in degrees Kelvin
K	Hydraulic conductivity
K_d	Distribution coefficient, or partition coefficient
Ksat	Saturated hydraulic conductivity
L	Length (a dimension)
L_{ai}	Leaf area index (Ritchie, 1972)
LAI	Leaf area index
LLW, LLRW	Low-level radioactive waste
M	Mass (a dimension)
m	Meter
n	Number of moles (wherein a mole equals 6.023×10^{23} entities)
n	Porosity
n_e	Effective porosity
N-63	Nickel-63
nCi	Nanocuries (10^{-9} Curies)
NUREG	U.S. NRC nuclear regulatory guide
p	Pressure
Pa	Pascals
PA	Performance Assessment
PAWG	Performance Assessment Working Group
pH	$-\log(H^+)$
PET	Potential evapotranspiration
ppm	Parts per million
p_{sat}	Saturation vapor pressure
PV_{sat}	Saturation vapor pressure
Q^{cap}	Capacity flow rate per unit depth
R	Universal gas constant
RESRAD	A suite of computer codes designed to assess human health and environmental risk at sites contaminated with radioactive materials and hazardous chemicals
RFI	Request for information
RML	Radioactive materials license
s	Second(s)
SAR	Sodium absorption ratio
SCF	Soil cover fraction
SI	Systéme International d'Unités (International System of Units)
Sr-90	Strontium-90
T	Time (a dimension)
T	Transmissivity
T	Temperature in degrees Kelvin (usually, but may be in degrees C)
T_c	Temperature in degrees Celsius (this document)
T_p	Fraction of potential evapotranspiration attributable to transpiration (Šimůnek et al., 2009)

$\tan^{-1}$	Inverse tan, or arctan, a trigonometric function
TBq	TerraBecquerel = 1,000,000,000,000 Bq
TDS	Total dissolved solids
THOR^{SM}	A process utilizing pyrolysis and steam reforming, patented by Studsvik, that, without incinerating radioactive and organic waste to be treated, heats and reduces it
UAC	Utah Administrative Code
UNSAT	A model, originally built in 1972, for simulating flow of water in 2-D variably saturated porous media under conditions in which the Richards equation, coupled with root uptake of water, is applicable, and having the capability of employing any of several different boundary conditions
USGS	U.S. Geological Survey
U.S. NRC	United States Nuclear Regulatory Commission
V	Volume
yr	Year(s)

Request for Information
Energy*Solutions*
Utah Low-Level Radioactive Material License (RML UT2300249)
Updated Site-Specific Performance Assessment
Dated October 8, 2012

1.0 INTRODUCTION

The Utah Division of Radiation Control (DRC) is seeking to ensure that, in accordance with Utah's performance assessment rule [UAC R313-25-8(1)], low-level radioactive waste (LLW) not previously analyzed by the U.S. Nuclear Regulatory Commission (U.S. NRC) in 10 CFR Part 61 is evaluated with respect to potential impacts to the environment or to human health or safety prior to its disposal at the Energy*Solutions* (Licensee) Clive Disposal Facility.

UAC R313-25-8(1) is quoted as follows:

> R313-25-8. Technical Analyses.
>
> (1) *The licensee or applicant shall conduct a site-specific performance assessment and receive Director approval prior to accepting any radioactive waste if:*
>
> *(a) the waste was not considered in the development of the limits on Class A waste and not included in the analyses of the Draft Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste," NUREG-0782. U.S. Nuclear Regulatory Commission. September 1981, or*
>
> (b) the waste is likely to result in greater than 10 percent of the dose limits in R313-25-19 during the time period at which peak dose would occur, or
>
> (c) the waste will result in greater than 10 percent of the total site source term over the operational life of the facility, or
>
> *(d) the disposal of the waste would result in an unanalyzed condition not considered in R313-25.* [emphasis added]

One type of LLW not previously analyzed when10 CFR Part 61 and R313-25-8 were formulated is waste processed and packaged during large-scale blending and processing operations, such as at the Studsvik facility in Tennessee. It is noted that the Utah Board of Radiation has determined that the Licensee must conduct a new Performance Assessment (PA) and that this PA must be approved by the DRC Director (Director) before the Licensee can dispose of additional waste of this type at the facility. The PA must follow up-to-date U.S. NRC guidance (e.g., that found in NUREG 1573). The Licensee is acknowledged as having submitted an initial version of the PA in an effort to meet this requirement. This DRC Interrogatory (i) reviews and comments on the PA, (ii) provides relevant regulatory, rule-based and scientific and engineering references, and (iii) requests the Licensee to provide additional information and changes in the model and PA that will be needed prior to final approval by the Director.

In addition to an evaluation of performance in connection with receipt and storage of large quantities of processed LLW from Studsvik facility, this set of Interrogatories also evaluates performance of a newly proposed Class A West (CAW) embankment evapotranspirative cover system, described for the first time in the submitted PA. This cover system differs in substantive ways from the rip-rap cover system previously approved by the DRC for the CAW embankment.

Different sections of the PA deal frequently with a particular issue or point previously referenced within the PA, in some cases, referenced many times, although periodically in somewhat different contexts. This results in some repetition, although new information may be provided with some of these scattered and re-visited topics. While it would be possible in the present Interrogatory for the DRC to mirror the structure of the PA, and respond to each concern as it arises in that document, such an approach would result in excessive redundancy, and in repeated framing of the context in which various issues arise, which tends to make the Interrogatory very long. In addition, it would make it difficult to find all threads dealing with a particular topic. The DRC has chosen instead to arrange its comments in this Interrogatory topically, while still referring to the original sections of the PA. This has the effect of shortening the set of interrogatories, and providing for a more logical flow.

Interrogatory comments on a given section of the PA include (i) one or more PA section numbers, (ii) a quotation or paraphrase of each statement made in the relevant sections of the PA along with associated DRC interrogatories, (iii) a basis for each interrogatory, (iv) a listing of applicable rules and regulations, and (v) citations of pertinent regulatory guidance documents. Scientific or engineering research publications are generally cited within the comments themselves, and references are provided at the end of the Interrogatories. In instances where, in the opinion of the DRC, either the full basis is relatively lengthy or the full basis contains a high degree of technical detail, the full basis may be divided into two parts. In general, the first is a short, relatively non-technical summary of the basis for the interrogatory, and the second is an extended technical basis for the interrogatory. The short, relatively non-technical summary should be useful to reviewers not having a highly technical background in the areas being discussed. The listed references to rules and regulations, the cited guidance at the end of each section, and the research publications cited within the text and referenced at the end of the document are also intended to be considered implicitly along with any technical detail as part of the overall basis for each interrogatory.

2.0 CODES, REGULATONS AND LAW

SECTION: 1.4.1

INTERROGATORY STATEMENT(S): Under R313-15-401: Periods of Performance, the following statement is made on Page 1-3: "1. Licensees shall determine the peak annual total effective dose equivalent to the general public within 1,000 years after decommissioning." [UAC R313-15-401(4)] UAC R313-15-401(4) appears to be misquoted. Please quote it correctly in its entirety.

SUMMARY OF BASIS FOR INTERROGATORY: A comparison of the statement above and UAC R313-15-401(4) shows inconsistencies.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The PA statement above does not accurately quote rule R313-15-401(4). The following is an excerpt from the actual rule, modified such that words or letters in the actual rule that differ from words or letters in the PA version are included in bold and italics, and extraneous or inappropriately added words or letters found in the PA version are indicated by brackets: "***when calculating the total effective dose equivalent to the average member of the critical group, the*** licensee ***[. .]*** shall determine the peak annual total effective dose equivalent ***dose expected*** within ***the first*** 1000 years after decommissioning."

In the PA version below, words or letters shown in bold are extraneous additions to the actual rule, and changes or omissions to the rule in words or letters are shown by italics or brackets: "Licensee*s* shall determine the peak annual total effective dose equivalent ***[. . .] to the general public*** within ***[. . .] [. . .]*** 1,000 years after decommissioning." [UAC R313-15-401(4)]

The discrepancies between the misquotation in the PA text relative to UAC R313-15-401(4) need to be remedied.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 1.4.1 (cont'd)

INTERROGATORY STATEMENT(S): In Section 1.4.1.3 on Page 1-3, groundwater classifications and limits on groundwater contamination are discussed. Reference is made to (i) "the Ground Water Quality Discharge Permit, derived from Ground Water Quality Standards listed in UAC R317-6-2, (ii) "Class IV, (iii) "saline ground water" and (iv) "protection limits as 'non-degradation standards.'" The DRC does not fully understand the references to these terms made in Section 1.4.1.3 and requests that the Licensee clarify the meanings of all terms used in this section and also make explicit any arguments or requests that the Licensee is attempting to make.

BASIS FOR INTERROGATORY: Currently, the Licensee is held to ground water protection levels (GWPLs) derived from Ground Water Quality Standards (GWQS, UAC R317-6-2) as found in ground water quality discharge Permit No. UGW450005, with GWPLs listed for

* field and inorganic parameters

* dissolved metals

* organic parameters

* inorganic/metal parameters

* radiologic parameters – alpha emitters, beta and gamma emitters, and combined

These are found in tables in the Permit for

* Class A, Class A North, and Evaporation Pond wells (Table 1A)

* 11e.(2) wells (Table 1C)

* Mixed waste cells (Table 1E)

Exceptions are listed in Tables 1B, 1D and 1F

Mobile and non-mobile radionuclides are assigned in UAC R317-6 a performance standard of 500 years. However, a more recent rule in UAC R313-25-8(5)(a) assigns a standard of 10,000 years.

Policy regarding a possible change of classification of groundwater to Class IV is currently under review by state regulators. Please indicate this information in the PA, unless the policy decision is made prior to approval of the PA, in which case it should be reported in detail. Please define explicitly the meaning of "non-degradation standards" as intended in this section of the PA, and explain clearly how the Licensee is proposing to apply this term to groundwater at the site.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R317-6.

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 1.4.1 (cont'd)

INTERROGATORY STATEMENT(S): On Page 1-3, it says that "the limitation of this comparison is of concentration (not dose) for a period of 500 years following embankment closure, and of projected peak groundwater well concentrations for each individual radionuclide for a time period of 10,000 years following embankment closure. [UAC R317-6]" Please correct the reference, or provide a justification for it.

BASIS FOR INTERROGATORY: There is nothing that the DRC has found in UAC R317-6 that addresses "projected peak groundwater well concentrations for each individual radionuclide for a time period of 10,000 years following embankment closure." Information pertinent to this topic, however, can be found in UAC R313-25-8(5)(a).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(5)(a)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 1.4.2.1

INTERROGATORY STATEMENT(S): The Licensee writes in the PA that "the approach to dose assessment suggested by UAC R313-25-19 is now dated" and argues (incorrectly, as shown later in this document) that guidance from the NRC should override this rule.

Please rewrite section 1.4.2.1 to indicate conformity with UAC R313-25-19, entitled, Protection of the General Public, and the Federal regulation 10 CFR 61.41, entitled, Protection of the general population from releases of radioactivity, both of which read as follows:

> Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.

BASIS FOR INTERROGATORY: The Licensee states that, based on NRC guidance, the rule does not apply. However, NRC guidance, even if interpreted correctly, does not override rules or regulations.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-19; 10 CFR 61:41

REGULATORY GUIDANCE REFERENCE(S): N/A

SECTION: 1.4.2.2

INTERROGATORY STATEMENT(S): On page 1-5, the Licensee states:

"...and contacting the waste (which is in excess of the UAC R313-25's Class A requirements)."

Please correct the PA to remove the implication that the waste will exceed Class A limits.

BASIS FOR INTERROGATORY: Since the parenthetical statement beginning with "which is in excess of the UAC R313-25's Class A requirements" directly follows the word "waste", it strongly implies, based on standard English usage, that the Licensee is saying that the waste stored at Clive exceeds the Class A requirements found in UAC R313-25. This, of course, would not be the case. Therefore, the Licensee should revise this statement in the PA to show that Utah restrictions against receipt, storage and disposal of Class B and Class C waste will not be violated.

APPLICABLE RULE(S) OR REGULATION(S): UCA 19-3-103.7(1)

REGULATORY GUIDANCE REFERENCE(S): None Applicable. Restrictions against storage of Class B and Class C Waste are unique to the State of Utah.

3.0 WASTE AND SOURCE TERM

SECTION: 1.1

INTERROGATORY STATEMENT(S): On Page 1.1, the Licensee states:

> On 14 February 2011, Energy*Solutions* requested concurrence from the Utah Division of Radiation Control (the Division) that previous licensing activities allowed for the receipt and disposal of blended ion-exchange resin waste on a large-scale at the Clive facility (Shrum, 2011). The Division reviewed Energy*Solutions*' analysis supporting this request and determined that Energy*Solutions* could receive blended waste up to 40,000 cubic feet per year. However, in order to receive blended waste at volumes greater than 40,000 cubic feet per year, Energy*Solutions* would be required to conduct a new performance assessment analyses that include "prediction of nuclide concentration and peak dose (at the time peak dose would occur) using updated dose conversion factors, and a suggested model time frame of 10,000 years, as well as any need to revisit/update the waste source term, receptor and exposure pathways" (Lundberg, 2011).

In order to evaluate the submitted Performance Assessment (PA) and analyses contained therein concerning prediction of nuclide concentration and peak dose, the DRC requires modifications to the contaminant fate and transport modeling process. Some issues that remain to be resolved are discussed in the DRC (2011) document entitled Technical Assessment: Energy*Solutions* Proposed Disposal of Low-Level Radioactive Waste Generated by SempraSafe Treatment Process. This document summarizes a number of important issues and sets forth corresponding objectives that should be met in the PA. These have not yet been fully addressed by the Licensee. As indicated elsewhere within this review, numerous changes are required within the existing PA model. Once these changes are made, there will likely be a need to address multiple isotopes, not just the single isotope addressed in the current model. With greater infiltration, a model may show faster contaminant transport, with consequent breakthrough for a number of isotopes within the 10,000-year modeling period.

DRC (2011) describes several of the pertinent modeling problems. The licensee needs to address these. These problems include the following:

> "The horizontal domain of the July 19, 2000 ES PA model also simulated 24 isotopes, but many are different from those found in the NRC DEIS. Comparison shows that 17 nuclides from the NRC DEIS were omitted from the horizontal domain of the ES PA

model, as indicated in italics in Table 1, below. Most of the 17 omitted nuclides are not mobile in groundwater, and therefore are of little consequence to Clive embankment PA predictions. However, the same may not be said for 2 others not previously analyzed: carbon-14 (C-14), and neptunium-237 (Np-237). Two others, uranium-235 (U-235) and uranium-238 (U-238), may also need to be considered, in that they are somewhat mobile in oxidizing groundwater environments."

"The vertical domain of the July 19, 2000 ES PA model did consider all of the 24 isotopes NRC deemed important in its 1981 DEIS. However, additional work should be undertaken to re-examine the Clive horizontal domain predictions for at least 4 isotopes known to be mobile or somewhat mobile in groundwater (C-14, Np-237 and U-235 and U-238)."

"The effect of the new peak dose requirement in UAC R313-25-8(1)(b) on the Utah PA Standard that DRC previously applied to the Class A and Class A North Cells, is currently unknown, but can be examined during new PA analysis. New PA analysis is warranted in that after approval of the July, 2000 ES PA model, the NRC published new scientific guidance for PA modeling that has yet to be applied to the Clive facility. New PA modeling with this guidance will provide an opportunity to examine the effects of waste with elevated isotope source term concentrations with respect to disposal facility and site performance."

"More current human dosimetry research (and DCFs) . . . should be considered in determining GWQS for the Clive facility . . . "

"*Did the July 19, 2000 ES PA model predict peak nuclide groundwater concentrations (pCi/l) at the POC wells? If so, will the proposed SempraSafe waste have concentrations that are more than 10% of said ES PA source term?* Answer: peak concentrations were available for many nuclides in the vertical domain of the ES PA. However the POC well is found in the horizontal domain, and is currently considered the potential point of exposure to the public. DRC review of the ES PA horizontal model predictions shows peak concentration (and hence peak dose) for only 1 of the 90 nuclides simulated, rhenium-187 (Re-187). . . UAC R313-25-8(1)(c): (1) The licensee or applicant shall conduct a site-specific performance assessment and receive Executive Secretary approval prior to accepting any radioactive waste if: ... (c) the waste will result in greater than 10 percent of the total site source term over the operational life of the facility, or"

"Six examples of mobile isotopes in this situation are found in Table 3, below (Al-26, Ca-41, Cl-36, K-40, Re-187, and Tb-158). This finding reinforces the need to consider PA model inputs and results to establish maximum isotope activity inventory limits for each disposal cell (and for the site), in order to determine compliance with UAC R313-25-8(1)(c)."

"However, Table 4 also shows 11 other isotopes identified in the recent EPRI report were omitted from analysis in the horizontal domain of the July, 2000 ES PA model. Of these 11, six have half-lives that range from 30 to 76,000 years, and should be considered for analysis in a new PA model, including: C-14, Ni-59, Ni-63, Nb-94, Cs-137, and Pu-238. Here again, the opportunity to improve the ES PA model is important in order to assess the long term performance of these and other nuclides at the Clive disposal site."

> "DRC staff compared this ES information and found about 25 longer-lived isotopes have been disposed at Clive, and were not analyzed in the approved PA report. These same 24 unanalyzed isotopes were also not considered in the 1981 NRC DEIS. For details, see Table 5, below. While it is currently unclear if all or any of these 24 unanalyzed isotopes will actually be disposed as part of the SempraSafe waste, the Executive Secretary has decided to err on the side of conservatism until ES is able to successfully demonstrate otherwise. In summary, these 24 un-analyzed isotopes deserve consideration in a new PA model in order to determine if any pose a concern for long-term facility performance."

BASIS FOR INTERROGATORY: As established in DRC (2011), substantive changes in the PA model need to be undertaken, in part to follow UAC R313-25-8(1), and in part to be consistent with current NRC guidance (NRC, 2000). These changes will become important when modifications to the model requested elsewhere in this review are made, such as accounting for large expected changes in hydraulic conductivity of the cover system after it is built (e.g., see Benson et al., 2011). While the existing model does not indicate breakthrough of any radionuclides within the 10,000-year modeling timeframe, changes to the model to account for multi-order-of-magnitude increases in hydraulic conductivity will likely change that conclusion. At that point, inclusion of additional isotopes, as described in DRC (2011) will become important, and they need to be included in the model.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(1)

REGULATORY GUIDANCE REFERENCE(S): US NRC (2000)

SECTION: 1.1 (cont'd)

INTERROGATORY STATEMENT(S): On Page 1.1, the Licensee states:

> However, in order to receive blended waste at volumes greater than 40,000 cubic feet per year, Energy*Solutions* would be required to conduct a new performance assessment analyses that include "prediction of nuclide concentration and peak dose (at the time peak dose would occur) using updated dose conversion factors, and a suggested model time frame of 10,000 years, as well as any need to revisit/update the waste source term, receptor and exposure pathways" (Lundberg, 2011).

In order to assess the appropriateness of emplacement of blended cation-exchange resin waste in the Clive embankment, the DRC requires additional information regarding this waste source. Please provide as complete as possible a summary of estimated values for all potentially significant physical and chemical properties of the blended waste, and address, in detail, the variability and uncertainty associated with these properties, as is required under current NRC guidance.

Physical properties would include such factors as density, moisture content, organic carbon content, percent clay, particle size distribution, porosity and hydraulic conductivity. Other physical properties, where available, should be described as well. The anticipated forms and condition of the waste should be described in the PA. Containers and backfill also need to be described in detail. Stability should be addressed in terms of expected lifetime of the forms and how instability at some point is accounted for in modeling work.

The chemical and geochemical environments of the waste and materials around the waste need to be described, with particular reference to any factors potentially affecting transport. Discuss all factors potentially affecting rates of migration in all affected environmental media (e.g., contaminated zone, vadose zone, and saturated zone). Values of pertinent variables need to be estimated, where feasible, based on scientific or engineering assessments. Chemical properties and conditions that need to be estimated include diffusion rates, tortuosity, corrosion rates, soil-water partition information (e.g., K_ds, or batch-test isotherm data) and leaching rate constants, pH, Eh (or other redox parameter(s)), ionic strength, buffer capacity, chemical composition (including presence of non-radioactive metals or organics), speciation and complexation.

In estimating values for variables affecting the source term, both sensitivity analysis and uncertainty analysis should be conducted. Unless the most conservative parameter values are used in a deterministic model, from which a single set of outcomes will be obtained, probabilistic modeling is required. A Monte Carlo approach with a large number of model realizations may be appropriate. Tables and graphs illustrating geometric mean values, geometric standard deviations, and 75% confidence values for all significant outcomes should be provided. Where possible, field data should corroborate or justify the range and probability of model parameter values chosen.

APPLICABLE RULE(S) OR REGULATION(S): UAC Rule R313-15-1009(2)(a); R313-25-7(6); 10 CFR 61.2, 10 CFR 61.20; 10 CFR Ch. 1 (1-1-06 Edition), Part 20, App. G.

REGULATORY GUIDANCE REFERENCE(S): NUREG/CR-1573 [US NRC (2000)]; NUREG/CR-6758

SECTION: 1.3 (cont'd)

INTERROGATORY STATEMENT(S): On Page 1.1, the Licensee quotes part of a DRC statement speaking of a "need to revisit/update the waste source term . . . (Lundberg, 2011)".

Please provide the following:

- A listing of all variables commonly used to describe the source of contamination, i.e., the waste. This list may include, for example, those variables listed in the interrogatory above.
- Please identify which source or waste-related variables are not used in the existing PA model, and justify why it is not necessary to explicitly account for them.

- For all variables used in the model to describe the waste or the source term, please justify the values chosen for modeling.
- For those variables used in the model to describe the waste or the source, please indicate the possible range of values that might exist for that variable, given the uncertainties associated specifically with the site and the waste.
- Conduct a sensitivity analysis to determine which waste or source variables to which the model is most sensitive.
- Conduct an uncertainty analysis for the model applied to all sensitive waste or source variables.

BASIS FOR INTERROGATORY: The DRC cannot determine how well the model may predict future radionuclide concentrations and doses until it understands the variables of the model describing the waste or source of the contamination, how sensitive the model is to these variables, and how much variability may exist in their values.

APPLICABLE RULE(S) OR REGULATION(S): UAC Rule R313-15-1009(2)(a); R313-25-7(6); 10 CFR 61.2, 10 CFR 61.20; 10 CFR Ch. 1 (1-1-06 Edition), Part 20, App. G.

REGULATORY GUIDANCE REFERENCE(S): NUREG/CR-1573 [US NRC (2000)]; NUREG/CR-6758

SECTION: 1.3

INTERROGATORY STATEMENT(S): In Section 1.3, entitled Blended Ion-Exchange Resins, the term "Reformed residue" is used to describe the end product of the THOR^{SM} process, which is the same type of material that is disposed of in the Clive facility. Please use a different term other than "residue" in the PA and elsewhere in describing the waste. The term "residue", like the term "residual", is deemed by the DRC to be inappropriate for use in the state of Utah to describe thermally processed waste. Please replace the term "reformed residue" with a more appropriate term, e.g., processed ion-exchange resin waste.

BASIS FOR INTERROGATORY: The DRC has, in essence, previously addressed this issue. The following is an excerpt from a letter from the DRC to Generator Site Access (GSA) Permit holders and also provided to Energy*Solutions*, dated March 22, 2012:

> To Whom It May Concern:
>
> It has come to the attention of the Utah Department of Environmental Quality, Division of Radiation Control (DRC) that some Generator Site Access Permittees (GSAPs) have been ***describing LLRW***, which has been processed in an incinerator or other ***thermally treated*** processes, ***as residual waste***. The DRC has researched the rationale for this practice and has determined that ***this practice and description is not appropriate.***

> Some GSAPs reference Volume 60 of the Federal Register (FR) 3rd column of page 15,652, where the Nuclear Regulatory Commission (NRC) states "contaminated ash should be considered residual waste assigned to the processor." However, the next sentence further clarifies this statement: "If this interpretation is agreed to by the appropriate State or Compact authorities." The State of Utah does not agree with the interpretation offered by the NRC. Moreover, the practice is explicitly prohibited in our Generator Site Access rules Utah Admin. Code R313-26-4(4) . . . [emphasis added]

This latter rule states

> A Waste Collector, Waste Processor, or Waste Generator shall ensure all radioactive waste contained within a shipment for disposal at a land disposal facility in the state is traceable to the original generators and states regardless of whether the waste is shipped directly from the point of generation to the disposal facility.

The terms residue and residual are closely related. TheFreeDictionary.com, for example, in defining residual as an adjective, says,

> **re·sid·u·al**
> adj.
> 1. Of, relating to, or characteristic of a residue.
> 2. Remaining as a residue.

Both terms, "residual waste" and "reformed residue", are considered unacceptable descriptions for LLW received, stored or disposed of in the State of Utah.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-26-4(4)

REGULATORY GUIDANCE REFERENCE(S): Letter from the DRC to Generator Site Access (GSA) Permit holders, dated March 22, 2012: copy provided to Energy*Solutions*.

SECTION: 1.3 (cont'd)

INTERROGATORY STATEMENT(S): On Page 1-2, the licensee states, "The end result of the process is a homogeneous and environmentally-stable waste." Please define the term "environmentally stable," and demonstrate, using actual data, that the result of the THOR^{SM} process is environmentally stable.

BASIS FOR INTERROGATORY: The term "environmentally stable" could mean different things to different people and needs explanation. The assertion that the result of the THOR^{SM} process is environmentally stable is not supported within the current PA.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 1.3 (cont'd)

INTERROGATORY STATEMENT(S): On Page 1-3 of the PA, it says that NRC staff members have stated, "NRC's new position is that large-scale LLRW blending may be conducted when it can be demonstrated to be safe. (NRC, 2010)." Please fix the reference.

SUMMARY OF BASIS FOR INTERROGATORY: The reference is wrong.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: This quote above does not seem to be found in the document referenced in the PA as (NRC, 2010), identified in the list of references in the PA as the following: NRC. "Blending of Low-Level Radioactive Wastes" (SECY-10-0043) U.S. Nuclear Regulatory Commission, 7 April 2010.

It appears after doing a Web search that the quotation in reference is found, rather, in http://pbadupws.nrc.gov/docs/ML1100/ML110050122.pdf, where the quotation is given in full.

It is noted that LLW can be blended on a large scale "when it can be demonstrated to be safe." Also, in regard to large-scale LLRW blending, the U.S. NRC (2010) states,

> One type of waste being considered for blending is ion exchange resins from nuclear power plants, which can be blended into a relatively uniform mixture. These resins account for about half of the volume of Class B and C waste generated each year. Resins are also the focus of a waste processor's expanded LLW blending at its facility in the State of Tennessee. The waste processor has received approval for testing from its Agreement State regulator, and is continuing to develop a process for large-scale blending. (p. 2)

This statement appears to be referencing the Studsvik facility where "large-scale blending" is taking place.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); U.S. NRC (2010); http://pbadupws.nrc.gov/docs/ML1100/ML110050122.pdf

---

SECTION: NA

INTERROGATORY STATEMENT(S): No reference is provided in the PA in regard to the "sum of the fractions rule". Please describe the sum of the fractions rule in the PA and explain how it applies to waste disposed of at Clive.

SUMMARY OF BASIS FOR INTERROGATORY: The sum of the fractions rule plays an integral role in evaluating what kinds of blended and processed LLW can be disposed of safely at the Clive Facility. It is an important aspect of assessing disposal of blended and processed waste as Class A waste. Yet the sum of the fractions rule is not described or applied in the PA.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: It is noted that one of the requirements for defining Class A waste, a topic of major interest in regard to this PA dealing with the disposal of blended waste at the Clive Facility, is referred to as the "sum of the fractions rule." This rule applies to any shipment of radioactive waste. The average concentration of each individual nuclide in that shipment that is listed in R313-15-1009 Tables 1 and 2 is evaluated and then divided by the Class A limit for that nuclide, as found in Tables 1 and 2, to provide its fraction. The fractions for all listed nuclides are similarly calculated and then those within a particular table are summed. For the waste to be considered as a Class A waste, the sum must be equal to or less than unity (1.00).

A sum of the fractions rule assessment must be made for each shipment of LLW containing blended waste and then reported to the DRC.

It is important to recognize that the sum of the fractions rule may at times limit activity concentrations (expressed, for example, in Ci/m^3) in waste disposed of at Clive more so than what is specified in Tables 1 and 2 of R313-15-1009 for individual nuclides alone.

By way of illustration, consider two hypothetical shipments of LLW. The first shipment of LLW contains radioactive material consisting solely of tritium (H-3). H-3 is present at 30.00 Ci/m^3, which is under the limit of 40 Ci/m^3 specified in Table 1 of R313-15-1009. The total activity concentration of the shipment is 30.00 Ci/m^3.

The second shipment contains only H-3 and Cs-137. H-3, at 15.00 Ci/m^3, is present under the limit of 40.00 Ci/m^3 specified in Table 1 of R313-15-1009. Likewise, Cs-137, at 0.75 Ci/m^3, is present under the limit of 1.00 Ci/m^3 specified in Table 1 of R313-15-1009. The total activity of the second shipment is 15.75 Ci/m^3.

Yet the second shipment, containing only 52.5% of the total activity of the first, and having only half the H-3 activity of the first (and with Cs-137 activity being well below the Class A limit shown in Table 1 of R313-15-1009), cannot be disposed of at the Clive facility. Yet the first shipment can be disposed of there.

Why can the second shipment not be disposed of at Clive? It is because the sum of the fractions for the second shipment would be 1.125, greater than 1.0, and thus outside of the Class A sum-of-the-fractions limit. By contrast, the sum of the fractions for the first shipment would be 0.75, within the Class A sum-of-the-fraction limit.

APPLICABLE RULE(S) OR REGULATION(S): R313-15-1009, in particular 1c(iv); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: NA

INTERROGATORY STATEMENT(S): Please provide an analysis of the potential for generation of hydrogen from buried metals under the proposed evapotranspirative cover with subsequent fire or explosion.

BASIS FOR INTERROGATORY: Zero-valent metals, which may be present in the form of depleted uranium blocks or powder or in the form of iron containers, are known to produce hydrogen gas when reacting with water under anoxic conditions. Anoxic conditions could potentially form in containers with intact bottoms and sides that fill with water once covers, in long contact with moisture, corrode. Handley-Sidhu et al. (2009) describe "hydrogen produced by DU corrosion" in anoxic environments (see also Laue et al., 2004). Reactions with other metallic substances, such as those found in metal containers or contaminated metal scrap, may also produce hydrogen in anoxic or environments. For example, Liu and Neretnieks (2002) report that hydrogen is produced in large amounts by iron corroding under anoxic conditions.

Sinkov et al. (2010) indicate that uranium metal in sludge at Hanford releases hydrogen due primarily to a corrosion reaction with water. Gas bubbles associated with hydrogen release are reported to have been visible. The bubbles also contain radioactive gases associated with uranium corrosion. They state that, "Because H2 is flammable, its release into the gas phase above K Basin sludge during sludge storage, processing, immobilization, shipment, and disposal is a concern to the safety of those operations."

They give the chemical reactions that yield the hydrogen in the following description:

> Uranium metal is highly electropositive, reacting with water to produce hydrogen radicals (H·) and UO2. The reactive hydrogen radicals can combine to form H2:
>
> U + 2 H2O → UO2 + 4H· → UO2 + 2 H2 Reaction 1.1
>
> The H2 dissolves in water and, upon water saturation, forms bubbles that are released into the gas phase. The hydrogen radicals or H2 also can react with uranium metal to form UH3:
>
> U + 3H· (or 1.5 H2) → UH3 Reaction 1.2
>
> The UH3 then can react with water to liberate hydrogen radicals or H2:
>
> UH3 + 2 H2O → UO2 + 7 H· (or 3.5 H2) Reaction 1.3

The process, as a function of time, is depicted as follows:

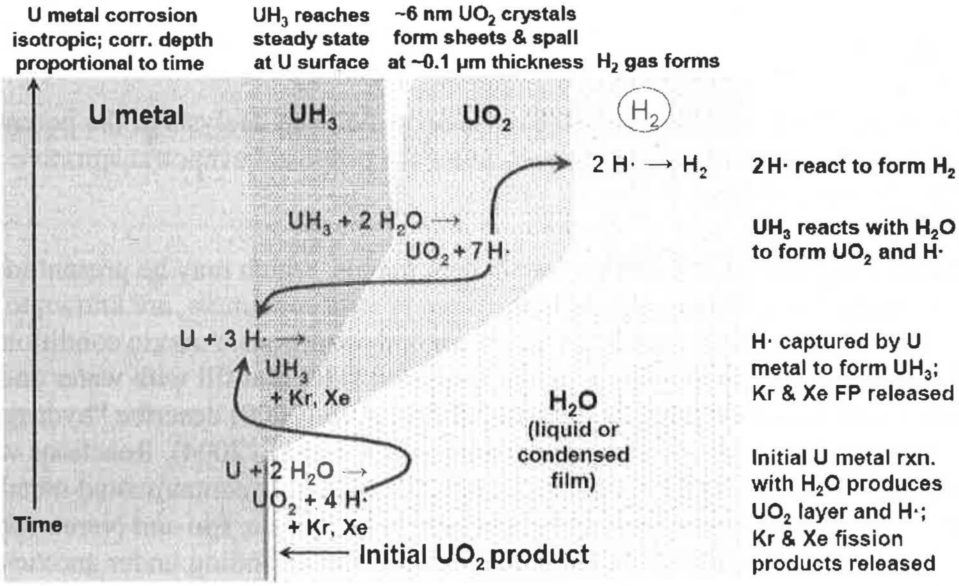


Figure 1.1. Uranium Metal Corrosion Mechanism in Anoxic Water with Time in the Vertical Axis (liquid or H_2O vapor; rate in H_2O vapor proportional to [relative humidity]$^{1/2}$)

Water passing down through a thick column of bulk waste (e.g., 50-70 feet) in an embankment at Clive is expected by the DRC to be largely depleted of oxygen at the base of the column due to biological activity in upper areas using up the oxygen. Sources of organic matter for carbon and a source of energy for microbes would include organic matter in soil and DAW, among other things.

Hydrogen production rates are expected to be related to uranium corrosion rates. Uranium corrosion rates in the presence of anoxic water in various tests are indicated by Sinkov et al. (2010) to be relatively high, near 0.01 g/cm^2/hr, at temperatures around 14°C. Their graph of corrosion rates vs. temperature does not extend to lower temperatures.

The potential for hydrogen release and build up to a hazardous level in the Clive Class A West (CAW) embankment over tens, hundreds or thousands of years is currently little understood. The DRC accordingly asks the Licensee to conduct research and determine and demonstrate that zero-valent DU and other metals buried at Clive will not potentially generate hydrogen in sufficient quantities such that its accumulation under or within the proposed evapotranspirative cover system could pose a hazard of fire or explosion. Confinement, release, mixing with oxygen, and possibly an ignition source or spark of some kind would be factors affecting a potential hazard. Release could potentially occur from biointrusion, seismic activity, etc. An ignition source or spark may potentially arise from excavation, industrial activities, lightning, etc. Hydrogen can burn upon ignition at concentrations ranging from 4.1% to 74.5% in air. Hydrogen, on the other hand, is explosive when mixed with air at proportions of 15% to 59% and is ignited by spark or open flame. Methane, by contrast, has a flammability/explosive limit range of 5% to 15%.

Hydrogen gas can also spontaneously ignite (without open flame or spark). Gummer and Hawksworth (2008) describe spontaneous hydrogen ignitions based on 81 incident reports. A variety of explanations have been proposed for these phenomena.

APPLICABLE RULE(S) OR REGULATION(S): R313-15- 1009(2)(a)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

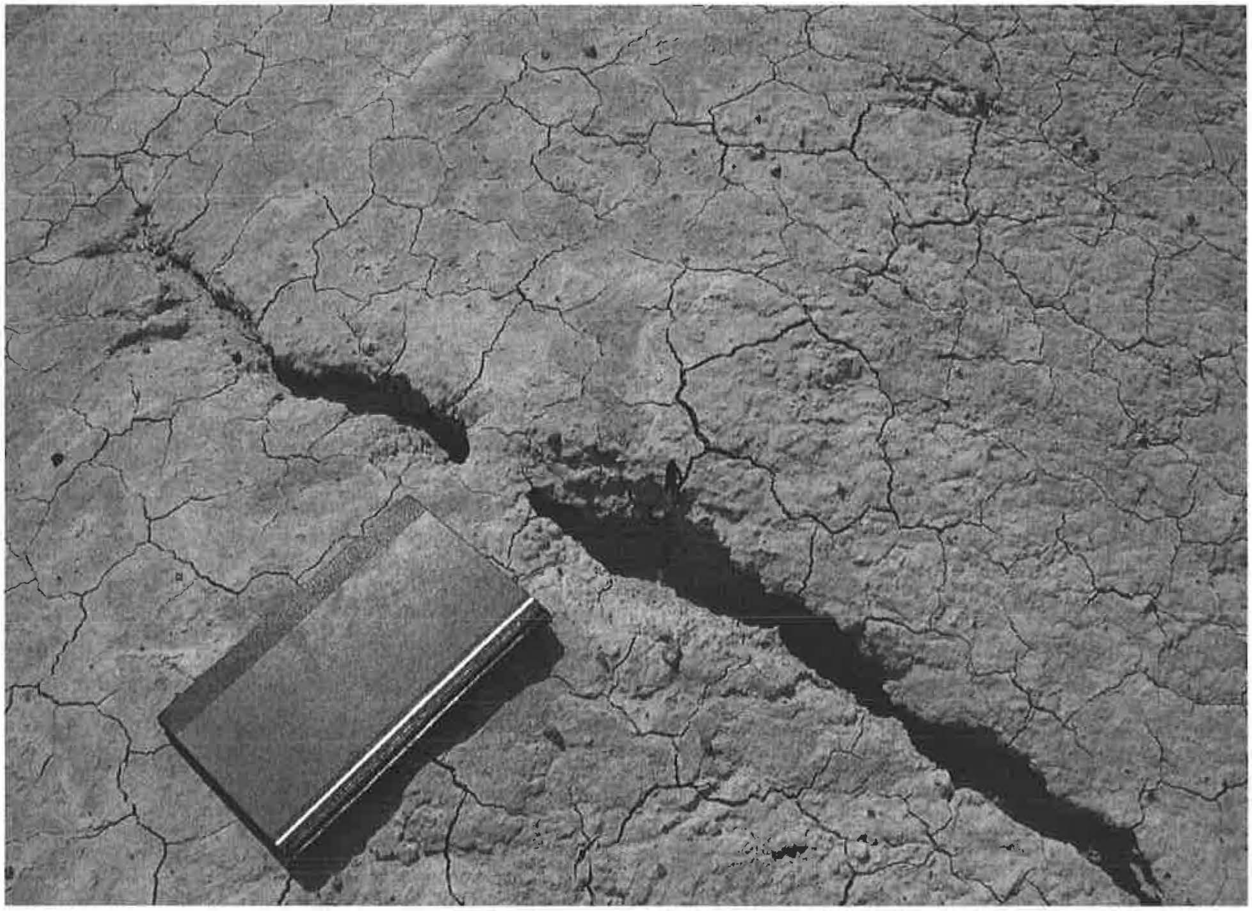
4.0 EROSION

SECTION: 2.2

INTERROGATORY STATEMENT(S): It is stated on Page 2-6 that "Long-term stabilization of the Embankment is accomplished through erosion control and flood protection."

The statement above that stabilization of the embankment is accomplished over the long-term using erosion control does not appear to be supported by existing data, as noted in the following photos. These photos show that existing erosion control for clay soils on site is in some places only partially effective, and that erosion control needs to be undertaken from year to year. Stabilization now does not necessarily indicate stabilization over time within the modeled timeframe (i.e., 10,000 years). Please either justify the statement above, or revise it to be consistent with existing data.

SUMMARY OF BASIS FOR INTERROGATORY: The DRC notes that soils at the site appear to develop rills and gullies every year. It is anticipated that, during a 10,000-year time period for modeling after site closure, the rills and gullies would grow in depth and length, potentially threatening, over time, the integrity of the embankment and exposing the waste. The following photos illustrate short-term development of rills and gullies at the site:



The photo above shows development of a rill several inches deep in clay/silt soil at Clive. Such rills appear to develop relatively quickly at Clive, and efforts are generally made at least annually to re-grade or otherwise remediate soils containing the rills. A pen and a notebook are presented for scale.

The photo above shows multiple rills developing on a sloped surface of clay/silt soil at Clive.

The photo above shows development of deeper rills and incipient gullies on a sloped surface of gravelly clay/silt soil at Clive.

It is noted that these rills and gullies develop on clay/silt soils on site relatively rapidly. Generally, the ones shown above develop within a year's time. As time goes on, rills and gullies tend to grow longer and/or deeper. It is not known how long or deep such gullies might become over longer periods of time up to 10,000 years.

Experts indicate the potential seriousness of erosion through a cover system and impoundments overlying contaminated material:

- Nelson et al. (1983) state, "The proper placement of rock riprap in ditches and on embankment slopes is *important to* dissipate the energy associated with flowing water and thus *prevent erosion that could lead to gullying and exposure of contaminated material.*"
- Abt et al. (1994) say, "*Gully intrusion into the cover is one of the greatest potential threats* to the long-term stability of an impoundment."
- "Research performed for the NRC staff (Nelson et al., 1983) has demonstrated that *if localized erosion and gullying occurs, damage to unprotected soil covers may occur rapidly, probably in a time period shorter than 200 years.*" - Johnson (2002) [Emphasis added]

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2 (cont'd)

INTERROGATORY STATEMENT(S): While the licensee claims on Page 2-6 that "Long-term stabilization of the Embankment is accomplished through erosion control and flood protection", the licensee must demonstrate through acceptable experiments and/or mathematical or numerical modeling that the proposed soil/gravel admixture with only 15% gravel in the surface layer will be adequate to prevent formation of rills and gullies in the surface layer of the cover system throughout the mandated 10,000-year modeling time period. Alternatively, the Licensee can redesign the cover system to ensure appropriate levels of erosion protection. The procedure described by Anderson and Stormont (2005) may be an appropriate starting place for this.

SUMMARY OF BASIS FOR INTERROGATORY: The DRC has concerns about the long-term stabilization of the embankment because of potential erosion of the embankment's surface layer. This layer, consisting of native Unit 4 material with 15% gravel, has fines consisting predominantly of clay- and silt-size grains of calcium carbonate. Calcium carbonate minerals, unlike clay minerals, do not possess a surface charge, and therefore, they, by themselves, tend not to be cohesive. Limited percentages of clay minerals in Unit 4 material provide an unknown amount of cohesiveness for the soil as a whole. It is not certain how cohesive the surface layer will be and how well it will resist erosion. Observations made to date on the site indicate that the potential exists for relatively rapid erosion of Unit 4 clays, with consequent development of rills and/or gullies on sloped surfaces. Admixed gravel of sufficient size and percentage of the total soil volume may be helpful in providing for some erosion resistance. However, the percentage of admixed gravel currently proposed for this type of soil at the site is far less than the percentage of gravel commonly used elsewhere in providing enhanced erosion protection of surface clays in waste embankments, as discussed in published literature.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The DRC has concerns about the erodibility of the proposed designed surface layer soil located at the top of the cover system. This soil may not allow for long-term stabilization of the embankment. This soil is described as follows on Page 12 of the Modeling Report included with the PA (Neptune and Company, Inc., 2012): "Surface layer: This layer is composed of native vegetated Unit 4 material with 15% gravel mixture. This layer is 6 inches thick."

Unit 4 material native to the site is described on Page 9 of the Modeling Report as follows: "This unit begins at the ground surface and extends to between 6 ft and 16.5 ft below the ground surface. The average thickness of this unit is 10 ft. This unit is composed of finer grained low permeability silty clay and clay silt."

As described earlier, the grains making up native Unit 4 soil consist dominantly (~65%) of clay- and silt-size calcium carbonate particles. It is unclear as to how resistant to erosion this type of material is when compacted. Accounts of several DRC personnel who have observed native soils that have been placed as temporary covers at the site or used as slopes for evaporation ponds indicate a high erosion potential, as development of rills and/or gullies has been reported.

Before the DRC can accept proposals for use of Unit 4 silty clay with 15% gravel as cover material, the Licensee must provide either (i) experimental data regarding erosion potential of this material, once normally compacted, or (ii) detailed literature data dealing specifically with erodibility of silt- and clay-sized carbonate-particle analogs regarding the potential for compacted Unit 4 erodibility under extreme precipitation conditions likely to occur over the next 10,000 years at the site.

While admixing gravel in fine-grained soil is considered a potential method of reducing erosion in a cover-system surface layer, the size and percentage of gravel must be carefully engineered to provide a sufficiently resistant layer for a design precipitation event (see Anderson and Stormont, 2005; Anderson and Wall, 2010). In an example given by Anderson and Stormont (2005), the "gravel admixture was designed to provide protection from a 100-year precipitation event and included the following specifications: proportion of gravel to total at 50 percent (1 part gravel to 1 part soil); size at 1.6 to 3.2 cm (0.65 to 1.3 in.); and thickness of layer at 16 cm (6 in.)." It is noted that, in this example, admittedly for a steeper slope, the percentage of gravel was 50%. This compares with the proposed Clive design of only 15%, which is less than a third of that described by Anderson and Stormont (2005).

In another example, Waugh and Richardson (1997) describe the surface layer at the Monticello site. The layer contains 40% gravel. It is 20-cm (7.9 in) thick, with 2-6 cm (0.8-2.4 in) diameter gravel. The thickness of the surface layer, and the percentage and diameter of the gravel is much larger than is proposed for Clive in the proposed design.

Benson (2011) shows through modeling that even when a cover-system surface soil contains 40% gravel, erosion may still be much greater compared to erosion of a system covered with rip rap. He models a cover system for one site over only a thousand-year period and shows that erosion tends to be much deeper and more extensive with a gravel admixture compared to erosion on an otherwise comparable a rip-rap system. It is expected that the effects of erosion would be even more severe on a surface soil having only 15% gravel. The licensee needs to carefully consider how to avoid erosion of the surface soil, while still permitting any needed evaporation and transpiration to take place.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2 (cont'd)

INTERROGATORY STATEMENT(S): It is stated on Page 2-6 that "Long-term stabilization of the Embankment is accomplished through erosion control and flood protection."

The surface layer, which is the focus of erosion control, contains a gravel admixture of 15% gravel within Unit 4 material. However, the size and shape of the gravel are not specified. Please specify them.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2 (cont'd)

INTERROGATORY STATEMENT(S): On Page 2-6, it says, "However, as part of this updated Performance Assessment, the Division requested EnergySolutions evaluate alternative cover designs that more efficiently maximize the amount of time that precipitation is available for evapotranspiration within the alternative cover designs."

The DRC once again asks the Licensee to research pertinent data and examine potential designs for the cover-system, paying special attention to developing a system that not only strongly resists erosion, but also provides for better water storage, prevents or minimizes biointrusion, allows for minimal distortion, enables long-term stability, and enhances evaporation and transpiration to very high levels (or alternatively provides robust drains to remove infiltrated water). Such a low-erosion system needs to be planned for and described in a revised PA.

SUMMARY OF BASIS FOR INTERROGATORY: The surface layer of the alternative cover system proposed in the PA involves placement of Unit 4 clay, which contains a relatively large fraction of silt, and whose clay-size grains consist predominantly of calcium carbonate, along with 15% gravel. This type of soil material, as described above, appears to be potentially susceptible to erosion. Evidence of erosion of Unit 4 clay is currently evident in the field. Unit 4 clay with 15% gravel is clearly unlike the rock/soil-matrix layer with a finer soil matrix infilling voids between rock materials originally recommended for consideration as a surface layer by the DRC.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The DRC did indeed request the Licensee to evaluate potential alternative cover designs offering advantages over the conventional cover. However, the design modifications requested by the DRC are given as follows, as described in a Cover Test Cell (CTC) RFI (DRC, 2011):

> As an alternative to rebuilding the CTC, or to building a new CTC, the DRC would be willing to consider design modifications leading to a more-conservative and more-protective cover system. These would include designing and building cover systems based on new DOE cover-system designs involving, in lieu of an external layer of rip rap, an upper rock/soil-matrix layer with a finer soil matrix filling in voids between rock materials. It is understood that the rock in the upper layer of a rock/soil-matrix layer provides as much protection against erosion as rip rap of the same general dimensions, but that the finer soil matrix provides media compatible with processes contemplated in standard soil physics equations, e.g., those considered in the HELP, UNSAT and HYDRUS models. These would include internal storage of significant quantities of moisture, capillary action, transport of moisture to the surface for evaporation, plant development, transpiration, etc. The DRC understands that large voids in rip rap overlying a sloping filter layer in an LLW embankment do not contribute significantly to these processes.

The modifications described in this PA do not propose design and construction of "an upper rock/soil-matrix layer with a finer soil matrix filling in voids between rock materials." The proposed design for the upper soil layer of the cover system does not provide for inclusion of rock cobbles having an infilling of fine soil matrix within voids between the rock materials. Because there is no framework consisting of rock cobbles included as part of the design, the DRC has serious concerns about the erosional stability of the upper layer. In general, a layer of silty clay with up to 42% silt (Bingham Engineering, 1993) may or may not function effectively in resisting erosion, depending on fluid flow velocities. Clay is typically not as effective in resisting erosion as large cobbles, and silt is typically not nearly as effective as clay in that regard. There is some doubt as to whether the system as proposed would function adequately as a cover for this site within the expected range of surface flow velocities. This uncertainty is amplified when considering that 65% of the silt- or clay-size particles in the silty clay consist of uncharged calcium carbonate, and only 18% of the silt- or clay-size particles consist of clay minerals having a surface charge. Only particles with a surface charge tend to provide for cohesiveness; so, there is added uncertainty here. Evidence of Unit 4 soil's erodibility is found in the field.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2 (cont'd)

INTERROGATORY STATEMENT(S): On Pages 2-6 and 2-7, a "traditional rock armor" cover system is described. Such a system has a number of advantages. Some disadvantages are mentioned in the PA. Please design a system that offers, to the extent feasible, the advantages of a "traditional rock armor" system without its disadvantages. This will involve designing a cover system that, while offering erosional resistance, e.g., as using cobble layers in a "traditional rock armor" cover system may do, also focuses on permitting evaporation and transpiration to readily occur, as can generally occur using clayey or silty loams. This may involve design and use of innovative cover-system materials.

SUMMARY OF BASIS FOR INTERROGATORY: The presence of cobbles or rip rap in a "traditional rock armor" cover system offers advantages over soil covers without cobbles or rip rap such as erosion resistance and removal of water through filter layers. On the other hand, a "traditional rock armor" cover system does not provide for capillarity, and it minimizes evaporation, limits transpiration and fails in general to provide adequate biointrusion resistance. For these reasons, use of fine-grained materials in the embankment surface soil may be needed as well as cobbles. Fine-grained materials can potentially be utilized as infilling between cobbles in a rock/soil-matrix system.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: A "traditional rock armor" cover system as originally proposed for the CAW cover system has many potential advantages. One advantage is relatively high erosion resistance. Another advantage is the presence of two filters, one of which directly overlies a clay layer of very low hydraulic conductivity and which drains most percolated fluids externally off of the embankment. In addition, assuming that it is properly designed, one of the filters, in conjunction with a finer-grained layer above it, may be able to function somewhat as a capillary barrier to retain storage of moisture internally within a root zone.

However, the "traditional rock armor" cover system utilizes a surface layer of rock cobbles, which, in the absence of fine-grained infilling, tends to minimize evaporation. Also, the rock armor cover by itself provides minimal biointrusion protection. Many plants and burrowing mammals may be able to penetrate a rock armor cover by migrating through the large interstices or voids between its cobbles. Larger fossorial mammals, such as badgers, may be able to remove by digging or burrowing some or all of the smaller cobbles. In addition, in contrast to a silty loam soil containing suitable organic matter and nutrients, the rock cover does not greatly facilitate plant growth at the surface for the purpose of enhancing transpiration loss of water.
A "traditional rock armor" cover system, e.g., for the CAW cover system, does not provide for enhanced evaporation and transpiration needed in an effective cover system. A "traditional rock armor" cover system does not provide for small pores in the upper part of the vadose zone allowing for relatively high evaporation and transpiration rates.

In contrast, clay and silty loam are media having relatively small pores that support capillarity, and thus evaporation and transpiration, in the vadose zone. On the other hand, a silty clay loam by itself (and perhaps even clay by itself) may not provide for adequate resistance to erosion at flow velocities that may be encountered in the field during extreme storm events. Adequate resistance to erosion of a silty clay loam has not been proven for the site in the PA.

The water in the vadose zone is under negative pressure. Directly above the ground water table is the capillary fringe, which tends to be fully saturated, albeit at negative pressure. Above the capillary fringe, i.e., in the remainder of the vadose zone, the water saturation generally decreases with height, and water pressures generally tend to become increasingly negative, except in places where a wetted front of infiltrated water is moving downward through the subsurface. In the absence of a wetted front, as water is removed at or near the surface by either evaporation or transpiration, additional water may flow upward under a consequently increased negative potential gradient. This is further explained by Dwyer et al. (2007) as follows:

> Matric potential gradients can be many orders of magnitude greater than the gradient component due to gravity. Evaporation from the surface will decrease the water content and thus increase the matric potential of the soil, resulting in an upward matric potential gradient and inducing upward flow. Plant transpiration also relies upon matric potential gradients to remove water from the cover soil layer.

Where surface tension and capillarity are small or non-existent due to larger pore throat sizes in a soil, as with an emplaced sand or gravel layer, evaporation and transpiration of underlying water is strongly limited. This is readily inferred from the results of a number of studies. For example, those addressing evaporation include Hadas and Hillel (1972), Groenevelt et al. (1989), Reith and Caldwell (1990), Kemper et al. (1994), Diaz et al. (2005), Albright et al. (2010) and Neptune and Company, Inc. (2012).

Together, studies such as these confirm the inadvisability of using unfilled cobbles or rip rap for the upper layer of a cover system in instances where evapotranspiration rates must be maximized for minimization of drainage of water into waste and into underlying vadose and groundwater zones. The studies also confirm the need for infilling the voids of any surface or near-surface rip rap, cobbles, or gravel, if such materials exist, predominantly with fine-grained soils rather than with coarse granular material so as to maximize capillary effects, transpiration and evaporation taking place at or near the surface.

Moreover, when cobbles or boulders are present in the uppermost portion of the cover system, an infilling of clay or silty clay between them also tends to greatly reduce the hydraulic conductivity associated with pore space in the biobarrier (by many orders of magnitude), and, again very importantly, this decreases infiltration. In a properly designed water-shedding cover system, this is highly advantageous. Diversion of water decreases drainage into the waste and vadose zone and decreases percolation into the groundwater system.

Fine-grained clay or silty clay, when loosely compacted, may also serve as a soil suitable for the growth of some salt-tolerant grasses, forbs or shrubs. This can be a good thing or a bad thing. It is a good thing when the salt-tolerant grasses, forbs or shrubs have roots that, because of appropriately engineered capillary barriers, phytobarriers, or other suitable soil conditions, only penetrate several feet below the surface, yet they remove water by transpiration. It is a bad thing when the salt-tolerant grasses, forbs or shrubs have long roots that, because of a lack of appropriately engineered capillary barriers, phytobarriers, or other suitable soil conditions, penetrate down into the radon barrier, or even into the waste. This could potentially happen with greasewood, as discussed later.

A design for a cover system is needed that offers, to the extent feasible, the advantages of a "traditional rock armor" system without its disadvantages. This may require use of cobbles infilled with fine-grained materials.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2.2 (cont'd)

INTERROGATORY STATEMENT(S): Page 2-8 states that the surface layer "is composed of native vegetated Unit 4 material with 15% gravel mixture. This layer is 6 inches thick. The functions of this layer are to control runoff, minimize erosion, and maximize water loss from evapotranspiration. This layer of silty clay used in both evapotranspirative designs provides storage for water accumulating from precipitation events, enhances losses due to evaporation, and provides a rooting zone for plants that will further decrease the water available for downward movement."

Please conduct a complete engineering analysis of erosion. It should be based on the measured mineralogical as well as grain-size characteristics of site-specific clays, and, preferably, on experimental data. If modeling is selected for use in support of the analysis, then please specify exactly what type of model is used, and provide all assumptions used in modeling. Please design the cover system so as to be able to withstand all anticipated flows, including those of a foreseeable storm or series of storms of maximum intensity. Please incorporate within the model various scenarios including that of up to 10.87 cm (4.28 inches) of precipitation falling at the Clive Disposal Facility in one month, as occurred in May of 2011.

If the layer of silty clay with only 15% gravel is considered to be highly erosion resistant, then please justify that opinion through experimental data or through comparisons with studies of erosion of clays consisting dominantly of calcium carbonate, as are found on site, combined with approximately 15% gravel.

If it is decided that the surface layer of silty clay with 15% gravel as proposed in the October 2012 PA would not be sufficiently erosion resistant, then please redesign the surface layer. The combined use of rock cobbles and clay may provide superior erosional resistance. Please evaluate, via experiment and/or modeling, the potential use of an infilled cobble system (see Abt et al., 1986), or something comparable in terms of performance for a surface layer, and develop a design based on that evaluation.

Regardless of the quantitative outcome of modeling or experimentation dealing with erosion, please address radionuclide exposure associated with erosion of soil or waste particles coupled with water-borne or air-borne transport.

BASIS FOR INTERROGATORY: The DRC commends the Licensee for its concerns about controlling runoff, minimizing erosion, and maximizing water loss from evapotranspiration. The DRC acknowledges that the proposed design for the surface layer, while likely having some relatively severe weaknesses, does have some strengths. The surface layer, while relatively thin (only 6 inches) does offer some water-storage capacity, should enhance water losses via evaporation (compared with the previous design of a rock cobble layer), and, depending on factors such as compaction, salinity, organic matter fraction, and nutrient levels, may allow for some growth of plant roots that may enhance transpiration and thereby somewhat reduce water available for downward movement.

On the other hand, the DRC has serious reservations about the proposed use of native vegetated Unit 4 clay/silt material with 15% gravel mixture as a material for the surface layer in the preferred designs. Of particular concern is how this layer's hydraulic conductivity may change over time and how that may have consequent impacts on drainage of infiltrated water down into waste, soils and groundwater, as addressed for other soils elsewhere in this Interrogatory. Another concern, as previously addressed, is the relatively low percentage of gravel to be contained in the proposed layer, which may make the soil susceptible to erosion. Other topics of concern, which yet need to be addressed more fully, include plant growth and transpiration, biointrusion by plant roots, biointrusion by animals, freeze-thaw, wet-dry cycling, and distortion. Some of these processes could affect exposure of radioactivity to inadvertent intruders.

The DRC also has concerns about use of silty clay obtained on-site as a sole soil matrix or framework for gravel in the surface layer. Some clays that are highly cohesive may be strongly resistant to erosion. However, other clays are dispersive and tend to be weakly resistant to erosion. Some clays have erosional resistance between these extremes.

Silty clays at Clive associated with temporary cover or construction of evaporation ponds have been noted to have developed erosional rills and even gullies over the course of only a single year or less. Development of gullies, with headward erosion, possibly into radon barriers, or even into the waste itself, is a concern at Clive over the modeling period of 10,000 years. This tendency could markedly increase risk to human health and the environment. Sufficiently deep erosion can lead to movement of underlying waste by wind or water. Once erosion cuts through a cover system, exposures to waste may potentially occur for thousands of years. This is one reason why the NRC's proposed change in language extending modeling of inadvertent intruder scenarios to at least 10,000 years makes sense.

Unit 4 silty clay at Clive is somewhat unusual in that it contains very little clay mineralogically. A Clive silty clay sample tested is reported to contain only about 18% clay minerals (University of Utah Research Institute, 1993). The remainder of the sample (about 82%) consists of non-clay minerals. Most of it is calcium carbonate (about 65% of the total). Calcium carbonate grains, unlike clay minerals, do not have much, if any, surface charge, and they therefore do not, by themselves, tend to cohere nearly as much; in essence, they are not considered cohesive. The question is whether or not the presence of 18% +/- clay minerals in the silty clay material is sufficient by itself to enable the soil mix to cohere well enough internally to resist traction forces associated with flows of water across the cover-system surface expected as a result of future storms.

While addition of gravel to the clay could improve erosion resistance, how well that is achieved depends on the gravel percentage in the soil and the size of the gravel. Elsewhere in this document, it is shown that the percentage of gravel proposed for the surface layer appears, based on comparison with gravel/soil layers at other sites, to be inadequate.

The PA does not presently provide a full engineering analysis of this problem of erosion on the cover systems proposed within the PA, especially with due consideration of the site-specific characteristics of the on-site silty clays proposed for use in proposed design.

Rock cobbles, if large enough, can provide more resistance to tractive forces in flowing water during higher velocities of flow than clay can, particularly if many particles in that clay are actually silt particles. Use of rock cobbles can decrease soil erosion at higher water flow velocities. This is evident in many studies of erosion, as may be illustrated, for example, in a Hjulstrum's diagram of the erosion field delineated on a plot of water velocity vs. grain or particle size.

Proposed design plans at Clive call for the placement of silty clay with 15% gravel as the surface layer in the cover-system. As previously reported, a sample of Unit 4 silty clay at Clive is reported by University of Utah Research Institute (1993) as consisting of only about 18% clay minerals. With 82% of the Unit 4 material thus consisting of minerals that, by themselves, do not tend to be cohesive, the DRC has concerns about how resistant to erosion a surface layer consisting of silty clay with 15% gravel would be. Notwithstanding this concern, it is possible that the 18% clay contained within the silty clay would be sufficient to attain some measure of resistance to erosion. However, this must be tested experimentally.

The presence of gravel in clay may or may not help increase its erosion resistance. It depends on the size and percentage of gravel in the mixture. Kamphuis (1990) reports finding that addition of either some sand or some gravel to a cohesive fine-grained soil may actually decrease the soil's resistance to erosion. If the fluid velocity is sufficiently high, and the sand or gravel is potentially mobile, the presence of rolling or saltating sand or gravel on upslope regions of a bed of sediment tends to knock the fine-grained particles loose from the bed, increasing the bed's overall erosion.

However, even if gravel were to help with erosion resistance, its presence would not necessarily take the place of employing cobbles, particularly large cobbles interlocking in grain-to-grain contact and providing a strong, stable framework for the cover-system surface layer. Large cobbles can be seen in a Hjulstrum's diagram to provide for maximum resistance to erosion of any uniformly sized set of particles.

However, use of cobbles alone, as described here and elsewhere in this document, would tend to greatly diminish evaporation and transpiration, as no media supporting substantial capillarity in the surface layer would be present. For this reason, infilled cobbles, with the infilling consisting of a silty clay, would likely be superior. A cover system consisting of cobbles or gravel infilled with silty clay may offer substantive benefits in terms of erosion resistance, as well as providing materials suitable for evaporation and transpiration from depth. Such cobbles or gravel could also provide some biointrusion resistance, depending on the size distribution of the cobbles or gravel and the cross-sectional diameters of burrowing animals of concern.

There are other reasons, as well, for considering infilling of cobbles in a surface layer. Abt et al. (1986) refer to "a soil-rock matrix" and they state, "the matrix should be comprised of rock to resist the design unit discharge and soil to fill the rock voids and reduce infiltration as well as provide a soil base for vegetation." They also state that the surface has a better, less-obtrusive appearance. They report that, based on their flume studies, cobbles with compacted fine-grained infill were about 10% more erosion resistant than the cobbles by themselves.

Jain and Kothyari (2009) studied erodibility of gravel/clay mixtures in flume studies and found that the rate of transport of eroded bedload in flowing water decreased greatly, i.e., by two to even more than ten times, when clay, present in different fractions (e.g., from 10 to 50%), was used in a framework of gravel bed material. Their results show the potential superiority of a gravel/clay mixture to a simple gravel sediment in terms of resistance to erosion.

Van Ledden et al. (2004) report on studies of mixtures of gravel and clay and how cohesive these mixtures are. They conclude that, in a mix of clay and gravel, the presence of 5-10% clay minerals (not clay-size particles, but clay minerals) constitutes the lower limit of the amount of clay minerals needed to enable the entire mix to be cohesive.

A cohesive mix of cobbles and clay may be more erosion resistant than simply the cobbles. If uniform cobbles in a randomly packed framework constitute 60% of the total volume of a layer, and silty clay (containing 18% clay minerals) infills the pore space at 40% of the total volume, then the percent clay in the layer is calculated at 7%. This may or may not be enough to make the soil conditions close to or at the boundary between a cohesive and a non-cohesive state. Compaction of the infilling into the pore space of the gravel or clay would likely be necessary to promote cohesiveness. Experimental testing before final design and construction would be necessary to confirm the adequacy of the preliminary design. It is possible that some minor addition of bentonite or other clay component might be necessary to provide a margin of safety. On the other hand, the amounts of clay naturally present may be sufficient.

Abt et al. (1986) report having added fine-grained infilling material in a thin (i.e., 3- to 4-inch) layer over cobbles and then using vibratory equipment to push the fine-grained material into the interstices or voids between the cobbles. The process is repeated until the fine-grained material is flush with the tops of the cobbles. There may be other means of filling the voids with fine-grained soil. The most important consideration in terms of facilitating evapotranspiration is that the fine-grained material be fully interconnected with no gaps between parts of the fine-grained material.

Similar approaches are sometimes used when engineers employ vegetated riprap for infrastructure construction and/or environmental protection. In this approach, a standard rock riprap section is infilled with soil, and grass or other vegetation is grown on the soil (e.g., Lagasse et al., 2006).

Adding clay in the interstices of cobbles will also increase runoff, minimize infiltration, lower the flow velocity of water within the cobble layer, and allow for capillary forces to move water upwards, sideways or both during transpiration and evaporation.

The PA does not presently provide a full engineering analysis of this problem of erosion on the cover systems proposed within the PA, especially with due consideration of the site-specific characteristics of the on-site silty clays proposed for use in proposed design.

There are also concerns about uptake risk associated with soil or waste removed during erosion. If silty clay with 15% gravel proposed to be laid down as a surface layer does erode, as it appears it will do under proposed design plans, then it is possible that at some point, erosion may go as deeply as the radon barrier or the waste. Soil contaminated by radioactive particles might then be made available to inadvertent intruders by soil, air or water exposure pathways at some future time up to and beyond 10,000 years. Pathways may include either ingestion or inhalation of soil or waste particles. As described elsewhere in this document, the proposed design to minimize or prevent erosion appears to be inadequate. Uptake of radionuclides via the soil ingestion or inhalation pathways then becomes a possibility. Additionally, erosion down to the level of the waste would expose waste much more fully to potential biointrusion and redistribution of radioactivity by animals and plants.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(b); UAC R313-25-8(4)(d); UAC R313-25-22; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2.2 (cont'd)

INTERROGATORY STATEMENT(S): The design surface-layer portion of the cover system as described on Page 2-8 consists of on-site silty clay mixed with only 15% gravel. Based on comparisons with percentages of gravel planned for or used in other alternative cover systems, the DRC finds that planned design of only 15% of gravel in the surface layer at the site appears to be too low to adequately resist erosion. Experts generally recommend percentages in the range of 30-50%. Please design a surface-layer using an appropriately higher percentage of gravel, or provide justification through experiment or modeling that use of only 15% gravel with provide erosion protection for 10,000 years.

BASIS FOR INTERROGATORY: If cohesion of clays on the Clive Waste Disposal Facility site is sufficiently ample, which it may or may not be, then a gravel/clay admixture might be suitable for erosion resistance on the cover system, provided that the gravel content is sufficiently high. However, the proposed design percentage of gravel, 15%, appears to be too low.

Amounts of gravel recommended by experts for gravel admixtures with soil on the surface of cover systems are appreciably higher than the Licensee's proposed design value of 15%. Anderson and Wall (2010) indicate that gravel admixtures containing 25-50% gravel could work, but they recommend use of 30-45% gravel for design purposes. Stenseng and Nixon (1997) recommend use of 40% gravel, which is the same percentage used at the Monticello site (Waugh and Richardson, 1997). Anderson and Stormant (2005) report having chosen 50% gravel for design of one site.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.1

INTERROGATORY STATEMENT(S): Pages 3-1 and 3-2 say, "that after final placement of the waste and closure of the Embankment with a rock armored cover, the facility design prevents any further migration of radioactivity through the air pathway. Analysis of the longevity of the alternate evapotranspirative cover designs, which provide equivalent isolation of waste from the atmosphere, also demonstrates that no such air-related doses are projected following closure and institutional control."

The DRC finds this statement to be inapplicable to the proposed cover system design and also finds that a possibility exists for transport of radioactivity through an air pathway should sufficient erosion in cover system soils occur, with consequent exposure of the waste to wind. Please address the issues associated with erosion potentially leading to a break of the cover system and devise and plan for the engineered means to prevent this. Show through modeling, if possible, that erosional breaching of the proposed cover will not occur with the relatively rare carbonate silty clay found at the Clive site, mixed with 15% gravel. Alternatively, redesign the cover to provide for greater long-term protection against erosion. If gullies do form down into the waste, then there would be high potential for transport of radioactive particles along with soil. There would accordingly be potential for windblown transport of radionuclides with consequent downwind exposure of people or animals through the air pathway. Show through modeling the risk from ingestion or inhalation of eroded soil that might occur to a receptor, such as an inadvertent intruder who builds a residence on site at some point in the future.

BASIS FOR INTERROGATORY: First, the recommended or preferred designs included in the PA do not involve rock armor, at least over the top cover and over the vast majority of the side cover. Thus, the argument quoted from the PA mentioned above seems to be without merit.

Releases of contaminated waste particles to air can potentially occur concurrently with, or subsequent to, deep erosion, as occurs during gully formation. With the proposed design, there appears that there may be less erosion protection than with the "traditional rock armor" design. Consider, for example, the top slope. In the proposed design for the top slope (see Pages 2-6 through 2-9), only 0.30 to 0.61 meters (12 to 24 inches) of native, on-site silty clays mixed with 15% gravel are used for the surface and evaporative zone layers. This may be less resistant to erosion by water than 0.61 meters (24 inches) of riprap cobbles ranging "in size from 0.75 to 4.5 inches" (0.02 to 0.11 meters), with "a nominal diameter of approximately 1.25 to 2 inches" (0.03 to 0.05 meters) as planned for use in the uppermost layer in the current, approved design. Not only is the thickness of the proposed cover system under the proposed design potentially smaller, but the particle size range is highly different. Silty clay may, as shown in many published articles through Hjulstrom's diagram, tend to erode at lower flow velocities than cobble of nominal size 1.25 to 2 inches (0.03 to 0.05 meters). Additionally, silty clay may be much more easily biointruded by most burrowing mammals than riprap cobbles.

Erosion on the side slopes, where most of the surface is proposed to consist of clay soil admixed with 15% gravel, may be even greater. This is because of the much higher slopes.

Abt et al. (1994) report on studies of 11 gullies that had formed at reclaimed mine sites in the western United States. Interestingly, five of the 11 gullies are reported to have had depths of erosion in excess of 5.5 feet. Cover-system soil thickness of only 4.5 to 5.5 feet is proposed for the Clive Disposal Facility. Vegetative cover at these five highly eroded gullies is reported to be 25%, 15%, 5%, 20%, and 15%, respectively. It is noted that current vegetative cover other than microbes in soil crusts (e.g., shrubs, forbs and grasses) at the Clive Facility, after an extremely lengthy period of plant adaptation to the local environment, is not much more than 20%. It is reported on Page 2-5 that "ground cover is dominated by 79.2% biological soil crust cover."

If gullies formed at the Clive Facility and eroded through the cover system, then there would be the potential for subaerial exposure of waste and surrounding soil, and the potential for ingestion or for "migration of radioactivity through the air pathway" as winds picked up waste particles and dispersed them. This could lead to exposure of humans and animals in the environment. As Abt et al. (1994) have said, "Gully intrusion into the cover is one of the greatest potential threats to the long-term stability of an impoundment." Since, for safety, the cover on the engineered embankment on site must remain intact for thousands of years, a realistic analysis of potential erosion problems is essential. A period of thousands of years for possible erosion is much longer than the time that humans have had experiencing impacts on well-engineered cover systems to potential erosional stresses.

There have been multiple sites associated with waste or mining that, over an observational period of only decades, have experienced development of gullies as a result of erosion of soils (e.g., U.S. Bureau of Land Management, 1986). This can lead to serious consequences. Remarks about the potential danger of gullying in cover systems are addressed, as previously referred to, by Johnson (2002) and (Nelson et al., 1983).

A PowerPoint presentation is available describing a mathematical model of peak ranch dose from depleted uranium initially buried three meters below cover in the southeast corner of the Clive Disposal Facility over a 10,000-year period (Black et al., 2012). The mean peak ranch dose for radioactivity from the depleted uranium is said (in Slide 17) to be 4.8 times as great if gullies form in the cover system compared to if no gullies form (Black et al., 2012). It is not clear if this increase in modeled dose would be associated with actual exposure of waste or simply be associated with reduced cover thickness. While factors for radioactivity increase may be different for bulk waste or blended waste, the concept that gully erosion from the site may greatly increase radioactive dose is clear cut.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.2

INTERROGATORY STATEMENT(S): On Page 3-2, the PA claims, "After closure of the embankment, all waste is covered by a cover system designed to protect against erosion and losses of integrity due to waste settlement." Please revise the above statement as the DRC finds that, based on available evidence, adequate protection against erosion of proposed cover-system soils has not yet been demonstrated in the PA.

BASIS FOR INTERROGATORY: As mentioned in the previous set of comments, additional information from the literature, from modeling, and/or from experiment is needed before the DRC can accept that the planned surface layer of the proposed cover system will be sufficiently protected against erosion.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 53 says that the model uses the rainfall and runoff factor of 0.01, whereas the default value in RESRAD-OFFSITE is 160. The rainfall and runoff factor is said to be "set to 0.01 to produce a negligible erosion rate."

Existing evidence of serious erosion potential on site refutes the concept that the model should have rainfall and runoff factors "set to 0.01 to produce a negligible erosion rate." Please develop and support by documented evidence an appropriate design for a cover system for the Class A West embankment that protects against erosion while still enhancing evaporation and transpiration. Please also make relevant and appropriate changes in the model and the PA text. Alternatively, provide justification for the existing plans.

SUMMARY OF BASIS FOR INTERROGATORY: Concentration of water with consequent erosion via channelization in the form of rills and/or gullies is observed each year at the Clive site. This is well documented. Channelization during erosion so as to form rills and gullies is not believed to be accounted for in erosion code written internal to RESRAD-OFFSITE. Many erosion codes account for sheet erosion, some smaller number account for rill erosion, but very few account for gully erosion. Gully formation must generally be modeled by specialized programs written specifically to account for formation of gullies.

Current PA analyses that assume a negligible erosion rate appear to be grossly in error. This is clearly refuted by existing photographic and other evidence of serious erosion potential on site. The DRC requires that the Licensee develop suitable models to account for erosion of the site over the modeling timeframe. In addition, the DRC requires that the Class A West cover system design be modified to more fully protect the cover system against erosion, yet still achieving enhanced transpiration and evaporation. This is essential to meet the requirements of the rules and regulations listed below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Please provide a technical basis for the rainfall and runoff factor chosen, as well as the resulting erosion rate. The rainfall and runoff factors chosen for modeling are four orders of magnitude less than the RESRAD-OFFSITE default values. This choice of extremely low values for these factors has huge impacts on erosion calculations. It is claimed on Page 53 that the internal RESRAD-OFFSITE internally calculated erosion rate, based on current model inputs, is only 6.9×10^{-10} m/year. This is an essentially negligible value. In essence, this is like saying that virtually no erosion of the cover system will occur over the 10,000 year modeling period. This value is six orders of magnitude less than the default RESRAD-OFFSITE erosion rate of 0.001 m/year (Yu et al., 1993). Even the latter rate may inadequately describe potential erosion on site, as the erosion depicted in that rate is presumably assumed to be uniform sheet erosion, whereas actual erosional features on the site are likely to be narrowly focused or concentrated in certain areas, thus causing non-uniform but localized deep removal of soil across the surface.

The rate of erosion assumed in the modeling is inconsistent with observed erosional features reported to be produced each year at the Clive facility in Unit 4 clays. Several previously provided DRC photos depict a number of these features.

In the previously provided photo of a single erosional rill (as shown with a pen and notebook – see the beginning of the Interrogatory 4.0 for PA Section 2.2), two types of features are apparent, each of which is potentially related to erosion. One type of feature is polygonal cracking of the surficial clay. Cracking of the clay can occur for many reasons. One possible reason is desiccation associated with wet-dry cycling. Another possible reason is freeze-thaw activity. As cracks develop in the clay, conduits are opened for infiltration and for the rapid and concentrated flow of water into portions of the subsurface. This tends to accelerate local erosion. As rills deepen, soils on edges of rills fail due to fluid-traction and gravitational forces. Sections of the surficial clay, fractured into smaller blocks, and proximate to deeper, faster running water in rills and gullies, become more susceptible to erosion.

The second feature apparent in this photo is the formation of an erosional rill. These rills develop yearly on Unit 4 clay at the facility. As evident based on the use of a pen and a binder for scale, the rills on the site can develop to depths of several inches within only a year's time. Over hundreds of years, rills in soils can potentially develop into gullies, which are much deeper. The claimed erosion rate in the current model of only 6.9 x 10^{-10} m/yr (which is essentially negligible) given on Page 53 appears to be severely in error.

The second photo provided shows development of rills on a sloping clay surface at the Clive site over a year's time. Each year, these clay surfaces have to be repaired, because damage by erosion is sufficiently great to justify it, and erosion would otherwise worsen over time.

The third photo is one of young gullies at the Clive site illustrates two important points relative to erosion of Unit 4 gravelly silty clays. One point, understood from the work of many geomorphologists, is that rills on sloped surfaces tend to become longer and larger over time, eventually becoming gullies. Smaller rills and gullies deepen to form larger rills and gullies, which tend to migrate upslope. Headward erosion (near the existing top of a rill or a gully) generally occurs. Once larger gullies develop, they tend to concentrate and channelize much of the flow, which, in turn, produces much more severe, albeit localized, erosion. As gullies grow deeper, and migrate upslope, the gullies may threaten the integrity of underlying and upslope soil-based constructed entities, such as cover systems on embankments.

This type of channelization during erosion is not believed to be accounted for in erosion code written internal to RESRAD-OFFSITE. Some codes account for sheet erosion, some specialized codes account for rill erosion, but very few account for gully erosion. Gully formation must generally be modeled using highly specialized programs written specifically to account for formation of gullies.

The second point illustrated in this photo is that the presence of a limited amount of gravel in clay soils at the site does not protect well against erosion. The clays in this photo contain an appreciable but limited amount of gravel, and even some cobbles, but the gravel and cobbles are not present in sufficient density to stop erosional development, even over a relatively short span of time.

Not only does the model assume negligible cover-system erosion on Page 53, but also on Pages 54 and 64.

Johnson (1992) discusses design of cover systems effective over the long term in NUREG-1623. He says, "Presently, very little information exists on designing cover to remain effective . . . Numerous examples can be cited where covers for protection of tailings embankments and other applications have experienced significant erosion over relatively short periods (less than 50 years). Experience with reclamation of coal-mining projects, for example, indicates that it is usually necessary to provide relatively flat slopes to maintain overall site stability (Wells and Jercinovic, 1983)." It is noted that the side slopes of the cover system of the embankment under the proposed design do not have relatively flat slopes, but rather slopes of approximately 20 degrees.

Dwyer et al. (2007) show in Figure 5.2-2 (see copy below) a photo of gully erosion that took place in a sloped gravelly soil in Albuquerque, NM. They state that the maximum depth of the gullies is said to have been measured at greater than six feet. If erosion to that depth were to take place at in the proposed cover system at the Clive site, then it would expose bulk waste that otherwise would lie protected beneath the cover system.

Johnson's (2002) concern that "a serious threat to stability at any given site is likely to be gully erosion resulting from concentration of runoff from local precipitation" indicates that to ensure long-term stability, it is important to control localized erosion and the formation of rills and gullies. Research performed for the NRC staff (Nelson et al., 1983) that has "demonstrated that if localized erosion and gullying occurs, damage to unprotected soil covers may occur rapidly, probably in a time period shorter than 200 years" is another reason to develop improved cover-system design to protect against erosion. This is important, because, as Ayres et al. (2006), say, "Gully erosion poses the greatest environmental threat to covered waste storage facilities containing hazardous materials such as acid-generating or radioactive materials."

The DRC requires that the Class A West cover system design be modified to more fully protect the cover system against erosion, yet still achieving enhanced transpiration and evaporation. Attaining this objective this most likely entails, but does not necessarily entail, a design involving the use of one or more layers of cobbles, infilled with clay or gravelly clay. The clay or gravelly clay is considered important to have to allow for evaporation and transpiration at significant rates; the cobbles appear to be essential at this site for preventing erosion. Properly designed layers having cobble frameworks may also offer some protection against biointrusion.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

5.0 BIOINTRUSION BY MAMMALS

SECTION: 2.1.11

INTERROGATORY STATEMENT(S): On Page 2-5, it says that, during a biological survey, there were "83 deer mice and one kangaroo rat trapped" at the Clive disposal facility site. Please remedy the cover design to prevent or minimize biointrusion by kangaroo rats and deer mice.

SUMMARY OF BASIS FOR INTERROGATORY: Kangaroo rats and deer mice are known at other sites to burrow deeply in soil. Their acknowledged presence at the Clive site will necessitate developing features of the cover system design to effectively prevent or minimize biointrusion into cover-system soils and possibly even into waste by these animals.

The cover system needs to provide a high level of protection from biointrusion. This will help minimize damage to the cover system and possible spread of radioactivity to other locations.

Biointrusion can have deleterious effects on infiltration of water into waste and migration of radionuclides that could, under some conditions, adversely impact inadvertent intruders and others on the Clive site, contrary to rules in UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: This finding during the biological survey raises the potential for significant mammalian biointrusion on site. Recently, 83 deer mice and one kangaroo rat were trapped during a single biological survey on site, and other animals, including badgers, have been sighted on site.

Kenagy (1973) reports on the depth of nests of the kangaroo rat, *Dipodomys merriami*, at a site in Owens Valley between the Mohave Desert and the Great Basin. Maximum depth of kangaroo rats that could be located by tracking devices used at this site is reported to have been 1.75 m. However, many of the kangaroo rats are reported to have stayed in their burrows during the study at considerably greater depths than this maximum depth to which the tracking devices used in the study could read a signal and track them. Different species of kangaroo rat may burrow more deeply or less deeply. The species of kangaroo rat found at the site is not mentioned in the PA. The Kangaroo rat captured by SWCA Environmental Consultants (2012) is thought to have been an Ord's Kangaroo rat (see Page 23 of SWCA, 2012b).

Arthur and Markham (1986, 1987; see also Bowerman and Redente, 1998) note that deer mice penetrated an Idaho National Environmental Laboratory (INEL) cover system having a thickness of 2.4 meters. Many of the mice are reported to have received relatively high radiation doses, some of which are said to have been lethal.

Landeen and Mitchell (1981) found that pocket mice at the Hanford site burrowed about 79% deeper in disturbed soils than in native soils. This indicates that, for some combinations of mammals and soils, biointrusion may be deeper in disturbed soils than in nondisturbed soils.

Based on the foregoing, it appears that the potential for biointrusion exists for both kangaroo rats and deer mice. Kangaroo rats are noted in field observations to have burrowed down to soil depths of at least 1.75 meters (5.74 feet). It is not known how species variation affects burrowing depth. Deer mice can burrow down to at least 2.4 meters (7.9 feet). These are depths obtained from relatively few samples. Therefore, greater depths of burrowing could be expected if the entire population were to be evaluated. Furthermore, as reported for one species in one soil by Landeen and Mitchell (1981), burrowing depths may possibly tend to be greater in disturbed soil.

For the Licensee-preferred cover design at the site (see Pages 12 and 15), the proposed cover-system soil thickness is proposed to be only 1.4 to 1.7 meters (54 inches or 4.5 feet to 66 inches or 5.5 feet). Both kangaroo rats and deer mice have been reported to burrow down into soil more deeply than the total depth of soil in the cover system design. This indicates the potential for biointrusion.

As discussed elsewhere in this document, biointrusion can damage cover systems, allow too much water to percolate into waste, and permit release of radon into the atmosphere, increasing risk to people and the environment. Moreover, if kangaroo rats or deer mice get into waste, they may themselves become surficially contaminated by radioactive particles and may spread the radioactive particles to other parts of the environment. Additionally, if ingested or inhaled by kangaroo rats or deer mice, radioactive materials may subsequently impact the environment via excretion of the animals' urine, feces or other bodily fluids, or, when the animals die, through decomposition of their flesh.

Depending on design characteristics, one or more layers of infilled gravel or cobbles may effectively provide for some protection against biointrusion by these species. However, the average size and range of sizes of individual pieces of gravel need to be considered in design. If sufficiently heavy, pieces cannot be lifted to the surface by the burrowing animal, which is advantageous. If too large, pieces of gravel or cobbles may have voids sufficiently large for burrowing animals to penetrate, which is disadvantageous. Fine-grained infilling between larger gravel- or cobble-size particles is necessary to allow for capillary effects, such as capillary rise during transpiration or evaporation. Having a cover system only 1.4 to 1.7 meters (4.5 to 5.5 feet) thick **will *not*** achieve biointrusion protection, as these and other animals on site can burrow deeper.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): Also on Page 2-5, it says that, during the biological survey, burrows of badgers were observed at the Clive disposal facility site. This is in addition to the siting of multiple badgers on site (SWCA, 2012). Please remedy the cover design to prevent or minimize biointrusion by badgers.

BASIS FOR INTERROGATORY: The presence of badgers on site indicates the potential for biointrusion of cover system soils. Lindzey (1976), based on studies of a few badgers in Utah and Idaho, reports on one badger burrowing to a depth of 2.3 meters (7.5 feet). McKenzie et al. (1982) is reported to have given a value for burrowing depth for badgers of greater than 2.0 meters, or 6.6 feet (Hampton, 2006).

Burrowing depths of 2 to 2.3 meters (6.6 to 7.5 feet) are significantly greater than the depth of the cover system soil proposed for the site of 1.4 to 1.7 meters (4.5 to 5.5 feet). The potential for badgers to penetrate through the cover is therefore present.

It is estimated in Eldridge (2004) that each badger creates or enlarges up to 1,000 to 1,700 burrows or pits each year. Badgers do this primarily while searching for fossorial mammals (e.g., ground squirrels, kangaroo rats or deer mice) to eat. Since each pit lasts, on average, about four years, one badger may be responsible for the presence of 4,000 to 6,800 relatively large pits in existence each year. Multiple badgers have been seen on or near the Clive site.

Biointrusion can potentially cause a number of problems. Biointrusion can potentially damage cover systems, allow too much water to percolate into waste, and permit release of radon into the atmosphere, increasing doses to humans and the environment. If badgers get into waste, they may become contaminated by radioactive particles and may spread them throughout the environment. Badgers may also ingest radioactive materials by eating other fossorial mammals impacted by waste. They may then spread radioactivity through the environment via urine, feces other bodily fluids, and, when they die, via decomposing flesh.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): In addition to badgers, kangaroo rates and deer mice, it is said on Page 2-5 that ground squirrels were observed during field studies at the Clive facility site. Please provide an appropriate design to defend against biointrusion by ground squirrels.

BASIS FOR INTERROGATORY: SWCA Environmental Consultants (2012) reports on the species of ground squirrels observed: *Spermophilus* spp.. Suter (1993) and Suter et al. (1993) report ground squirrel burrowing to depths of at least 1.4 meters (4.6 feet) but do not mention species. HERD (1998) reports that ground squirrels in California burrow to depths of at least 66 inches (1.7 meters, or 5.5 feet). These data indicate that the potential depth to which ground squirrels may burrow may be as deep as or deeper than the proposed cover system soil thickness. These data indicate the potential for ground squirrels to biointrude through the cover-system soils at the site.

Biointrusion by ground squirrels can badly damage cover systems, possibly allowing a direct path for water to percolate into waste, and permitting the release of radon into the atmosphere, increasing risk to people and the environment. If ground squirrels get into waste, they may become surficially contaminated by radioactive particles and may spread these radioactive particles to other parts of the environment. Additionally, radioactive materials within the ground squirrels may subsequently adversely impact the environment via excretion of badgers' urine, feces or other bodily fluids, or through decomposition of their flesh. The cover system needs to provide a high level of protection from intrusion by burrowing animals, including ground squirrels.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): While badgers, ground squirrels, kangaroo rats, and deer mice are mentioned in the PA as burrowing mammals that live on or near the site, coyotes are not mentioned in the PA. Please provide an appropriate design to defend against biointrusion by coyotes.

BASIS FOR INTERROGATORY: Coyotes are not mentioned in the PA. Yet, coyote burrows and/or dens are noted elsewhere to have been observed on or near the site. On Page 47 of SWCA (2011), it is stated that "coyote burrows/dens were observed near survey plots, but none fell within plot boundaries."

The proximity of coyotes to the site indicates the potential for cover-soil damage due to coyote burrowing. Coyotes are capable of deep burrowing. In one study, it is reported that minimum depth of 17 dens ranged from two (2) to over five (5) meters, with an average depth of 2.5 m (Way et al., 2001). This depth is much greater than the maximum 1.7-meter depth of the proposed cover system, so a risk from biointrusion into radon barriers and waste exists.

Biointrusion by coyotes can badly damage cover systems, possibly allowing a direct path for water to percolate into waste, and permitting the release of radon into the atmosphere, increasing risk to people and the environment. If coyotes get into waste, they may become surficially contaminated by radioactive particles and may spread these radioactive particles to other parts of the environment. Additionally, radioactive materials within the coyotes (e.g., from eating other fossorial mammals) may subsequently adversely impact the environment via excretion of coyotes' urine, feces or other bodily fluids, or, when they die, through decomposition of their flesh. The cover system needs to provide a high level of protection from intrusion by burrowing animals, including coyotes.

Biointrusion can have deleterious effects on migration of radionuclides that could, under some conditions, adversely impact human health and the environment, contrary to rules UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): Not mentioned in the PA in this section describing burrowing animals on site are kit foxes. Kit foxes should be mentioned here. Please do so.

BASIS FOR INTERROGATORY: It is not appropriate to leave out kit foxes in this section describing burrowing animals on site. Kit foxes, which are found in western Utah, among other places, either create or use (in some cases) dens as deep as 2.5 meters (8.2 feet; Tannerfeldt et al., 2003, referencing O'Neal et al., 1987). Again, this depth is considerably deeper than the design depth of the top of radon barrier depths, and considerably deeper than the design depth of the top of the waste.

Foxes are briefly mentioned in another section of the PA, Section 3.1.6, which states, "Other burrowing animals at the site include jackrabbits, mice, and foxes."

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): Page 2-5 contains the following paragraph:

> Although a vegetation community of sufficient diversity and density is desired to maximize transpiration from the soil, vegetation density was positively correlated with small mammal and burrowing activity. As such, bioturbation should be expected to increase with increasing vegetation. Furthermore, the presence of badgers and a large family of burrowing owls indicates that the biota can potentially move large volumes of soil. Because of this, the bank-run borrow material layer has been included in both of the

evapotranspirative cover designs as a bio-intrusion and bioturbation barrier (also serving to minimize the penetration by ants through the cover layers).

The DRC finds that the bank-run borrow material layer included in the proposed design is not likely to minimize biointrusion. The DRC accordingly requires a more effective and detailed plan than proposed.

BASIS FOR INTERROGATORY: The Licensee acknowledges the potential for burrowing on the site by small mammals. However, the design proposed for minimizing burrowing, i.e., using a bank-run borrow material layer in the amounts and manner prescribed in the PA, is found to be deficient. The thickness of the bank-run borrow material layer included in proposed evapotranspirative cover designs (1.4 to 1.7 meters, or 4.5 to 5.5 feet) is not considered by the DRC to provide nearly enough resistance to biointrusion to make cover systems effective over the long term. Successful implementation of approaches for dealing with the problems of on-site burrowing and root penetration depends on integration within cover-system design of multiple considerations relative to prevention or minimization of erosion, biointrusion and infiltration/percolation. As stated by Bowerman and Redent (1998),

> Barriers have been designed that may seem impenetrable based on engineering standards, but this is hardly the case once the design has been implemented because of the lack of foresight into the effects that ecological processes may have on a barrier. The different components taken into consideration for the design of a landfill (e.g., biointrusion, erosion, and hydrology) need to be examined synergistically for their effects on barrier performance. If the ecological characteristics of a site were investigated a priori, and used in engineering decisions, then the chances for longer-term successful performances may be achieved.

Burrowing mammals do not only bioturbate, mix or disturb soils, which can be devastating to the functionality of capillary barriers, but these animals also create extensive burrows or burrow systems, which can effectively function in soils as open conduits or tunnels and thus adversely change the physical and hydrologic characteristics of those soils. Dwyer et al. (2007) state that "biointrusion," among other factors, "can lead to increased infiltration and preferential flow of surface water through the cover system as well as contribute to the change in the soil layer's hydraulic properties." Mammalian biointrusion, along with plant-root intrusion, frost heave, freeze/thaw activity, wet/dry cycling and distortion, are known to contribute over time to an increase in the hydraulic conductivity of initially low-permeability soils. The increase in hydraulic conductivity over time can sometimes be, and often is, of several orders of magnitude. Studies pertaining to this are well documented in Benson et al. (2011). This increase in hydraulic conductivity over time can potentially result in failure of cover-system soils to adequately reduce infiltration and percolation.

Burrowing by mammals can create a number of problems. Some of these deal with cover-system infiltration. Dwyer et al. (2007), for example, state that "biointrusion can lead to increased infiltration and preferential flow of surface water through the cover system as well as contribute to the change in the soil layer's hydraulic properties." Laundre (1993) shows that burrowing by ground squirrels can increase the amount of snowmelt infiltration into soils in the spring by as much as 34%. Hakonson (1998) indicates that pocket gophers can increase rates of infiltration by 200 to 300%. Breshears et al. (2005) report that burrows made by pocket gophers in simulated landfills dramatically increased infiltration rates, i.e., by about one order of magnitude. Badger burrows at the Hanford site are reported to have captured much runoff and allowed the runoff to infiltrate into soils deeper than elsewhere on site. Measurements by researchers of moisture in soils under the burrows after artificial rainfall events demonstrated this impact. "These measurements confirmed that larger mammal burrows can and do cause the deep penetration of precipitation-generated runoff at Hanford" (Link et al., 1995).

The presence of actively growing plants appears to be a somewhat mediating influence on the effects of burrowing on subsurface drainage of water to waste. Adequate transpiration can help offset some of the impacts of burrowing. If environmental changes result in a major loss or diminution of cover-system plants, then it is likely that there will be an increase in drainage of water through radon barriers and into the radioactive waste. Hakonson (2002) says, "Erosion and percolation increase dramatically when the vegetation cover is absent in the presence of burrowing." Vegetative cover may diminish due to inadequate nutrition, excessive herbivory, or adverse environmental conditions such as fire or plant disease. Such events could potentially cause substantial increases in drainage/percolation.

On the other hand, SWCA Environmental Consultants (2012) reports that "field studies demonstrated that the density of small mammals and animal burrows increases with increasing vegetation cover."

Adverse impacts to cover-system hydrology due to burrowing by mammals cannot in general be discounted and viewed as a non-threat.

Biointrusion by animals can also lead to problems of contaminant transport in the vapor phase in the vadose zone. Hakonson (2002) says, "Vapor phase transport may also be more pronounced near the ground surface where changes in soil barometric pressure, rapid wetting and drying of soil, and plant root biomass and animal burrowing leading to macropore formation are greatest."

When mammals burrow deeply enough, they can dig into radon-barrier clay and, in some instances, bioinvade radioactive materials intended to be stored and protected underneath (See Winsor and Whicker, 1980; Landeen and Mitchell, 1981; Hakonson et al., 1982; Arthur and Markham, 1983; Hakonson, 1999, 2002; Cadwell et al., 1989; Sejkora, 1989; Landeen, 1994, Waugh and Richardson, 1997; Waugh et al., 2001; Dwyer et al., 2007). With a lack of suitable defenses against in it the design cover system, mammalian biointrusion poses an unacceptable risk at the Clive disposal facility site.

The bank-run borrow material included in the proposed ET cover-system, said in the PA to function as a bio-intrusion and bioturbation barrier, is present in cover-system design at a thickness that appears to be far below what would be required to act as an effective biointrusion barrier. As documented earlier, mammals at the site include deer mice, kangaroo rats, ground squirrels, badgers and coyotes, and each of these types of mammals has been documented at other sites to burrow deeper, and, in some instances, to burrow much deeper, than the depth of soils proposed for construction at the Clive disposal facility site. The Licensee needs to justify the design for the proposed ET cover system in terms of providing long-term protection against biointrusion.

The presence of a moderately thick soil layer by itself is recognized by a number of experts as not necessarily being sufficient to prevent biointrusion. Concerns exist because many mammals can burrow relatively deeply, just as many forbs, shrubs and trees can root very deeply.

For a moderately thick (2-meter, or 6.6 feet, thick) soil layer on a particular site, which is thicker than that proposed at Clive, Hakonson (2002) addresses the issue of whether the cover thickness alone would offer biointrusion protection, saying that he "would add that the addition of less than two meters of clean soil during ET cap construction does not assure that problems with biointrusion go away. Most plants and many animals have the potential to penetrate deeper than the proposed thickness of the ET cover."

Smith et al. (1997) make statements that indicate that a cover-system soil thickness less than three meters (9.8 feet) is probably insufficient in most areas to ensure lack of mammalian burrowing: "Infiltration barriers should be covered by a soil layer sufficient thick to extend below the frost line, to accommodate the typical rooting depths of native plants expected to invade the site, and to extend below the probable depth of animal burrows (i.e., at least 3 m in most areas)." The proposed plans for the Clive cover-system soil do not have the soil depth extending even to two meters, much less to three or more. Furthermore, deep soil by itself does little or nothing to protect underlying waste from percolation of infiltrated precipitation. As stated by SWCA Environmental Consultants (2012) , "A bioturbation barrier will likely be needed that is designed to exclude large and small burrowing mammals (i.e., mice, rats, hares, badgers)." The DRC finds the proposed plans for the cover system deficient with respect to protection against biointrusion.

On the other hand, as will be described subsequently, use of a soil layer that is sufficiently thick to minimize biointrusion by itself but without needed transpiration capability, and/or capillary-barrier capability may likely lead to severe problems with soil moisture not being fully stored in, retained in, and restricted to the plant rooting zone. Instead, in such a layer, depending on the relative evapotranspiration rate, infiltrated moisture may continue to move downwards, potentially penetrating waste, the vadose zone, and, eventually, the saturated zone. Effective approaches to biointrusion that are not dependent simply on the use of a thick soil layer, on the other hand, have been developed and implemented by various biointrusion experts, and may provide concepts useful at the Clive facility.

One approach said to be effective is the use of a cobbles in one or more biointrusion barriers. This approach is designed to minimize or prevent burrowing by animals to depths greater than the depth of the top of the cobble layer (e.g., see Cline et al., 1980; 1982).

At the Department of Energy tailings site in Monticello, Utah, a biointrusion layer of this type consists of a layer of native cobbles interspersed with finer topsoil. This layer is approximately 30 cm (~1 foot) thick, and it is buried at a depth below approximately one meter (~3 feet) (see Waugh and Richardson, 1997; Waugh et al., 2001). The biointrusion layer overlies about 30 cm (~1 foot) of fine-grained soil, which in turn overlies a capillary barrier. An biointrusion layer of appropriately sized cobbles may be useful at the site for one or more species of burrowing animals.

Dwyer et al. (2007) confirm the appropriateness of a cobble-based mammal-biointrusion barrier, provided that each cobble weighs at least 1.5 times that of the biointruding animal, and that the cobble-to-soil ratio is at least 50%. Assuming a relative particle density of rock of 2.65 compared to that of about 1.0 for mammalian flesh, the volume ratio between cobble and animal would be about 0.56. Additional information on design of biointrusion barriers is found in several sources, including Dwyer et al. (2007).

However, cobble-based approaches must achieve two different objectives, only one of which is referenced by Dwyer et al. (2007). First, a layer of cobbles must consist of cobbles having weights too great for a species of concern to lift or push. Second, a layer of cobbles must consist of cobbles with openings between themselves too small for that species to enter and move downward within. These objectives must generally be attained by materials species or size-range specific for each layer.

A layer of cobbles that meets these criteria for one species may not do so for another. Thus, a sequence of layers each tailored individually for each species, or at least one general size of animal, may generally be necessary when multiple species of burrowing animals may be present. An exception would be if layers prevented burrowing by all smaller prey species, thereby limiting incentive for a larger predator to burrow for food.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): Page 2-6 says, "Soil conditions on and near the Clive site are typical of soils formed in arid environments." Please rewrite the text to show that soils on site are not typical of but are, in fact, relatively rare for arid environments.

BASIS FOR INTERROGATORY: Soils at Clive actually cannot be considered as soils typical of those formed in arid climates. Their atypical nature has a number of important ramifications.

It is rather hard to say, first of all, what types of soils in an arid or a semi-arid environment are typical. Arid environments include hot deserts, cold deserts (as at the poles, but also the Great Salt Lake Desert), and rain-shadow areas downwind of mountain ranges (also applicable to the Great Salt Lake Desert). Some deserts contain windblown siliciclastic sand dunes, other deserts are hamadas or regs with stony or bedrock surfaces, while some deserts contain various other types of soils. Clive soils obviously cannot be typical of all of these arid environments.

Rather than being typical, soils at and near the Clive site actually appear to be relatively rare for soils formed in arid environments. This is apparent when viewing classification schemes for surface rock and soil features of deserts and other arid environments abroad (e.g., see Petrov, 1976). It is also apparent when comparing other arid regions of the United States. In a study of the mineralogy of windblown dusts in southern Nevada and California, for example, the sand- and silt-sized fractions were mostly quartz and feldspar, with minor carbonate, and the clay-size fraction was mostly smectite and biotite, with little if any carbonate (Reheis and Kihl, 1995). By contrast, based on studies for the Licensee conducted at the University of Utah Research Institute (1993), clay and silt particles of Unit 4 silty clay at the Clive site are reported to consist predominantly of calcium carbonate (65% of total fines). Of that, most is aragonite (82% of all calcium carbonate). Clay minerals (i.e., smectite, kaolinite and illite/mica) make up only 18% of the total fines. Fine calcium carbonate particles are not commonly predominant in most desert or other arid-land soils.

Calcium carbonate dissolves much more readily under mildly acidic conditions (e.g., pH =3-5) than do silicon dioxide, feldspar or clay minerals, which are common minerals in many arid environments. This fact may be important in some waste repositories if and when mildly acidic materials are disposed of. Calcium carbonate also has other physical and chemical properties that silicon dioxide, feldspar or clay minerals do not have. Very importantly, clay-size calcium carbonate grains do not contain the relatively high surface charges per unit area of clay mineral grains. Surface charges are generally responsible, for example, for cohesion, and thus, to a large extent, erosion resistance, in clays consisting largely of clay minerals.

Not only do the grains in Clive soils consist predominantly of calcium carbonate, but most of the particles (e.g., 95%) are silt or clay size (sub-microns to tens of microns). This contrasts with carbonate caliche often found in arid sediments, which generally appears as a hard, cohesive rock layer. The smallest calcium carbonate grains at Clive also differ significantly in some ways from similarly sized particles consisting solely of clay minerals (e.g., kaolinite and illite), as are commonly found in some arid environments. On the other hand, it is acknowledged that the soils at Clive do contain some smectite clay minerals (e.g., $\leq$ 15%), and these do impart some cohesive properties to these finer-grained soils.

On the whole, it is apparent that soil conditions at Clive are not typical of soils found in arid environments. They are, in fact, relatively rare.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6

INTERROGATORY STATEMENT(S): Page 3-4 says, "The site-specific Performance Assessment developed in support of the disposal of depleted uranium evaluated the impact of ant burrowing on the transport of contaminant and found no significant associated impact to the performance of the Embankment." That study and its conclusions are not found to be relevant to this PA. Please revise this PA to provide analysis of potential significant impact on embankment performance and effects on human health and the environment due to harvester ants burrowing through cover-system soils.

SUMMARY OF BASIS FOR INTERROGATORY: The argument from the PA in the quotation above is not accepted by the DRC. The site-specific PA, in speaking of depleted uranium, says, "ant nests are not assumed to get into the waste, which is about 5m or more below ground surface." However, the cover system described in the current site-specific PA being evaluated in these interrogatories is designed for all LLW in the CAW embankment – not just blended and processed resin LLW buried at depth. Waste considered in these interrogatories thus must also include Class A waste located just below the radon barrier at 1.4 to 1.7 meters (4.5 to 5.5 feet) of depth. So, based on the ant burrowing depth described in PA itself, it is evident that harvester ants can biointrude into LLW. It is known from published resources that harvester ants can damage cover system integrity, impact near-surface hydrology including drainage of water, and bring radionuclides to the surface. Failure to consider this in the PA and to develop successful countermeasures to minimize risk to human health and the environment is unacceptable based on the rules and regulations cited below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The PA argument dismissing ant burrowing impacts on the cover system is not accepted by the DRC. What was determined in the case of the PA for disposal of depleted uranium is not relevant to design of covers for disposal of Class A waste, owing to the fact that depths to waste of interest differ. The newly proposed cover system described in the PA for blended spent ion-exchange media is for all wastes in the embankment, including Class A waste located just below the radon barrier. The PA document states, "Although the effect of burrowing ants is modeled, it is not expected to have a large influence on model results because ant nests are not assumed to get into the waste, which is about 5m or more below ground surface for the disposal configurations considered." However, under the proposed design, bulk Class A waste may be found at depths of only 54 to 66 inches (1.4 to 1.7 meters) below the surface, not just at 197 inches (5 meters) or deeper.

Harvester ants can potentially tunnel into the Class A waste at the Clive Disposal Facility under the proposed design. Results of a field study at the Clive Waste Disposal Facility in 2010 indicate that Western harvester ants (*Pogonomrymex occidentalis*) maintain nests in areas of abundant grass at the site at densities of up to 33 nests per hectare (SWCA, 2012b). Many ant species, including harvester ants, are reported to be able to tunnel down into soil to relatively great depths. Willard (1964), for example, reports that harvester ants can burrow down to 2.7 to 4.6 meters in semiarid and arid areas.

Any depth of burrowing over the 30-42 inches (0.76-1.1 meters) of depth to the radon barrier in the proposed design affects the radon barrier, and any depth of burrowing over the 54-66 inches plus whatever depth of thin layer of soil exists below cover (1.4-1.7 meters, plus the depth of the thin layer of soil below cover) in the proposed design affects the waste. Observed tunneling by harvester ants to depths of 2.7 to 4.6 meters noted at some sites is certainly greater than the depth of the base of the cover system at Clive at 1.4 to 1.7 meters. Harvester ant tunneling beneath mounds and removal of vegetation above and around mounds affects movement and storage of water in soil (Blom, 1994). In addition, bioturbation of soil in ant mounds can mix radioactive waste into upper portions of the soil. Blom et al. (1991) show that, because of harvester ant tunneling, Cesium-137 (^{137}Cs) and Cobalt-60 (^{60}Co) activities in Idaho National Engineering Laboratory soils at wastewater ponds near laboratory reactors were twice as high in ant mounds as in surrounding soils. Thus, burrowing by ants in cover-system soils at the site will create additional risk that must be evaluated.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6 (cont'd)

INTERROGATORY STATEMENT(S): After mention of ants, it says on Page 3-4, "other burrowing animals at the site include jackrabbits, mice, and foxes." Please make this listing of burrowing animals at the site more complete by adding to the list kangaroo rats, ground squirrels, badgers and coyotes.

BASIS FOR INTERROGATORY: While jackrabbits, mice and foxes may exist on site, and some of these do burrow, there are other mammals of equal or greater local concern that may burrow on site. As previously discussed, these include kangaroo rats, ground squirrels, badgers and coyotes. All of these, along with mice and foxes, have been reported to have been seen on or near the site in SWCA (2011; 2012). The current PA fails to acknowledge in Section 3.1.6 some of the more important fossorial (burrowing) animals when claiming to list burrowing animals at the site. This leaves the statement incomplete and potentially misleading.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6 (cont'd)

INTERROGATORY STATEMENT(S): Page 3-4 refers to "other burrowing animals at the site" and lists among them "jackrabbits". Jackrabbits do not burrow, per se. Please correct the quoted statement.

BASIS FOR INTERROGATORY: This information in the Page 3-4 statement quoted above is not correct. Black-tailed jackrabbits (*Lepus califonicus*) found at the site cannot properly be described as burrowing mammals.

"Jackrabbits are not true rabbits at all, but are actually hares . . . hares use only forms or surface nests, whereas most rabbits retreat to burrows when alarmed" (McAdoo and Young, 1980).

"Black-tailed jackrabbits are herbivorous and do not burrow . . . " (Nagy et al., 1976).

Please correct the erroneous statement made in the text about jackrabbits burrowing.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6 (cont'd)

INTERROGATORY STATEMENT(S): On Page 3-4, it states, "The first deterrent to burrowing animals is the rock armor rip-rap erosion barrier and evapotranspirative bioturbation barrier." Why is a barrier made of rip rap material mentioned in connection with deterrence of burrowing when preferred cover system designs discussed in the PA do not use rip rap? Also, what is meant by "evapotranspirative bioturbation barrier" which supposedly is a component of the first deterrent to burrowing animals? Also, please revise the language here to clarify statements made and to be consistent with peer-reviewed literature references. Please correct technical errors. Alternatively, please justify the statement quoted as is.

SUMMARY OF BASIS FOR INTERROGATORY: There is no "design rock armor rip rap erosion barrier" mentioned in the PA for proposed cover-system Designs 1 and 2. Throughout the PA, cover-system Design 3 is not favored, primarily because its rip rap surface layer substantially reduces evaporation. The evaporative zone layer in the preferred design(s) is where much evapotranspirative uptake of water is thought to take place, but it does not offer significant resistance to burrowing by mammals or to plant-root biointrusion. The argument by the Licensee quoted above appears to be incorrect.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The statement above is not applicable to the design cover system. There is no "design rock armor rip rap erosion barrier" mentioned in the PA for cover-system Designs 1 and 2. Cover-system Design 3 is not favored throughout most of the PA, in part because its rip rap surface layer substantially reduces evaporation.

The DRC does not expect the evaporative zone layer, or any other layers in the proposed design cover system, to offer much resistance to burrowing by a determined fossorial mammal of suitable size. The statement quoted above from the PA is not supported by available evidence.

Fossorial mammals of large size, such as badgers, can burrow well. Badgers, in particular, are extremely strong. Badgers are remarkably adapted for digging in many sorts of soils. They can likely remove cobbles of considerable size while digging for prey or burrowing. Dwyer et al. (2007) suggest that cobbles used in a cobble biointrusion barrier weigh at least 1.5 times the weight of the burrowing mammal. Badgers can weigh up to about 26 pounds in late fall after eating heartily all summer long. So, if protection were to be made against burrowing by badgers, then the weight of the lightest framework elements (e.g., cobbles or boulders) at Clive would need to be approximately 39 pounds. For a spherical cobble or boulder with a solid density of 2.65 g/cm^3, the diameter would be at least 0.23 meters (9.2 inches, or 0.77 feet).

To prevent biointrusion by badgers, not only would each cobble or boulder need to be as weighty as described above, but the pore throats linking the pores or voids between the cobbles or boulders (considering them only in a self-supporting framework at this point) would each need to have a diameter narrower than the largest transverse diameter of the head, rib cage and hips (exclusive of fur or hair) of a badger seeking to intrude. Badgers can presumably remove any infilling cobbles or gravel smaller than this as they burrow.

A large mammal, such as a badger, would have no problem burrowing through the evaporative zone layer, consisting, as it does, of only silty clay. Neither the grain size nor the thickness of the layer would offer substantive deterrence to the mammal's burrowing. In other layers, such as the surface layer, or the frost protection layer, smaller cobbles, gravel, sand, silt and clay can be removed as needed by a larger mammal as it burrows. Smaller mammals may be able to remove materials up to a given size and fit between the cobbles or gravel associated with larger materials. Very small animals, such as deer mice, can easily fit through voids created between cobbles or large gravel by removing small gravel, sand, silt and clay as they burrow.

To deter biointrusion by other species would likely involve additional design considerations, e.g., those related to infilling material, or multiple protective layers. Protection must be sought against biointrusion not only by larger mammals but by smaller mammals that can pass through larger pore throats.

One possible alternative to designing the cover-system specifically to prevent burrowing by badgers is to eliminate or minimize motivation for badgers to burrow. Despite a cover system containing edible vegetation attractive to smaller mammals, smaller mammals that could serve as prey for badgers can be kept from burrowing, or their burrowing can be minimized, by constructing biointrusion barriers specifically designed to keep the smaller mammals out of the cover system. If there is no prey for badgers to dig for, then burrowing by badgers on the cover-system might be greatly minimized. The vast majority of badger burrows are dug in search of prey.

Elsewhere in this document, it is made abundantly clear that a potential exposure pathway for the site is the burrowing animal pathway.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6 (cont'd)

INTERROGATORY STATEMENT(S): On Page 3-4, the following is stated, with reference to the "rock armor rip-rap erosion barrier" (which does not exist in the proposed preferred design

1 and design 2 designs), and "evapotranspirative bioturbation barrier" (which, as proposed in the design, would be nearly useless against burrowing by many species of mammals): "While these may be only partially effective in deterring animals, the primary protective barrier is the clay radon barrier. The burrowing species at the site are not known to dig to such a depth that their burrows could penetrate through the entire cover and into the waste." Please revise the text description and incorporate into it the modeling effects of damages to the proposed cover system from burrowing into the proposed cover system soils and the underlying waste, and design the cover system to prevent or minimize biointrusion. In models, use conservative assumptions based on professional literature findings when considering potential effects of burrowing.

SUMMARY OF BASIS FOR INTERROGATORY: The statement that "burrowing species at the site are not known to dig to such a depth that their burrows could penetrate through the entire cover and into the waste" does not appear to be valid. The total thickness of the proposed design cover system is given in the document as ranging from 1.4 to 1.7 meters (4.5 to 5.5 feet), depending on the thickness selected for the frost-protection layer. Deer mice, kangaroo rats, ground squirrels, kit foxes, badgers, and coyotes are species each reported to have been seen on or near the site. Documented maximum burrowing depths reported for these fossorial mammals are 7.9 feet, 5.7 feet, 5.5 feet, 8.2 feet, 7.5 feet, and 16.2 feet, respectively. These depths are equivalent to depths of 2.4, 1.7, 1.7, 2.5, 2.3 and 4.9 meters. It appears that individuals of any of these species can likely penetrate the cover system and enter the waste. Soils like those proposed for the cover system do not appear to act as deterrents to burrowing. All of the mammals mentioned above can thus potentially burrow into the waste. Please revise the PA, which implies or states that these mammals cannot do so.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The statement that "burrowing species at the site are not known to dig to such a depth that their burrows could penetrate through the entire cover and into the waste" is invalid. The total thickness of the proposed design cover system is given in the document as ranging from 1.4 to 1.7 meters (4.5 to 5.5 feet), depending on the thickness chosen for the frost-protection layer. The thickness of soil above the radon barrier is equal to the total thickness less 0.6 meters (2 feet), or 0.8 to 1.1 meters (2.5 to 3.5 feet). As documented earlier in this document,

- Coyotes are reported to burrow down to as deep as 16.2 feet (4.9 meters).
- Kit foxes are reported to burrow down to as deep as 8.2 feet (2.5 meters).
- Deer mice are reported to burrow down to as deep as 7.9 feet (2.4 meters).
- Badgers are reported to burrow down to as deep as 7.5 feet (2.3 meters).
- Kangaroo rats are reported to burrow down to as deep as 5.7 feet (1.7 meters).
- Some species of ground squirrels are reported to burrow down to as deep as 5.5 feet (1.7 meters)

The depths reported above reflect only maximum depths reported from a limited number of scientific studies. It is assumed that the absolute maximum depths of burrows attainable by the species of mammals listed above is actually higher. It is apparent, then, that the potential exists for a mammal of any of the species listed above to "dig to such a depth that their burrows could penetrate through the entire cover and into the waste" at the Clive Waste Disposal Facility.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.6 (cont'd)

INTERROGATORY STATEMENT(S): It says on Page 3-4 "After final placement of the cover, the design features of the facility, primarily the thick soil cover that isolates the waste from burrowing animals, will control releases and doses. Because of this, the likelihood of any animals burrowing through the entire cover and exhuming waste materials is sufficiently low that it was not included in the safety assessment calculations." The Licensee needs to recognize the potential problem here. The statement that "the likelihood of any animals burrowing through the entire cover and exhuming waste materials is" sufficiently low that the Licensee need not regard it in safety assessment calculations appears to be egregiously in error. The Licensee needs to develop in both its design and its modeling efforts effective measures to understand and prevent or minimize mammalian biointrusion into the radon barrier and waste. Any modeling that assumes no changes in cover-system soil hydraulic conductivity, such as that resulting from biointrusion and other processes, is unacceptable to the DRC. The Licensee must consider biointrusion through the cover and into the waste in its safety assessment calculations.

BASIS FOR INTERROGATORY: As previously reported for other sites, biointrusion in soils by mammals to depths beyond that of the design thickness of the proposed cover-system is well documented. Deer mice, kangaroo rats, ground squirrels, kit foxes, coyotes and badgers, all of which have been noted at or very near the Clive site, may potentially biointrude into or through the site cover-system soils, based on proposed cover-system design depth and materials. Each of these types of mammals is known to burrow to depths equal to or greater than the depth of the planned base of the cover system. Proposed design for cover-system soils does little to prevent or minimize mammalian biointrusion.

Burrowing by mammals can create a number of problems. Some of these deal with cover-system infiltration. Dwyer et al. (2007), for example, state that "biointrusion can lead to increased infiltration and preferential flow of surface water through the cover system as well as contribute to the change in the soil layer's hydraulic properties." Laundre (1993) shows that burrowing by ground squirrels can increase the amount of snowmelt infiltration into soils in the spring by as much as 34%. Hakonson (1998) indicates that pocket gophers can increase rates of infiltration by 200 to 300%. Breshears et al. (2005) report that burrows made by pocket gophers in simulated landfills dramatically increased infiltration rates, i.e., by about one order of magnitude. Badger burrows at the Hanford site are reported to have captured much runoff and allowed the runoff to infiltrate into soils deeper than elsewhere on site. Measurements by researchers of moisture in soils under the burrows after artificial rainfall events demonstrated this impact. "These measurements confirmed that larger mammal burrows can and do cause the deep penetration of precipitation-generated runoff at Hanford" (Link et al., 1995). Much greater than anticipated infiltration can result in long-term safety and performance problems.

The presence of actively growing plants appears to be a somewhat mediating influence on the effects of burrowing on subsurface drainage of water to waste. Adequate transpiration can help offset the impacts of some burrowing. If environmental changes result in a major loss or diminution of cover-system plants, on the other hand, then it is likely that an increase in drainage of water through radon barriers and into the radioactive waste will follow. Hakonson (2002) says, "Erosion and percolation increase dramatically when the vegetation cover is absent in the presence of burrowing." Vegetative cover may diminish due to inadequate nutrition, excessive herbivory, or adverse environmental conditions such as fire or plant disease. Such events could potentially cause substantial increases in drainage/percolation.

On the other hand, SWCA (2012) reports that "field studies demonstrated that the density of small mammals and animal burrows increases with increasing vegetation cover."

Adverse impacts to cover-system hydrology due to burrowing by mammals should not in general be discounted and viewed as a non-threat.

Biointrusion by animals can also lead to problems of contaminant transport in the vapor phase in the vadose zone. Hakonson (2002) says, "Vapor phase transport may also be more pronounced near the ground surface where changes in soil barometric pressure, rapid wetting and drying of soil, and plant root biomass and animal burrowing leading to macropore formation are greatest."

This site will require a biointrusion barrier. In a report about the potential for an evapotranspirative cover for the site, SWCA (2012) reported very clearly and forcefully states on Page ii of its Executive Summary that "a bioturbation barrier will be needed." The potential for uncontrolled or poorly controlled releases of radionuclides such as radon and associated doses thus exists. The statement "the likelihood of any animals burrowing through the entire cover and exhuming waste materials is sufficiently low that it was not included in the safety assessment calculations" is without sufficient foundation.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.3

INTERROGATORY STATEMENT(S): On page 3-7, it says, with respect to the current operational period, "Burrowing animals are prevented from contacting the waste materials." Please explain how this is currently being accomplished.

BASIS FOR INTERROGATORY: It is not clear from the PA how burrowing animals are currently prevented from contacting the waste materials.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

6.0 PLANT COVER, MODEL PLANT PARAMETERS AND BIOINTRUSION BY PLANT ROOTS

SECTION: 2.1.11

INTERROGATORY STATEMENT(S): It is said on Page 2-5 "The plant species selected for the evapotranspirative cover system should consist of native and desirable non-native, salt tolerant shrubs and grasses." The DRC requests the Licensee to specify whether they will attempt to plant flora on the engineered embankment as part of the proposed ET cover. If so, then the Licensee must describe the suitability of plants used, and the suitability of the soil properties and soil thickness for growing them. Also, if plants intended for planting (if that is to be done) have successfully been introduced during reclamation into other environments similar to the one at Clive, please describe and document this as well.

SUMMARY OF BASIS FOR INTERROGATORY: The growth of desirable native plants at the site can potentially enhance cover-system effectiveness and consequently reduce the migration of radionuclides that could otherwise adversely impact the general population that may exist at any time during the next 10,000 years at Clive, including inadvertent intruders; see rules UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20. However, little if any information is provided in the PA about what types of plants, if any, might be planted at the site, what their properties are, and what properties of soils in which the plants may be planted are.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: In addition to being salt tolerant, plants that may thrive at the Clive facility site must have other characteristics suitable for the environment before they can be sustained over long periods of time. Please indicate which plants are intended to be planted, and discuss, among other things, (1) the range of precipitation for environments in which these plants tend to naturally grow, (2) altitudes at which these plants tend to naturally grow, and (3) average and maximum documented root depths for these plants.

In addition, cover-system soils must support planted grasses and shrubs over an extended period of time. The cover-system soils therefore require soil characteristics and thicknesses adequate to support or accommodate a healthy growth of plants and plant roots, and these soils must also be able to store sufficient water to support plant growth. Therefore, please provide a chart detailing characteristics of soil to be used in the rooting-depth zone of the cover at Clive in terms of (1) pH, (2) percent organic matter, (3) percent total nitrogen, (4) extractable phosphorus in mg/kg, (5) extractable potassium in mg/kg, (6) percent clay-size particles, (7) percent sand-size particles, (8) gravimetric or volumetric water content, (9) cation exchange capacity, (10) electrical conductance, (11) sodium adsorption ratio (SAR), and (12) bulk dry density, and also describe how these characteristics compare with generally recommended levels for plant emergence, growth and sustainability.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): It is said on Page 2-5 "The plant species selected for the evapotranspirative cover system should consist of native and desirable non-native, salt tolerant shrubs and grasses." Please provide an appropriate biointrusion defense design for the cover system effective against deep plant rooting, or account in modeling for increases over time in infiltration rates.

SUMMARY OF BASIS FOR INTERROGATORY: The penetration of plant roots below a protection layer is undesirable for the ET cover system. Without a suitable biobarrier effective against plant root growth into the radon barrier or into the radioactive waste, plant rooting at the Clive Disposal Facility can potentially threaten the integrity of cover system components and damage the cover system, allowing excessive water to drain into waste and to percolate into and contaminate groundwater, permitting the release of radon into the atmosphere, or both, thereby increasing risk to people and the environment. Biointrusion by roots can potentially increase the hydraulic conductivity of cover-system soil by as much as two orders of magnitude. This might have highly negative impacts on percolation of infiltrated water into the waste. The model needs to account for increased infiltration over time due to enhanced hydraulic conductivity.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Biointrusion of radon barriers and waste by plant roots at the Clive site is a concern based on inadequate plans for barriers to resist biointrusion provided for in the proposed cover-system design. The proposed cover system is only 1.4 to 1.7 meters (4.5 to 5.5 feet) thick. Many plant roots are capable of penetrating layers of soil material that thick or thicker (See Waugh et al., 1999; Hakonson, 2002; Schenk and Jackson, 2002). Hakonson (2002), for example, says that he "would add that the addition of less than two meters of clean soil during ET cap construction does not assure that problems with biointrusion go away. Most plants and many animals have the potential to penetrate deeper than the proposed thickness of the ET cover." Elsewhere in the same document, he says, "most 'shallow rooted' plant species have the capability to send roots much deeper than the couple of meters of cover proposed." It is noted that he says here "much deeper". The presence of silty clay soil, well-graded frost protection soil, and other soils in the proposed cover-system design are not expected to provide adequate resistance to plant rooting to create an effective deterrent to plant biointrusion.

Schenk and Jackson (2002) indicate that the 90% range for root-system depth for forbs and semi-shrubs in areas of low water availability extends to 3.7 meters (~12.1 feet), with some 10% of other forbs and semi-shrubs going deeper. They also indicate that the 90% range for root-system depth for shrubs in areas of low water availability extends to 7.2 meters (~23.6 feet), with 10% of other shrubs going deeper. Obviously, these documented root-system depths are much greater than the proposed planned cover-system depth. This is critical because, as Schenk and Jackson (2002) state, "It is important to remember . . . that root channels and macro-pores are likely to act as conduits for water recharge deeper than predicted by simple infiltration models."

Penetration of a radon barrier by roots can dramatically increase the hydraulic conductivity of the radon barrier. Waugh et al. (1997; 1998) state that, at one site containing buried radioactive materials that they investigated, in Burrell, Pennsylvania, "We measured a 2-orders-of-magnitude increase in the Ksat where plant roots penetrated the compacted soil layer (CSL or radon barrier)."

There is no guarantee that shrubs on site will not root deeply through the cover system as it is currently proposed and penetrate the radon barrier and the waste sometime during the 10,000-year post-closure modeling time period. The DRC has, in fact, noted incipient encroachment of shrubs or larger plants on covers at other facilities, even over relatively short time spans. Without a suitable biobarrier system at Clive, the likelihood of biointrusion interfering with effective storage of waste becomes much greater. The DRC anticipates biointrusion into radon barriers and possibly waste if no effective biointrusion barriers are implemented as part of the cover system.

One potential deterrent to plant biointrusion at depths greater than about four feet is a properly constructed capillary barrier. It is surmised by Anderson and Forman (2002) that a properly constructed capillary barrier should "restrict root growth so long as the underlying materials are relatively dry." Sands and gravels in deeper portions of a capillary barrier should remain dry except occasionally during times when infiltration fronts move through the system. At such times, a properly constructed capillary barrier, with an underlying clay layer below it, could function as a filter layer to help remove the water.

Without a suitable biobarrier system at the Clive disposal facility site, the DRC is concerned about the potential for biointrusion, especially by roots of shrubs. One danger of having no effective biobarrier to plant rooting in cover system soils and/or no relatively dry capillary barrier is that some plants may send one or more of their tap roots down to great depths in search for water, and such deep root growth could potentially lead to developing holes in the cover system and even into the waste. These holes could serve as conduits for liquid or gas movement, e.g., that of radon gas flowing to the surface, or that of water percolating into waste.

The lack of a competent biointrusion barrier in the proposed plans for the cover system is of serious concern to the DRC. The DRC does not view 1.4 to 1.7 meters (4.5 to 5.5 feet) of random fill as an effective deterrent, much less a guarantee, against biointrusion. Please revise the cover system design to address this concern.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): It is said on Page 2-5 "The plant species selected for the evapotranspirative cover system should consist of native and desirable non-native, salt tolerant shrubs and grasses." The Licensee needs to account for the potential for greasewood, a native, salt-tolerant shrub presently growing on site, to grow roots to depths much deeper than the proposed thickness of the entire cover system. This has obvious implications for biointrusion into the radon barriers and waste and also speaks to an onsite need for effective plant-root biointrusion barriers. Please address these.

The PA, on Page 2-6, also says, "A few large, woody roots were encountered in deeper soils. Rooting depths were shallower than expected, with the maximum rooting depth of dominant woody plant species ranging from 16 to 28 inches." The Licensee needs to acknowledge that potential exists at site locations other than those excavated for black greasewood to root more deeply than 0.4 to 0.7 meters (16 to 28 inches), perhaps even down to depths of 3 to 9 meters (10 to 30 feet), and adjust modeling concepts and parameters accordingly.

SUMMARY OF BASIS FOR INTERROGATORY: Plants at Clive can biointrude into radon barriers and possibly into waste. Roots of halogeton, for example, have been found in radon barriers in the Vitro Embankment at Clive (see Bowerman and Redente, 1998). Many reports about sites at other locations indicate that black greasewood, a shrub commonly found in parts of the Clive site, is an obligate phreatophyte, a plant that depends on obtaining water from taproots sent down to the water table, or just above it. These reports often indicate that greasewood can send down roots as deep as 10 meters (33 feet) or more. Deep rooting by greasewood or other plants can potentially damage cover-system soils at a site and can cause penetration of radon barriers and even waste. This can have deleterious effects on migration of radionuclides that could, under some conditions, adversely impact the general population, including inadvertent intruders, contrary to rules UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: While on the topic of shrubs and biointrusion, it is pointed out that a dominant shrub growing natively at the Clive site is greasewood. Greasewood is reported on page 36 of the PA (see also Page 2-6) to have been noted on site to root to only relatively shallow depths, i.e., to only about 0.8 meter. However, that report is based solely on three excavations in natural soils made on site, which are not necessarily representative of all conditions on site.

The scientific name of greasewood is *Sarcobatus vermiculatus*. Nichols (1993) refers to greasewood as "the most important phreatophyte in the Great Basin." A phreatophyte is, by definition, a plant whose root or roots extend down to the water table, or to the capillary fringe directly above the water table. Actual sourcing of groundwater uptake by phreatophytes may be from the saturated capillary fringe, which is under negative gage pressure, which may extend upwards from the water table for some distance, depending on soil grain size. Waugh (1998) states that "*Sarcobatus* is an obligate phreatophyte requiring a permanent ground-water supply, and can transpire water from aquifers as deep as 18 meters below the land surface (Nichols 1993)." An obligate phreatophyte is a plant that depends for survival on access to groundwater through one or more of its roots, usually one or more tap roots. Maxwell et al. (2007) also state that greasewood is an obligate phreatophyte, whose roots *almost always* grow into groundwater. WSDNR (2011) states that "*Sarcobatus vermiculatus* is an obligate phreatophyte and is able to tap into groundwater at great depth (>10 meters)." Ten meters is equivalent to 33 feet. These statements by experts indicate that the rooting depth of greasewood on site of only about 0.7 to 0.8 meters (2.3 to 2.6 feet) as reported by the Licensee at several locations is not likely to be representative for greasewood at all locations on site, since the water table on site may be 5 to 10 meters (16 to 33 feet) deep.

Numerous studies indicate that greasewood can send down tap roots to exceptional depths in search of the groundwater table or a capillary fringe above a zone of groundwater. Meinzer (1927) states that "Near Grandview, Idaho, H. T. Stearns observed roots of greasewood penetrating the roof of a tunnel 57 feet below the surface." Fifty-seven feet below the surface is equivalent to a depth of 17 meters. White (1932) reports greasewood generally growing at localities where the depth to groundwater is 25-40 feet (7.6 to 12 meters) deep, and in several small tracts where the depth to groundwater is 50 to 60 feet (15 to 18 meters). Robinson (1958) refers to Shantz and Piermeisel (1940) reporting that, along a stream bank near Moab, Utah, ". . . a greasewood 6 feet tall had roots down 18 feet, a taproot 3 inches in diameter down 6 feet and abundant feeding roots, some 10 feet long, at a depth of 10 to 12 feet." Eighteen feet is equivalent to 5.5 meters. Harr and Price (1972) report greasewood rooting depths of at least 12.7 m (42 feet). According to Cooper et al. (2006), Robertson (1983) is said to have reported greasewood roots to depths of 11 meters (36 feet). Nichols (1993) states that numerous studies indicate that greasewood grows in areas with depths of groundwater down to relatively great depths, including some to 18 meters (60 feet). Chimner and Cooper (2004) report that xylem water from greasewood plants overlying a groundwater table at a depth of about 13 meters (43 feet) was isotopically similar to xylem water from greasewood at other sites where groundwater ranged from 2 to 13 meters (6 to 43 feet) deep.

Studies of black greasewood rooting depth at Clive to date involve limited exploration effort, with exploration to date having been limited to only three excavations. There is thus no reason to assume that maximum site rooting depth at all places on site will be limited to 0.71 meters (28 inches), even though roots of black greasewood plants have been found in the three excavations only down to this level. This shallow level, however, is only four to eight percent of the maximum rooting depth reported to have been found for black greasewood at other sites. This reported depth (0.71 m = 28 inches) happens to be inconsistent with the depth shown for rooting in Figure 11 of the PA (down to 31.5 inches = 0.80 m).

Neptune and Company, Inc. (2011a), as part of their analysis of biological issues related to burial of depleted uranium at the Clive site, hypothesize that the many small greasewood plants observed on the site have shallow roots that, they think, cannot penetrate drier soil. They do not provide any supporting evidence for this hypothesis. They do say, however, in reference to black greasewood, "Still, *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 [emphasis added]. A maximum root depth of 5.7 meters (Robertson, 1983, p. 311) is used in this model." However, the model in which greasewood was considered to move down to depths of as much as 5.7 meters was the depleted uranium (DU) PA for the Clive site. By contrast, the current PA does not recognize plant rooting of dominant woody plants beyond a very shallow depth of 0.7 meters (28 inches) (Page 2-6; see also Page 36 of Neptune and Company, Inc., 2012). Not only is the assumption of rooting only down to 0.7 meters (28 inches) non-conservative, but it is inconsistent with conservative assumptions of the DU PA.

Other plants on site can also potentially send roots down into deeper layers such as the clay radon barrier and the waste. USDA (2013) states that Kearney et al. (1960), for example, report that fourwing saltbush roots, in soils that permit it, can penetrate the soils down to depths of up to 6 m (20 feet).

Deep rooting on the cover system soil can damage them and have deleterious effects on migration of radionuclides that could, under some conditions, adversely impact human health or the environment through one or more releases, including inadvertent intruders, contrary to rules UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.1.11 (cont'd)

INTERROGATORY STATEMENT(S): On Page 2-5, it says, "The plant species selected for the evapotranspirative cover system should consist of native and desirable non-native, salt tolerant shrubs and grasses." Please revise proposed plans accordingly to include only native plants, or justify inclusion of non-native species. If non-native species are included, then the licensee must provide the percent coverage of "desirable" non-native plants and their names to allow the DRC to assess vegetative cover design performance.

SUMMARY OF BASIS FOR INTERROGATORY: In general, Federal guidance recommends against fostering the growth of non-native plant species at disturbed sites.

Growth of undesirable non-native plants at the site can potentially have deleterious effects on cover-system effectiveness and consequently on the migration of radionuclides that could, under some conditions, adversely impact the general population that may exist at any time during the next 10,000 years at Clive, including inadvertent intruders, contrary to rules UAC R313-25-

8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20. The selection of plant species is an important consideration in the design of the evapotranspirative (ET) cover system.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Please justify why non-native species should be included in the mix at all. Native plants, occurring either presently on site, or having previously lived on site, are generally preferred as a means of achieving reclamation.

Elliot et al. (1987) state "Using native plants is a preferred reclamation strategy when attempting to reclaim lands disturbed by industry or industry-related activities."

Relative to minimizing adverse impacts on soils at in-situ leaching (ISL) facilities, the U.S. NRC recommends "best management construction practices to prevent or substantially reduce soil impacts", which include "reestablishing native vegetation as soon as possible after disturbance" (U.S. NRC, 2003).

The U.S. Department of the Interior's Bureau of Land Management (BLM) advocates preferential use of native plants. The following information is provided on the Web page http://www.blm.gov/wy/st/en/programs/pcp/materials/why.html:

> Restoration and Reclamation efforts are more likely to be successful when locally-sourced native plant materials are used because those plants are genetically adapted to the local conditions. So:
>
> - Try to use local native plants. Locally collected seed can be used directly or can be increased agriculturally. You can also use transplants from disturbance salvage, or nursery container stock grown from local seed sources.
> - The next best choice is to use native plant materials (seed, transplant or other propagule) derived from regional genotypes. Plant materials originating in Utah are likely to be more successful in Wyoming than those from Iowa, simply because they are adapted to similar growing conditions including drought and high elevation.
> - In general, use native plant materials rather than non-native species. If non-native species replace local native plants at any particular site, we lose the genetic diversity of plants, microbes and sometimes animals that have evolved to adapt to the environmental conditions at that location.

The BLM (2008) says elsewhere,

> To the extent possible, seeds and plants used in restoration, erosion control, burned area stabilization and rehabilitation, forage enhancement and other projects should originate from local sources. Local sources often possess genotypes that are adapted to the local environment, leading to higher short-term and long-term establishment and survival rates.

"Local" refers to sources within or as close as possible to the project area and within the same ecological region.

It is somewhat debatable as to what would be a "desirable" non-native plant. Just because a plant species is salt-tolerant and can achieve some sort of desirable performance (e.g., it grows quickly, or it allows other desirable species to grow near it as well, or it crowds out undesirable invasive species, etc.) does not necessarily mean that this species would be desirable in every other important way relative to ensuring proper cover-system functioning. Many undesirable non-native species were introduced to this country under the assumption that they would be desirable for some purpose, and it was only later that the plant was found to create problems for people or the environment. Among potential problems are excessive rooting depth, excessive use of groundwater, competition with native plants that reduces their ability to grow on site, toxicity to local fauna, and attraction of undesirable fauna to the site as a source of potential food or shelter. As part of the PA, the licensee must provide the percent coverage of "desirable" non-native plants and their names to allow the DRC to assess vegetative cover design performance.

As an alternative to providing justification as to why non-native species should be included in the mix of planted species at all, the Licensee could re-do the design to include only native species in the cover-system.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.5

INTERROGATORY STATEMENT(S): On Page 3-3, the PA claims, "The plant uptake pathway is not a viable exposure pathway at the embankment because of natural site characteristics and design features of the embankment. Exposure by the plant uptake pathway could occur by (1) the production of food crops in contaminated soil at the site, and (2) root intrusion into the waste by native plants that are subsequently consumed by humans or animals."

Please either justify the statement that "the plant uptake pathway is not a viable exposure pathway at the embankment" or else revise this section of the PA to take into account information about potential plant uptake of radionuclides from greasewood or other phreatophytes on site, as presented previously and below. If the latter course is selected, then please provide an assessment of possible plant uptake at the site from all potentially deep-rooting plants existing at the site.

SUMMARY OF BASIS FOR INTERROGATORY: Many desert plants root to relatively great depths. One of these is greasewood. Greasewood is an obligate phreatophyte. It needs to have its tap roots go down to groundwater or to the capillary fringe just above it. Greasewood roots have been documented to go down well past 10 meters (33 feet). This is definitely deep enough for it to take up radionuclides from waste or contamination from waste at the LLW.

Other plants exist on site that, at other sites, are known to root deeply. These, also, might contribute to uptake of radionuclides at the surface.

Cattle and sheep are known to eat the leaves of black greasewood or other deep-rooting plants in the spring. The leaves of the plants presumably would contain non-volatile yet soluble radionuclides, since water moves through the plant to the leaves and exits via the stomata in the leaves during transpiration. The presence of radionuclides in the leaves would constitute a plant uptake pathway, which therefore appears to be a viable exposure pathway. To dismiss this possibility without careful analysis violates the intent of the rules and regulations cited below. Please revise the treatment made of this topic in the PA.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: As outlined elsewhere in this document, root intrusion into the waste by native plants is presented as a distinct possibility. This is particularly possible for greasewood, whose roots are well-documented at other sites to penetrate to depths of many meters, well beyond the proposed depth of the base of the radon barrier in the proposed cover-system design. A previous section of this document provides support for this concept. There are also other desert plants whose roots may extend to relatively great depths. Once plants take up radionuclides via their roots, the radionuclides can be transferred to animals who consume parts of the plants in their diet.

According to the U.S. Department of Agriculture (2009), "Black greasewood is poisonous year round, but plants can be consumed safely in light to very moderate amounts in the spring while the leaves are growing, as long as there is a substantial amount of other preferable forage available." Cattle can generally eat up to two or three pounds at a time and not be poisoned. Sheep can generally eat up to about two pounds at a time.

Another plant on site – one known on other sites to root deeply – is four-wing saltbush. Four-wing saltbush leaves are also reported to serve as forage for cattle and sheep. Dreesen and Marple (1979) report that, in a greenhouse experiment, radionuclides uranium and radium-226 were taken up from soil-covered uranium-mill alkaline tailings by four-wing saltbush (*Atriplex canescens*) and were found in the plant's aboveground biomass at elevated concentrations. Uranium was found at mean concentrations about 41 times that found in four-wing saltbush grown in uncontaminated soil, and radium-226 was found at mean concentrations about 15.5 times that found in four-wing saltbush grown in uncontaminated soil.

If cattle or sheep were to eat leaves of black greasewood or four-wing saltbush containing radionuclides from root uptake, then people eating the cattle or sheep could potentially receive doses of radionuclides.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.5 (cont'd)

INTERROGATORY STATEMENT(S): Page 3-3 includes this statement: "The candidate thick covers include capillary break, biointrusion, and bioturbation barriers that make the waste less accessible to plant roots after closure of the facility." Please explain how the proposed cover-system design 1 and design 2 include effective biointrusion barriers.

BASIS FOR INTERROGATORY: It is not apparent to the DRC how any effective biointrusion barriers are included in the proposed design. There are no specific details provided about biointrusion or bioturbation barriers per se. Several feet of silty clay soil or well-graded soil from a quarry do not generally constitute an effective biointrusion barrier. Several species of burrowing mammals near the site can readily burrow through several feet of such soil.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.5 (cont'd)

INTERROGATORY STATEMENT(S): The statement is made on Page 3-3 that "the overall scarcity of deep-rooted plant species in the site vicinity and the configuration of the earthen cover will offer an inhospitable environment for extension of these types of roots into the waste." This statement is not correct, since greasewood is relatively prevalent at Clive and it constitutes up to 14% of the plant community there. Please modify the PA text to reflect the facts that greasewood is not scarce on site, and that it can potentially root far more deeply than the top of the waste. Alternatively, justify the text as is. The configuration of the proposed cover seems to have little to do with whether greasewood roots can penetrate the waste, although the DRC is willing to consider an explanation.

BASIS FOR INTERROGATORY: Greasewood is said on Page 2-5 to cover 14.3% of the surface on the site. It is the one plant seemingly having the greatest coverage. While greasewood rooting depth was noted in two excavations on site to occur down to a depth of only 0.8 meters (about 2.6 feet), greasewood roots at many other sites are reported to be found down to depths greater than 10 meters (33 feet). Thus, with greasewood being the dominant plant on site, and with its potential to send down roots to great depth, there does not appear to be an "overall scarcity of deep-rooted plant species in the site vicinity."

There is no reason that the DRC knows of right now that would make the configuration of the cover an inhospitable environment for the plant to send its roots into the waste. A vegetative cover system without a plant biointrusion barrier cannot be assumed to be an inhospitable environment for deep-rooted plants to grow.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 19 of Neptune and Company, Inc. (2012) says, "Parameters for describing root water uptake were available from vegetation surveys at the site."

Please specify exactly which parameters were used and which values were obtained for these parameters, along with specific reference information.

BASIS FOR INTERROGATORY: The PA does not describe in detail which parameters were used in the model to describe and quantify root water uptake and which values of these parameters were used. Specific reference information is also missing.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 29 of Neptune and Company, Inc. (2012) speaks of "site characteristics influencing movement of water from precipitation through the vadose zone to the water table at the Clive site" and mentions one as "native vegetation." Please clarify whether proposed plans are to plant or transplant either native or non-native shrubs and grasses, or do proposed plans only envision establishment of native plants through natural succession? If a proposal is made to plant, please indicate the percent coverage intended.

BASIS FOR INTERROGATORY: On Page 2-5, it says, "The plant species selected for the evapotranspirative cover system should consist of native and desirable non-native, salt tolerant shrubs and grasses." This comment sounds as if recommendations are being made in the plans for growth of not only native but non-native plants. But Page 29 speaks of only "native vegetation." Likewise, on Page 2-8, reference is made to the Surface Layer being "composed of native vegetated Unit 4 material with 15% gravel mixture."

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 29 of Neptune and Company, Inc. (2012) speaks of "site characteristics influencing movement of water from precipitation through the vadose zone to the water table at the Clive site" and mentions one as "native vegetation." Please clarify whether proposed plans are to plant or transplant either native or non-native shrubs and grasses, or do proposed plans only envision establishment of native plants through natural succession?

Assuming that the cover system will undergo natural succession with growth of native plants, the DRC requires plans and surety for the following:

- Development of design criteria and submission of them to the DRC for approval in a revised PA detailing plans for (1) minimum percent vegetative cover, (2) plant species diversity, and (3) maximum allowable spatial density of any potentially deep-rooting plants, such as black greasewood or fourwing saltbush;
- Development and costing out mitigative measures that would need to be taken in the event that plant cover growth does not meet each of the design criteria in the above paragraph during various intervals of the 100-year institutional control period as described below;
- Natural succession needs to be monitored during an initial five-year interval, another five-year interval immediately following the first interval, a 10-year interval following that, and four subsequent twenty-year intervals collectively constituting the 100-year institutional control period;
- At the end of each interval, a report will be needed on progress of plant and plant community growth and succession to ensure that they meet the criteria described in the design specification;
- If not, then the planned mitigative measures must be taken to establish individual plants and plant communities so as to meet the criteria described above over the remainder of the institutional control period.

BASIS FOR INTERROGATORY: If native plants are expected to colonize disturbed soils added to the embankment cover system in a natural succession process, then there must be design plans in place for appropriate minimum percent vegetative cover and plant species diversity. Furthermore, limits must be set on maximum allowable spatial density of any potentially deep-rooting plants, such as black greasewood or fourwing saltbush, whose roots, if deep, could potential adversely affect cover-system effectiveness. Natural succession must be monitored over time to ensure that vegetation goals are being met and that no unexpected adverse developments occur. Mitigative measures must be developed and documented. If there are any problems with plant cover growth, then mitigative measures need to be implemented.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Table 3 of the Neptune and Company, Inc. (2012) report shows mean values for black greasewood, Sandberg bluegrass, shadscale saltbush, and gray molly on SWCA vegetation survey plots on site to be 8.5%, 0.7%, 3.7%, and 1.5%, respectively.

Please fix, note and comment on, or justify all discrepancies associated with this and like statements in the PA. Part of the information about species is missing from the statement above, as discussed below. Please add it.

BASIS FOR INTERROGATORY: There are many discrepancies associated with percent ground cover values referenced in the Neptune and Company, Inc. (2012) report. The values in Table 3, for example, do not appear to agree with data presented on Page 2-5 of the PA, where it says,

> These studies observed average plant species cover consist of 14.3% black greasewood, 5.9% Sandberg bluegrass, and approximately 3% cover each of shadscale saltbrush and gray molly occurring in low densities with 1.6% and 1.3% cover, respectively. Ground cover is dominated by 79.2% biological soil crust cover.

The statement on Page 2-5 in the PA quoted above appears to be an incorrect summary, restatement or quote of what is actually reported by SWCA in a report on results of field studies from June 13 – June 23, 2012 (SWCA, 2012b):

> Vegetation: Average plant species cover consisted of 14.3% black greasewood (*Sarcobatus vermiculatus*), 5.9% Sandberg bluegrass (*Poa secunda*), and approximately 3% cover each of shadscale saltbush (*Atriplex confertifolia*) and Mojave seablite (*Suaeda torreyana*). Fourwing saltbush (*Atriplex canescens*) and gray molly (*Bassia americana*) occurred in low densities with 1.6% and 1.3% cover, respectively. Ground cover was dominated by 79.2% average biological soil crust cover.

(see Page i of the Executive Summary.) Note that this statement from the SWCA (2012) shows that the PA statement on Page 2-5 appears to have erroneously left out the following words "and Mojave seablite (*Suaeda torreyana*). Fourwing saltbush (*Atriplex canescens*)" after mention of the name "shadscale saltbrush" [sic]. "Saltbrush" should be "saltbush."

Shadscale saltbush is described as such in http://plants.usda.gov/java/profile?symbol=atco, where the scientific name for the plant, *Atriplex confertifolia* (Torr. & Frém.) S. Watson, is also given. *Atriplex confertifolia* is known variously as shadscale, spiny saltbush, shadscale saltbush, and hop sage (Wildflower Center, 2012).

The percentages mentioned in the SWCA (2012) paragraph for black greasewood, Sandberg bluegrass, shadscale saltbush, Mojave seablite, fourwing saltbush, gray molly and biological soil crust are as follows: 14.3%, 5.9%, 3%, 3%, 1.6%, 1.3%, and 79.2%. It is noted that these do not add up to 100%. Instead, they add up to 108%. There are also apparent errors in Table 3 of the Neptune and Company, Inc. (2012) report. For example, the percentage values for Plots 7 and 11 add up to 127% and 108%, respectively.

All of these values are in apparent conflict with a report of the on-site black greasewood plot (Plot 3) as discussed in an earlier report, SWCA (2011). This earlier report indicates that black greasewood constitutes 4.5% of ground cover, with Mojave seablite, Gray molly, and shadscale saltbush constituting 0.3%, 0.2% and 0.1% of soil cover, respectively. The total for these four shrubs is thus 5.1% soil cover. Biological soil crust is said to constitute 84.8% of soil cover. Plant litter covers 6.1% of the soil. Bare ground makes up 2.3% of the surface.

The other two plots on or very near the site had only 0.2% or less of the ground cover comprising black greasewood (SWCA, 2011). Yet, supposedly, according to the Neptune and Company, Inc. (2012) statement quoted above, average plant species cover on site consisted of 14.3% black greasewood. This does not appear to be possible given the plot-by-plot percentages above.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): On Page 36 of Neptune and Company, Inc. (2012), there is mention of two excavations by SWCA Environmental Consultants (2011) from which data for Figure 11 rooting depths for shadscale and greasewood were obtained. Roots are claimed to only extend down to about 0.8 meters (2.6 feet) of depth. Elsewhere (SWCA, 2011), it is said that roots extend only to about 0.4 to 0.7 meters (1.3 to 2.3 feet) of depth, depending on location of excavation.

The DRC requests the Licensee provide a synopsis of research findings for greasewood rooting depths at other sites and compare the data to that found in these two excavations. Please provide an explanation for the anomalous on-site data, reconcile discrepancies, and assess the likelihood that the data from the limited number of excavations represents all land locally owned or leased by licensee, i.e., the entire site and surrounding area. Provide support or justification for all assumptions and claims.

The DRC specifically requests the Licensee discuss rooting depths for greasewood at the site in the context of (1) the shallow rooting of greasewood noted at a few locations at Clive does not necessary mean that rooting will be shallow at all locations at Clive, (2) greasewood is an obligate phreatophyte, with roots that almost always go down to within a short distance of the water table, and rooting depths for greasewood are noted at other sites to be as deep as 10 meters (33 feet) or more, (3) roots for greasewood at the site tend to terminate at or about at a thin, highly compressed layer noted to be present at an average depth of approximately 60 centimeters (2.0 feet) in several excavations, (4) thin, highly compressed layer will no longer exist locally once soil is mined for cover systems, (5) according to a recent NRC document (Benson et al., 2011), low-permeability cover-system soil over time is likely to experience greatly increased hydraulic conductivity due to multiple potential causes, which may include plant root intrusion, and (6) in the absence of a perched aquifer or other biological barrier, greasewood roots growing down to typical depths reported in the literature could potentially extend down through the radon barrier, through the waste, and into the capillary fringe, or water table, which may be present at a substantial depth.

The DRC requests that the Licensee consider in modeling work that biointrusion by greasewood (1) may damage the cover system soils and increase their effective hydraulic conductivity values, (2) this could dramatically increase drainage of infiltrated water, (3) this could potentially increase radon emanations through the cover, and (4) biointrusion of greasewood roots into waste may also allow for the conveyance of contaminated water up through roots and then through stems and leaves of greasewood, resulting in transport of radionuclides to the surface. The leaves may be eaten by foraging animals, such as cattle or sheep. Some of the animals may then be eaten by humans. This source of risk needs to be addressed fully in risk assessment and in the context of inadvertent intruder analysis.

SUMMARY OF BASIS FOR INTERROGATORY: While it is not disputed that greasewood plant roots may extend down to only about 0.4 to 0.8 meters (1.3 to 2.6 feet) in several small areas excavated on site, this would appear to be an anomalous condition. Many published reports, as described elsewhere in this document, indicate that greasewood is an obligate phreatophyte, generally extending its roots either to the water table or to the capillary fringe lying just above it. At the Clive site, the water table generally lies at a depth of 6 to 9 meters (20 to 30 feet) below the natural surface (see Page 2-4 of the PA).

However, it is reported in SWCA (2011) that at those locations where Unit 4 soil was excavated in order to study rooting depth, a thin, highly compacted clay layer was observed at an average depth of approximately 0.6 meters (2.0 feet). Often, thin, low-permeability layers in vadose-zone or generally unsaturated soil zones act to trap and pool infiltrated precipitation, even locally forming perched aquifers, usually relatively thin zones of saturation in an otherwise unsaturated environment. It is possible that greasewood roots at these excavated areas had stopped their vertically downward growth at, or close to, the thin, highly compacted clay layer. It is reported that plant roots were found growing laterally along the top of this layer, as might be expected if it periodically held a thin saturated zone of relatively available water.

The fact that, in these few excavations, roots only extended down to 0.4 to 0.8 meters (1.3 to 2.6 feet), at about or just above a depth where a thin, compacted zone of clay is also found, does not mean that the thin, compacted clay layer is continuous across the entire site. Field experience on site leads DRC staff to conclude that most layers of soil on site are discontinuous; they taper or wedge out laterally. It is generally difficult to find a layer in two distant locations that can be correlated.

Furthermore, once native Unit 4 soil is mined, and the proposed cover system soil layers are constructed using it, any thin, highly compacted zone of clay naturally present in the native soil will be broken up. In the cover system, no longer would there be a highly compacted clay layer that would be expected to trap perched water. Since greasewood is commonly acknowledged to send its roots down to the water table, or just above it, greasewood rooting on the cover of the embankment poses a threat to the integrity of the radon barriers in the cover system, and greasewood roots could potentially extend down into the waste or beyond. Also, biointrusion by roots can potentially damage cover systems, greatly increasing their overall hydraulic conductivity. These concerns indicate that greasewood rooting is an important issue. To meet requirements of the rules and regulations listed below, the Licensee must find a way to inhibit damage to the cover system via rooting by greasewood or other local plants.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: It is interesting that SWCA (2011) reports shallow rooting of greasewood at the site. Greasewood is described in the professional literature as an obligate phreatophyte whose roots nearly always go down to the water table or to the capillary fringe lying just above it. The documented rooting depth of greasewood plant roots at a number of sites described in SWCA (2011) is 10 meters (33 feet) or more. At these depths, the greasewood roots access abundant water found in the capillary fringe or in groundwater table.

However, SWCA (2011) indicates that recent fieldwork at the Clive site in three excavations in a single plot (Plot 3) shows greasewood roots going down into the Unit 4 clay to a depth of only 0.4 to 0.7 meters (1.3 to 2.3 feet), depending on excavation. This is only several percent of the total depth of rooting for greasewood reported at many other sites.

There is a possible explanation for this. As reported in SWCA (2011), greasewood roots found at the excavations tend to go not much deeper, if at all, than the depth of a thin, highly compacted clay layer. The thin, compacted clay layer is said to be found at an average depth of about 60 cm. It is said that roots from plants tend to grow vertically downward to this thin, highly compacted layer and then spread out laterally along its upper surface.

A thin, highly compacted clay layer in the subsurface can serve as a low-permeability perching layer. A low-permeability perching layer may permit perched bodies of water (or even aquifers) to temporarily form on the layer after significant precipitation and infiltration events.

Perched water at Clive may provide water for greasewood tap root uptake. If so, then tap roots from greasewood may stop at or just above a perching layer, at least locally.

However, a few excavations at Clive do not necessarily provide adequate data for assessing conditions generally throughout the site. The compacted clay layer may be localized, limited in areal extent. In general, there is little lateral continuity in thin strata found in Units 2, 3 and 4 at the site, based on field knowledge obtained both directly and indirectly by DRC staff, and as is evident in many historical cross sections based on a series of well logs at the site. The data presented in Figure 11 in the Neptune and Company, Inc. (2012) report showing a maximum rooting depth of only 0.8 meters (2.6 feet) for greasewood may be for a local area. It cannot be ruled out that, elsewhere on the site, the compacted clay layer may not be present at all, and, under suitable conditions, greasewood may extend its roots to a very great depth until groundwater or the capillary fringe is found.

Moreover, and this is very important, while at least two local areas of the site may today be characterized by a thin compacted clay layer at "approximately 60 cm depth", or approximately 2.0 feet depth, this compacted clay layer, if initially present elsewhere throughout the site, would undoubtedly be destroyed as a layer once mined for use in cover system construction. It is not expected that the layer would be reconstituted in its current condition during construction of the cover system. Thus, a soil layer that may currently exist and that might be preventing at least some greasewood plants from rooting deeply at the site may no longer exist in future cover systems at Clive so as to be able to function the same way and provide any protection against deep rooting.

While a chemically treated clay layer constituting the upper radon barrier in the cover system may have low hydraulic conductivity at the time of construction, over time (e.g., less than a decade), that clay layer will likely be subject to a variety of disruptive processes that will tend to greatly increase its hydraulic conductivity (see Benson et al., 2011). Depending on cover-system design and construction, these processes may involve freeze-thaw processes, wet-dry cycling, distortion, and burrowing by fossorial mammals. These disruptive processes, as Benson et al. (2011) have determined, will likely permit greatly increased infiltration.

It may be doubtful, then, that water would pool or perch on any compacted clay horizon in the upper radon barrier once the clay has been subjected to mining and construction processes. It is possible that tap roots of greasewood could subsequently penetrate the radon barrier and the waste below it to great depths in search of an abundant source of water existing under saturated conditions, either the water table or the capillary fringe lying directly above the water table. Although there is some uncertainty about whether this would happen in the future, it is known that

- (i) greasewood at several excavations on site appears to have its rooting terminate at about 0.4 to 0.8 meters (1.3 to 2.6 feet)
- (ii) this is approximately the depth, or just a little beyond the depth, of a thin compacted clay layer observed at about a depth of 60 centimeters (2.0 feet) on average in the vadose, or unsaturated, zone
- (iii) low-permeability layers in what is otherwise an unsaturated zone can greatly slow the downward movement of water and allow a relatively thin layer of saturated water (or a perched aquifer) to form atop the layer (see Domenico and Schwartz, 1998)
- (iv) greasewood is an obligate phreatophyte, which depends on accessing, via its tap roots, a source of saturation, usually either the water table, or the capillary fringe
- (v) at other sites, greasewood may extend its tap roots down to a source of saturated water to depths of 10 meters (33 feet) or more
- (vi) mining of silty clay soil containing a shallow, thin, highly compacted layer within it will generally disrupt that thin layer and mix its remnants with other soil
- (vii) such remnants, even if included in a constructed soil layer within a cover system, cannot function by themselves as a perching layer, so infiltrated water reaching them will not be stopped by their presence alone

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); Benson et al. (2011)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): It states on Page 36 of Neptune and Company, Inc. (2012) that "root density was modeled as decreasing linearly with depth" and that maximum depth was 80 centimeters (0.80 meters, or 2.6 feet)).

Please explain, justify or fix the function characterizing root density as a function of depth.

BASIS FOR INTERROGATORY: Figure 11 shows that reported root density is a nonlinear, rather than linear, function of depth and that an assumed linear decrease in root density with depth in the model would poorly correlate with reported actual data.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Figure 11 of Neptune and Company, Inc. (2012) is entitled "Root Density with Depth." The abscissa axis is labeled "Root Density [roots/cm].

Please explain, justify or fix root density data. Please explain the significance of the values in Figure 11 [roots/cm] from a physical and biological standpoint. Please explain how the root density values are used in the Hydrus-1D model. Does the input for root density in the Hydrus-1D model match the definition of root density given by SWCA (2011)? Are the units the same? Is the meaning of root density the same? Please document all of this.

BASIS FOR INTERROGATORY: Root density is often expressed in the literature as the number of roots per cm^3 volume [roots/cm^{-3}], the number of roots per square cm of scanning area [roots/cm^{-2}] on a planar cut soil surface, the length of roots in cm per square cm of scanning area [cm/cm^2] or [cm^{-1}], or the length of roots in cm per cm^3 volume [cm/cm^3] or [cm^{-2}].

However, the abscissa on Figure 11 is labeled Root Density [roots/cm]. This does not correlate with usual measures of root density. Sometimes, the number of lateral roots per cm of root is measured and reported with units of [roots/cm]. However, this does not give a standard measure of root density, and it is not believed that Hydrus accepts this kind of root density input.

SWCA (2011) indicates that, in this case, "root density measurements were collected by measuring the width of the rooting mass and by counting visible roots across a set of sample widths or for the entire width of the root mass." This does not correlate with common expressions for root density as given above.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): On Page 37 of Neptune and Company, Inc. (2012), it says, "osmotic stress is assumed to be negligible for these simulations so h_φ is zero."

Please justify this assumption, or correct the model, as needed.

BASIS FOR INTERROGATORY: When plants grow in saline soil, as at Clive, osmotic stress may be substantial. Ignoring its influence in root water uptake equations, as is done currently in the PA model, tends to result in excessively optimistic estimates of transpiration. High salinity in water outside plant roots tends to markedly reduce potential transpiration, decrease leaf size, and diminish plant yield (e.g., see Katerji et al., 1994 and 1996; Homaee and Feddes, 2002). Zhu et al. (2002) state that, "even minor osmotic stress can substantially reduce plant productivity." The failure in the PA model to account for this tends to result in overly optimistic predictions in the model for transpiration, with correspondingly underpredicted deep infiltration or recharge rates. Therefore, the assumption made in the PA model that osmotic stress is negligible appears to be unsupported.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

7.0 TRANSPIRATION

SECTION: 2.2.2

INTERROGATORY STATEMENT(S): In regard to the Page 2-8 statement about the surface layer being "composed of native vegetated Unit 4 material with 15% gravel mixture", the DRC has concerns about plant growth and plant coverage on this layer and the ability of plants to provide as much transpiration as expected in the model. Based on information found in other interrogatories and concerns about the ability for plants to flourish and provide sufficient plant coverage on engineered embankments, as well as the potential for native shrub roots to biointrude past radon barriers and into the waste, the DRC requests that the licensee revisit sections dealing with transpiration and provide support or evidence for its assumed transpiration parameter values.

SUMMARY OF BASIS FOR INTERROGATORY: Information available in the PA tends to indicate that plant coverage on the embankment can be expected to be relatively low, providing for relatively little transpiration. A high percentage of plants that are expected to grow there will be undesirable phreatophyte shrubs, posing an unacceptable deep-rooting biointrusion risk.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: There are many reasons to have concerns about whether the plants on the cover system can provide as much transpiration as expected in the model. Currently, native Unit 4 soils at Clive do not support a robust plant community. Page 2-5 of the PA indicates that "ground cover is dominated by 79.2% biological soil crust cover". SWCA (2011) indicates that, depending on the plot studied, even higher percentages of the ground are dominated by biological soil crust. The fraction of total ground cover dominated by grasses, forbs, or shrubs at the site is, at a maximum, only about one-fifth to one-quarter of the plant cover. Several percent of the ground cover is occupied by barren ground or plant litter. In both the PA and a recent consulting report (SWCA, 2012), 14.3% of the total ground cover is said to be greasewood, which is generally an undesirable plant for the cover system since greasewood is an obligate phreatophyte that typically sends its roots down to the water table or the overlying capillary fringe. Its growth at the site with the currently designed cover system poses an unacceptable biointrusion risk.

Only several percent of the ground cover at the site consists of grasses or forbs. As stated on Page 2-6, the soils are highly saline, with elevated pH, and they appear to be low in some needed nutrients. In essence, unamended, the soils do not appear likely to support a robust engineered vegetative community that would markedly enhance transpiration from the cover system.

If a vegetative community is established, there is concern that prairie dogs, now encroaching on the northern edge of the site, will, with other herbivores, diminish cover-system vegetation through herbivory.

As discussed elsewhere in these comments, tap roots associated with some phreatophyte shrubs have the potential to biointrude the radon barrier and underlying waste.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 33 of Neptune and Company, Inc. (2012) says "Where the a_{bl} coefficient accounts for radiation intercepted by vegetation and is given the default value of 0.5 (Varado et al. 2006). Estimates of LAI are not available for the site so E_p and T_p were calculated using the method of Šimůnek et al. (2009). This method uses an estimate of vegetated soil cover fraction (SCF) to calculate E_p and T_p as

$$T_p = PET*SCF$$

$$E_p = PET * (1-SCF)$$

The soil cover fraction was estimated from vegetation surveys conducted in the vicinity of the site."

The Licensee must find another approach to account for T_p and E_p. Otherwise, the model will produce non-viable output, not being in harmony with the objectives and requirements found in the rules and regulations listed below.

SUMMARY OF BASIS FOR INTERROGATORY: The formula in the Neptune and Company, Inc. (2012) text quoted above that gives a value for T_p, the fraction of potential evapotranspiration (PET) attributable to transpiration, cannot be validly applied to desert plants growing in the periphery of the semiarid Great Salt Lake Desert in Utah, under water-limited conditions. The same is true for the equation for E_p, the fraction of potential evapotranspiration (PET) attributable to evaporation.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Although Page 33 of the Neptune and Company, Inc. (2012) report refers to "the method of Šimůnek et al. (2009)", the approach described in the PA is not one developed by Šimůnek et al. (2009). These researchers do provide the equations quoted above in the HYDRUS 2-D program, but they attribute the development of these equations to Ritchie (1972). However, a review of Ritchie (1972) by the DRC does not locate these equations in that source, either. Ritchie (1972) presents a single equation (Equation 9 in his paper) having a more complicated approach than that found in by Šimůnek et al. (2009):

$$E_p = E_o(-0.21 + 0.70 L_{ai}^{1/2}) \qquad \text{when } 0.1 < L_{ai} < 2.7 \qquad (9)$$

where E_p, E_o, and $L_{ai}^{1/2}$ are, respectively, the "plant evaporation" (transpiration) rate, the potential evaporation rate, and the leaf-area index. This equation, however, originally comes from Ritchie and Burnett (1971). As stated in both Ritchie (1972) and Ritchie and Burnett (1971), the equation is only applicable when water movement to the plant roots is not limited (unlike the condition in or near the semiarid Great Salt Lake Desert). Furthermore, it is developed using data from only two crops, cotton and grain sorghum (not applicable to plants growing natively in the semiarid Great Salt Lake Desert), in Texas (not Utah), in a subhumid climate (a condition not likely to be applicable to native plants in or near the semiarid Great Salt Lake Desert). It is noteworthy that Ritchie (1972) says, "Since (9) is empirical, its ability to be used with other climates and crops remains in doubt."

There is no reference for SCF found in Ritchie (1972). A search of Ritchie (1972) for the word "fraction" did not turn up anything for SCF or similar to SCF.

A review of the earlier work, Ritchie and Burnett (1971), did show information relating to fractional ground cover, apparently equivalent to SCF. Figure 8 of Ritchie and Burnett (1971) shows the ratio of "plant evaporation" (transpiration) to potential evaporation as a function of fractional ground cover. That relationship is nonlinear, not linear as presented in the PA. However, a very crude linear approximation, but only for higher fractional ground cover values, is indeed approximately equivalent to

$T_p = PET*SCF$

as referenced by Šimůnek et al. (2009). However, it is evident on reviewing Figure 8 of Ritchie and Burnett (1971) that this relationship fails badly for lower fractional ground cover values, e.g., those near 18%, which is the fractional ground cover determined by the Licensee for the Clive site (see Page 34 of the PA). The actual Ritchie and Burnett (1971) study reports on "plant evaporation" divided by potential evaporation for only two plants, cotton and grain sorghum, in subhumid Texas. Looking at data for cotton, at 18% fractional ground cover, the line connecting reported data for "plant evaporation" divided by potential evaporation on the graph gives a value of about 0.42. The $T_p = PET*SCF$ relationship given by Šimůnek et al. (2009) gives only 0.18. Thus, it is in substantial error relative to the data for cotton. The value of 0.18 is also in error relative to data shown for grain sorghum, but not as badly as in the case of cotton.

The Ritchie and Burnett (1971) equation is said to only apply when water movement to the plant roots is not limited, and, furthermore, it never was intended to apply to plants, climates, water availability and other conditions found in or near the Great Salt Lake Desert.

For all of these reasons, the $T_p = PET*SCF$ approach does not work for the Clive site, and another approach to modeling T_p, the fraction of potential evapotranspiration (PET) attributable to transpiration, must be employed.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 48 of Neptune and Company, Inc. (2012) discusses use of a soil cover fraction (SCF) of 0.18, which corresponds to a leaf area index (LAI) of 0.4. The claim is made that this value is low relative to literature values.

Please modify the model to use a more appropriate lower value for the SCF and the LAI, and also change the PA text to give an SCF value correlating to an LAI value that is comparable to relevant field-based values for LAI in the Great Basin area, obtained from the literature.

BASIS FOR INTERROGATORY: Goodman (1973) describes a study of adaptations of plants to salt desert conditions in Utah. Goodman (1973) says, "the field site at Curlew Valley (Fig. 1) was chosen as typical of the North American cold salt desert or 'Great Basin' . . ." This would presumably include the area in and around Clive.

Goodman (1973) reports on LAIs for different species in March, April and May. He reports the highest LAI for a pure *Atriplex* stand for May at 0.070, and the highest LAI for a pure *Eurotia* stand in May at 0.139. The total yield (all spp.) LAI in a mixed plot was highest in April at

0.082. In comparison to the reported field value for all species in a mixed plot of 0.082 in Goodman (1973), the 0.4 LAI value claimed for the Clive site in the PA is 388% too high. So, contrary to the PA text, the 0.4 LAI value is not low compared to relevant literature values. Its value in the PA needs to be changed. Changing it will change estimates for transpiration in the PA model.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 48 states that "the influence of plant transpiration on the long-term annual net infiltration into the waste was examined by modeling net infiltration for design 1 with a 6 inch thick Evaporative Zone with no root water uptake. The long-term annual net infiltration rate into the waste for the cover system without vegetation is shown in Table 8. A comparison with the results for design 1 with a 6 inch Evaporative Zone thickness shown in Table 5 indicates only a 3.5 percent increase in long-term net infiltration when the cover is not vegetated. The 1-D HYDRUS models and the associated input and output files are provided in the attached electronic files."

Research findings indicate that the absence of vegetation generally tends to result in greatly increased rates of infiltration. This is in contrast to results claimed for modeling. Please provide justification for the model results discussed above in light of these apparently conflicting published research findings, or review the model and re-run it with more appropriate parameter values (as discussed elsewhere in these comments) to obtain results consistent with published research findings.

BASIS FOR INTERROGATORY: The PA model results given above indicate that removing vegetation altogether from the cover system at the Clive site would have a minimal, almost insignificant, impact on the amount of long-term net infiltration (only a 3.5% increase). These results, however, are inconsistent with published research that, in general, shows a dramatic increase in infiltration when vegetation is removed from soil in a semi-arid or arid environment. Depending on soil type, climate and extent of biointrusion, recharge to the groundwater table of infiltrated water in non-vegetated (or de-vegetated) semi-arid to arid areas can constitute a substantial portion of precipitation. Gee et al. (1994) indicate that "Lysimeter data from Hanford and Las Cruces indicate that deep drainage (recharge) from bare, sandy soils can range from 10 to >50% of the annual precipitation." Hakonson (2002) says, "Erosion and percolation increase dramatically when the vegetation cover is absent in the presence of burrowing." Waugh (2004) states that recharge can exceed "60 percent of precipitation in arid-land soils denuded of vegetation." Vegetative cover may potentially diminish at some point in time due to inadequate nutrition, excessive herbivory, or adverse environmental conditions such as catastrophic fires or plant disease. Such events could potentially cause substantial increases in drainage/percolation.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

8.0 EVAPORATION

SECTION: 2.1.6

INTERROGATORY STATEMENT(S): On page 2-2, the Licensee discusses "the 17-year average annual evaporation rate at the Clive site", provides a value for it, and mentions that it is based on exclusion of two years of reported instrument malfunction. In the same paragraph, the Licensee states that "Pan evaporation measurements are taken from April through October . . ."

However, on Page 10 of the attached Modeling Report, reference is made to pan evaporation measurements having been made at the NOAA station at BYU. The text says, "Mean monthly values of pan evaporation measured at the BYU NOAA station in Provo, Utah over the period 1980 to 2005 are shown in Figure 2. Mean annual pan evaporation over this time period is 49.94 inches. This station is located 83 miles to the southeast of the Clive facility. Data from this station are used because pan evaporation data are not available for the Dugway station."

Please provide clarification regarding the apparent conflict between PA Section 2.1.6, which implies that pan evaporation measurements were taken at the Clive site, and latter references on Page 10 of the attached Modeling Report, which refers to use of pan evaporation measurements made at the NOAA Station at BYU.

BASIS FOR INTERROGATORY: Conflict between statements made in the PA must be resolved and issues clarified in general to diminish potential ambiguity and misinterpretation. This is particularly important with the recent changes which were made to the adjudicative process which requires clear and complete records be made to support license actions approved by the Director. Specifically, apparent conflicts must be resolved as to the location of pan evaporation instrumentation used in PA studies and which values were used in the model.

APPLICABLE RULE(S) OR REGULATION(S): Not applicable. Clarification of statements made in the PA and resolution of apparent conflicts is being requested.

REGULATORY GUIDANCE REFERENCE(S): Not applicable. Clarification of statements made in the PA and resolution of apparent conflicts is being requested.

SECTION: 2.2

INTERROGATORY STATEMENT(S): On Page 2-8, Cover Design 2, or Evapotranspiration Cover Design A, is described. A statement is made that indicates that the proposed cover system will assist in releasing water through evaporation from the soil surface. However, there are outstanding issues associated with anticipated erosion of the proposed surface soil if no cobbles are used. On the other hand, if only cobbles were to be used, then it would be expected that evaporation rates would greatly decline. Please take into account the following information and describe how cover-system soils will be selected and used so that evaporation rates will be maintained at high values while erosion is limited to acceptably low values.

BASIS FOR INTERROGATORY: Evaporation is an important model parameter for modeling performance of cover systems at semi-arid sites such as at Clive. One factor critical to success of evaporation in such a cover system is avoiding coarse-textured materials such as gravel or cobbles at the cover surface of embankments in which neither capillary barriers nor filter drains are used and for which it is therefore critical to remove as much water as possible by evaporation. This generally requires the use of fine-grained soil materials, or a combination of cobbles or rip rap and fine-grained soil materials, not just gravel or cobbles by themselves. This is well documented in the literature.

Hadas and Hillel (1972), for example, report that "soil layering reduces evaporation, especially when a coarse-textured soil overlies a fine-textured soil."

Groenevelt et al. (1989) show that addition of larger-diameter granular inorganic material to a soil surface substantially reduced evaporation from the soil. With the use of sand, for example, cumulative evaporation from soil, after 38 days, was reduced approximately 83%. Use of scoria rock was almost as effective in reducing evaporation.

Reith and Caldwell (1990) claim that a rock cover reduces evaporation from a cover system and makes more water present within the cover system.

Kemper et al. (1994) show that 5 cm of gravel placed on top of soil significantly reduced evaporation and increased retention of water in the subsurface to about 80-85% of total precipitation.

Diaz et al. (2005) show that reduction in evaporation was related to the thickness of volcanic tephra rock on the ground surface. A 2-cm layer, a 5-cm layer, and a 10-cm layer of tephra rock reduced soil evaporation after 31 days by 52%, 83% and 92%, respectively.

Albright et al. (2010) explain, "gravel mulches can also form a 'reverse' capillary barrier effect that limits surface evaporation, which may adversely affect the cover water balance . . . "

Finally, Neptune and Company, Inc. (2012) state, with reference to the originally proposed and currently accepted Clive cover system, “the presence of rip rap inhibits evaporation of moisture from underlying soils” and "the rip rap surface layer inhibits evaporation, so more water is available for infiltration."

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 11 of Neptune and Company, Inc. (2012) says, "Assuming pan evaporation is approximately equal to potential evapotranspiration (PET) the ratio of annual average precipitation to PET is 0.17."

Please recalculate the annual average pan evaporation in a way more consistent with current professional practice. Please use one of several equations developed and available in published sources to account for transfer of energy through the sides and bottom of the pan to re-calculate the estimated ratio between average annual precipitation and PET. Then, recalculate the ratio of annual average precipitation to PET. Alternatively, justify the calculation made in the quote above.

BASIS FOR INTERROGATORY: The assumption that "pan evaporation is approximately equal to potential evapotranspiration" is generally not a good assumption. It would be one if the pans were buried and maintained properly, but unburied pans are generally used for pan evaporation data collection. The U.S. Weather Bureau uses what are known as Class A pans as a standard practice. "The problem with the Class A pan is that it overestimates PET because energy enters the pan through the sides and bottom. Thus, it overestimates lake evaporation by 30 to 40%, depending on . . . location is the U.S. . . ." (Ward and Trimble, 1995).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Please fix the apparent misstatement copied below and clarify the message to make it consistent with other discussion in Appendix B. On Page 13 of Neptune and Company, Inc. (2012), it says, "References in this report to . . . evaporative zone depth refer only to the function and characteristics of a layer in the ET cover system designs."

BASIS FOR INTERROGATORY: This is not the case. In a description of the HELP model in the PA Modeling Report on Page 16, it says, "If the vertical percolation layer is located within the evaporative zone depth, evaporation is modeled as an extraction and can only occur until the specified wilting point moisture content has been reached." In this instance, the reference is not to a layer of arbitrary thickness and materials in the designed ET cover system, as claimed in the interrogatory statement quote but to an intangible construct in HELP referred to as the evaporative zone depth. The latter refers to the maximum depth from which water can be removed by evaporation, whose value depends on actual, physical soil, hydrological and meteorological variables.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Please provide clarification of apparent inconsistencies between various Licensee consultant reports relative to evaporation and use of rip rap. On one hand, the Whetstone Associates (2011a) document argues at length in its Pages 6 and 7 that significant evaporation would occur from the rip rap surface layer. On the other hand, it says on Page 13 of Neptune and Company, Inc. (2012) that "the rip rap surface layer inhibits evaporation, so more water is available for infiltration."

BASIS FOR INTERROGATORY: The concept in the PA that rip rap inhibits evaporation is an interesting statement in light of the discussion in Whetstone Associates (2011a) on Pages 6 and 7 that argues at length for significant evaporation occurring from the rip rap surface layer.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): As stated earlier in Chapter 7.0, Transpiration, Page 33 of the Neptune and Company, Inc. (2012) report gives an equation for potential evaporation as

$$E_p = PET * (1\text{-}SCF)$$

This equation is not appropriate for the Clive, Utah site. The Licensee must find another approach to account for E_p. Otherwise, the model will produce non-viable output,.

BASIS FOR INTERROGATORY: A similar issue was addressed previously in the Interrogatory relative to T_p, the fraction of evapotranspiration attributable to transpiration (see Chapter 7, on Transpiration). Use of the soil cover fraction (SCF) is proposed for use in the equation above to help account for E_p, where E_p is the fraction of evapotranspiration attributable to evaporation. However, as discussed in Chapter 7, use of the equation given above is not appropriate for a desert environment as found near Clive, Utah. It is only appropriate for a limited number of plants (which are not found in the Clive, Utah area), under semi-humid conditions (which are not found in the Clive, Utah area), where there is no restriction or limitation on availability of water (which is not found in the Clive, Utah area). The Licensee must find another approach to determining E_p. Otherwise, the model will produce non-viable output, not being in harmony with the objectives and requirements found in applicable rules and regulations.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 37 of Neptune and Company, Inc. (2012) indicates that "osmotic stress is assumed to be negligible . . ."

However, relatively high salinity causes osmotic stress leading to diminished evaporation. Please account for this when calculating infiltration in the model.

BASIS FOR INTERROGATORY: The PA model fails to account for the impact of salinity on evaporation rates. This tends to result in overly optimistic predictions in the model for evaporation, with correspondingly underpredicted deep infiltration or recharge rates. Studies of how salinity decreases evaporation rates include that of Salhotra et al. (1985).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

9.0 FREEZING OF THE RADON BARRIER

SECTION: 2.1.3

INTERROGATORY STATEMENT(S): On Page 2-2, under Temperature, it says that "data from the Clive facility from 1992 through 2011 indicate that monthly temperatures range from about -2°C (29°F) in December to 26°C (78°F) in July (MSI, 2012)." An analysis of temperature data for the Clive site indicates that there is potential for freezing of the radon barrier, with adverse consequences. Please revise the proposed CAW cover-system thickness to prevent potential freezing of radon barrier clay at depth.

SUMMARY OF BASIS FOR INTERROGATORY: The proposed CAW cover-system design is unacceptable to the DRC. This is because, with the proposed cover-system design, freezing temperatures could occur at a depth of 30 inches or more and damage the radon barrier.

Proposed cover-system design mandates the use of at least six inches of Unit 4 silty clay as part of the "evaporative zone" but also permits the use of 12 or 18 inches. With the option of using only six inches of Unit 4 silty clay (such that the total "evaporative zone" thickness is only six inches), the depth of the top of the radon barrier (which in an effective cover system must not freeze) will likely be subjected to below-freezing temperatures and could freeze. This assessment is based in part on data obtained previously on site from the Cover Test Cell, built according to DRC requests near the southwestern corner of the site. Freezing temperatures in soil at a depth of 30 inches have been reported by the licensee for January 2004, which was not an exceptionally cold month. Neither was the month before. In very cold winters, the zone of freezing may extend even deeper than the top of the radon barrier, and this may necessitate even thicker "evaporative zone" layers to protect the radon barrier.

Freezing of radon barriers can have deleterious effects on migration of radionuclides that could, under some conditions, adversely impact the general population, including inadvertent intruders, contrary to rules UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; and UAC R313-25-20.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: It has already been pointed out that these two temperatures (-2°C and 26°C) mentioned in the statement quoted above are not representative of all temperatures in the referenced month but are representative of the range of values of *mean monthly air temperatures* in that month from 1992 through 2011. On some days in December, for example, the temperatures undoubtedly dropped to lower values than -2°C, and, on other days, the temperatures were higher. While on this topic of temperature, it is appropriate to refer to temperature studies conducted by the Licensee and its consultants on the on-site Cover Test Cell, described in DRC (2011).

Before doing that, however, the nature of the cover system soils must first briefly be described. The cover system for the Cover Test Cell was constructed differently in some ways than the proposed design CAW cover-system (see DRC, 2011, and Neptune and Company, Inc., 2011b). With optional Unit 4 soils included, the design is as shown below in the right-hand column:

Depth	Test Cell Cover System	Proposed CAW Cover System (thickest)
0-6"	rip rap	Unit 4 silty clay with 15% gravel
6-12"	rip rap	Unit 4 silty clay (≤ 56% silt), evap. zone
12-18"	rip rap	Optional Unit 4 silty clay (≤ 56% silt)*
16-24"	coarse filter	Optional Unit 4 silty clay (≤ 56% silt)*
24-30"	sacrificial soil	frost protection layer, clay to 16" diam. rock
30-36"	sacrificial soil	frost protection layer, clay to 16" diam. rock
36-42"	coarse filter	frost protection layer, clay to 16" diam. rock
42-48"	radon barrier ($5x10^{-8}$ cm/s)	**radon barrier, upper ("lowest" K clay)**
48-54"	radon barrier ($5x10^{-8}$ cm/s)	radon barrier, upper ("lowest" K clay)
54-60"	radon barrier ($1x10^{-6}$ cm/s)	radon barrier, lower ("low" K clay)
60-66"	radon barrier ($1x10^{-6}$ cm/s)	radon barrier, lower ("low" K clay)

The depth of the upper radon barrier in the proposed CAW cover system is shown above in bold. If optional portions of Unit 4 silty clay, shown in the right-hand column above by the asterisk (*) symbol, are not included in the Evaporative Zone in the proposed CAW cover system, then the soil profile becomes shorter as is shown in the right-hand column:

Depth	Test Cell Cover System	Proposed CAW Cover System (thinnest)
0-6"	rip rap (open voids)	Unit 4 silty clay with 15% gravel
6-12"	rip rap (open voids)	Unit 4 silty clay (≤ 56% silt)

12-18"	rip rap (open voids)	frost protection layer, clay to 16" diam. rock
16-24"	coarse filter	frost protection layer, clay to 16" diam. rock
24-30"	sacrificial soil	frost protection layer, clay to 16" diam. rock
30-36"	sacrificial soil	**radon barrier, upper ("lowest" K clay)**
36-42"	coarse filter	radon barrier, upper ("lowest" K clay)
42-48"	radon barrier ($5x10^{-8}$ cm/s)	radon barrier, lower ("low" K clay)
48-54"	radon barrier ($5x10^{-8}$ cm/s)	radon barrier, lower ("low" K clay)
54-60"	radon barrier ($1x10^{-6}$ cm/s)	
60-66"	radon barrier ($1x10^{-6}$ cm/s)	

where, again, the top six inches of the upper radon barrier in the proposed CAW cover system is shown on the right-hand side in bold, with a depth range in bold given on the left-hand side.

The DRC cannot approve a design having the latter profile for construction at the Clive Disposal Facility site. The reason is that freezing or below-freezing temperatures may occur at a depth of 30 inches or deeper in the cover system (especially during exceptionally cold winters) and damage the radon barrier, as well as the overlying soil. For a cover system with only a six-inch-thick frost protection layer design as shown in the last table above, a depth of 30 inches extends all the way down to the top of the radon barrier. This could result in fracturing of the clay-size earth material in the barrier, either directly through frost-heave or other types of freezing activity, or indirectly by local desiccation associated with frost heave occurring in overlying soils with an accompanying upward wicking of moisture.

Frost heave is not always associated with proximity to a water table. Hermansson (2002) reports that frost heave can occur soils at substantial rates despite water table depth being relatively great. In a study at Sundsvall, Sweden, where the water table is located six meters below the surface, Hermansson (2002) noted that 7.9 cm of frost heave occurred over a 44-day period. Hermansson (2005) also reports that additional testing in the lab demonstrated that frost heave still occurs at significant rates even in the absence of an external source of water. Water is redistributed upwards through porous soil to the zone of freezing. Han and Goodings (2006) report that frost heave in clays is not sensitive to the position of the water table; frost heave in clays tends to act as if it were occurring in a closed system.

Freezing or close to freezing temperatures measured using thermocouple temperature probes at various depths are noted to have occurred at the midpoint of the sacrificial soil in the Cover Test Cell during testing in January, 2002 and January, 2004, at a depth of about 30 inches (see DRC, 2011 for a review). Temperatures slightly above freezing (e.g., 2 degrees C, or about 36 degrees F) were noted even down at a depth of 42 inches, which, in the Cover Test Cell, would be at the top of the upper radon barrier, but which in the proposed cover system, would actually extend 12 inches below the top of the radon barrier. This is a change of 3.6 degrees F over a vertical distance of 12 inches just above the radon barrier, for a gradient of 0.3 degrees F/inch.

During portions of an especially cold winter, temperatures inside the radon barrier, even at a depth of 42 inches, could potentially drop below freezing. This can be predicted based on air temperature records. Although air temperature records for Clive, Utah going back to 1951 are not available, air temperature records are available for Dugway, Utah. The DRC has established that mean air temperatures at Dugway are, to a reasonable extent, historically similar to those at Clive, Utah. In January, 2002 and January, 2004 at Clive, when freezing temperatures in soil at a depth of 30 inches are reported to have occurred, mean monthly low air temperatures are reported as having been, respectively, 15.45 F and 11.35 F. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?utdugw. However, in the 56 years between 1951 and 2006, inclusive, there were 13 years (23%) in which mean monthly low air temperatures for January dropped to values lower than 11.35 F (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?utdugw). These January mean monthly low air temperatures are shown below:

Year	Mean Monthly Low Air Temp (Degrees F)
1955	5.32
1961	11.23
1963	6.28
1973	8.35
1977	7.48
1979	7.84
1984	5.23
1985	8.13
1988	2.29
1989	0.39 ←
1991	9.58
1992	8.74
1993	5.84

It is noted that in 1989, the mean monthly low air temperature in January was 0.39 degrees F. This temperature is nearly 11 degrees colder than the mean monthly low air temperature reported for Clive in January, 2004, namely 11.35 degrees F, when soil temperatures at a depth of 42 inches in the Cover Test Cell were reported at 2 degrees F. During the 56-year period of record, about 25% of Januaries had mean monthly low temperatures colder than that of January 2004.

A sustained drop of 11 degrees F in the mean low air temperature compared to that of December and January 2004 values over a period of at least a month would likely have dropped the soil temperature at a depth of 42 inches significantly, very possibly by more than that required for the soil to have frozen. In the proposed cover-system design, with the thinnest evaporative zone option selected, a depth of 42 inches corresponds with the base of the upper radon barrier, or the top of the lower radon barrier. Freezing of the radon barrier in either portion of the radon barrier would likely severely damage its integrity.

The month prior to the month in which these temperature measurements were taken in the soil was also comparatively warm (mean monthly low of 19.77 F). By comparison, during the 56-year period of record, about 25% of Decembers had mean monthly low temperatures colder than that of December 2003.

While freezing-point depression occasioned by the presence of salts in the soil at Clive tends to occur, typically, for salinity concentrations such as those at Clive, this depression is only about 3.6 degrees (cf. 3.4 degrees for normal seawater). So a drop in mean air temperature of 11 degrees or possibly even less might very well imply freezing of all or part of the upper radon barrier, and possibly part of the lower radon barrier, in the design currently proposed.

The extent to which this might occur would likely depend on the relationship between the drop in air temperature and the drop in soil temperature over time. The latter is likely a function of water content, solution chemistry, and depth. At any rate, it appears from this data that the minimum thickness of the evaporative zone layer (Unit 4 silty clay with $\leq$ 56% silt) must be significantly greater than the proposed 6 inches in order to provide suitable protection against freezing for the radon barrier clay soils.

Proposed soil layers above the radon barrier, in addition to the evaporative zone layer (6-18" thick), are important, too. These include the frost protection layer (18" thick) and the surface layer with gravel and vegetation (6" thick). Collectively, this 30-42" thick group of sediments are responsible for, or strongly affect, frost protection, water storage, transpiration, evaporation and resistance, if any, to biointrusion. When the soil layers above the radon barrier are damaged by frost, important functionality of parts of the cover system may be lost. Radon emanation risk may increase. Infiltration may increase markedly.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2.2

INTERROGATORY STATEMENT(S): On Page 2-8, it says, concerning the Evaporative Zone Layer, "The thickness of this layer is varied in the Performance Assessment from 6 inches to 18 inches, to evaluate the influence of additional thickness on the water flow into the waste layer." The DRC finds a thickness of 6 inches to be inadequate. Please ensure that the thickness of soil underlying the surface layer in the zone now referred to as the Evaporative Zone Layer is adequate to protect against frost damage to the radon barrier soils and any overlying capillary barriers or biointrusion barriers.

BASIS FOR INTERROGATORY: As discussed previously, the thickness of the Evaporative Zone Layer cannot be six inches. This would allow for freezing or below-freezing temperatures to exist at or perhaps even within the radon barrier, which would be unacceptable. For this reason alone, a thicker Evaporative Zone Layer is needed.

Because the surface layer as well as at least portions of the low-permeability silty clay Evaporative Zone Layer of the cover system as proposed may be damaged by frost heave, wet-dry cycling, distortion, plant biointrusion, mammalian biointrusion, and erosion, it would seem valuable for there to be additional fine-grained soil placed below the surface layer to serve as redundant material for enhancing runoff, evaporation and transpiration. It is recommended that the Licensee not assign these functions to the surface layer, which may or may not survive erosion and biointrusion, but to restrict these functions to deeper layers. Therefore, it would be advisable for the Licensee to maintain in modeling and construction a thicker Evaporative Zone Layer than is presently being considered in the PA and Radioactive Materials License application.

The licensee should give consideration to effective designs against biointrusion. This might involve, for example, using one or more mixed clay/cobble layers beneath the surface layer with each intended to help protect against biointrusion by burrowing animal species of a particular size range. This would be preferable to providing only a silty-clay soil evaporative zone layer that provides little or no protection against biointrusion.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

10.0 CAPILLARY BARRIER

SECTION: 2.2.2

INTERROGATORY STATEMENT(S): Page 2-8 identifies a Frost Protection Layer in the proposed ET cover system ostensibly designed to prevent underlying layers from freezing. However, layers other than the Frost Protection Layer (e.g., one or more biointrusion barriers, and a capillary barrier) may be helpful or necessary in minimizing unwanted effects of biointrusion and in dealing with increases in hydraulic conductivity resulting in greater infiltration, drainage and percolation. Once the Hydrus 2/3-D model has been revised to more fully account for changes in hydraulic conductivity of low-permeability layers, mammalian burrowing, frost-heave, distortion, etc., please use the model to evaluate and compare scenarios of drainage of water through the cover system under the following scenarios: (i) with and without one or more biointrusion barriers (which, if present, may somewhat diminish increases in hydraulic conductivity from burrowing, and which may be needed to protect the upper surface of a capillary barrier), and (ii) with and without a capillary barrier (which, if present, may increase rates of evapotranspiration and decrease deeper drainage and percolation).

SUMMARY OF BASIS FOR INTERROGATORY: Protection against frost damage of the radon barrier might be attained by placing a somewhat thicker layer of soil above the radon barrier compared to that recommended in the current version of the PA. However, it may be preferable from the perspective of protecting human health and the environment in compliance with the rules and regulations listed below to design and construct specialized layers in the cover system that, while also protecting against frost, would also provide for additional functionality within the cover system. Layers for consideration and testing through modeling should include one or more biointrusion barriers, and a capillary barrier.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Protection of the radon barrier against freezing is a vital part of developing and maintaining protection of groundwater and inadvertent intruders at the site. Freezing of any fine-grained layer of the cover system may cause water to be drawn upwards toward the freezing front, leading to desiccation cracking, freeze-thaw problems, and frost heaving – all of which may tend to increase hydraulic conductivity significantly. Having a substantively thick layer of soil (e.g., at least three and a half feet thick or very possibly more, depending on modeling results) above the radon barrier helps to protect that barrier from freezing. However, it would preferable to use materials in that thick layer of soil that, unlike the Frost Protection Layer, also serve to prevent or minimize biointrusion while better storing and releasing water for transpiration and evaporation.

The DRC recommends consideration of use of layers of soil providing more valuable functions, than what is proposed in the PA. Layers that might be able to serve more valuable functions include a cobble/clay (soil-rock matrix) biointrusion barrier, a fine-grained cap, and a coarse-sand/fine-gravel capillary barrier.

A biointrusion barrier may be important for several reasons. First, it protects the interface above a capillary barrier, if present, from bioturbation or mixing of soil by animal burrowing. Bioturbation or mixing of soil at the upper interface of a capillary barrier could impair or destroy its functionality, since the functioning of a capillary barrier depends on the construction of a layer of fine grain size upon a layer of comparatively larger grain size, with a distinct boundary between the two. Second, a biointrusion barrier limits animal burrowing down through the cover system, and especially into the radon barrier or the waste. If one or more biointrusion barriers are present, consisting of appropriately sized cobbles infilled with silty clay compacted into the cobbles using a vibratory compactor, then the barrier or barriers can also function to help (i) create adequate soil depth above the radon barrier for frost protection, (ii) enhance evaporation, and (iii) provide a suitable thickness of soil for water to be transiently stored after precipitation or snow-melting events and for water to enter roots of transpiring plants.

Also, it appears that a properly constructed capillary barrier might be able to serve as a deterrent to plant biointrusion at depths greater than about four feet. It is surmised by Anderson and Forman (2002) that a properly constructed capillary barrier should "restrict root growth so long as the underlying materials are relatively dry." Sands and gravels in deeper portions of a capillary barrier and in a layer of clay or silt below it should remain dry except occasionally during times when infiltration fronts move through the system after very large precipitation or snow-melt events. At such times, a properly constructed and daylighted capillary barrier, with an underlying clay layer below it, could function as a filter layer to help remove the infiltrated water.

Currently, no layer in the proposed cover system, including the Frost Protection Layer, provides adequate protection against mammalian biointrusion. Certain mammals that may be present on site can easily dig through several feet of silty clay having a level of compaction appropriate for a plant rooting zone in the cover, e.g., the Surface Layer and the Evaporative Zone Layer. Burrowing mammals also tend to find ways to burrow through well-graded materials, such as in the Frost Protection Layer. Burrowing mammals generally do so by removing sufficiently small rocks or particles to the surface, and by penetrating pores or gaps between larger rocks or particles as necessary.

A combination of silt and fine sand in an overlying cap, and coarse sand and fine-gravel in an underlying capillary barrier may work well to store infiltrated water under unsaturated conditions. Without a capillary barrier, water may go deeper than rooting depth in the winter and early- to mid-spring seasons when evaporation rates are relatively low and when plants are not actively transpiring, when the water passes down into and out of the root zone with minimal evaporation and without it being transpired at all. A properly designed and constructed capillary barrier helps retain substantially more water in the root zone so that it can, at a later point, undergo evapotranspiration.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(b); UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 2.2.3

INTERROGATORY STATEMENT(S): COVER DESIGN 3: Evapotranspirative Cover Design B is described on Page 2-9 of the PA. This proposed design includes a filter zone. However, the filter zone is not described in the PA as acting as a capillary barrier. If it does not act as such, then how would overall infiltration, drainage and percolation at the site be modified by changing the grain-size distribution in the lower part of the Frost Protection Layer to form a fine-grained cap, thereby allowing the underlying filter zone (if the grain-size distribution is appropriately modified) to act as a capillary barrier?

BASIS FOR INTERROGATORY: This second design employs a desirable filter zone. However, the grain size distribution in the Frost Protection Layer above the filter zone is not designed appropriately to make it function as a capillary barrier. Creation of a capillary barrier is potentially very valuable for enhancing removal of water from storage in overlying materials by evapotranspiration. However, the clay-size particles in the Frost Protection layer located above the filter zone in this proposed design would tend to pipe down into the filter zone along with draining water and ultimately would tend to plug the filter zone. The larger grain sizes (up to 16 inches in some cases) in the Frost Protection Layer would tend to defeat the potential of the underlying filter zone serving as a capillary barrier. The zone overlying the capillary barrier typically must be fine-grained. It must be designed using filter criteria to prevent soil particle movement into the underlying soil layer. And the filter zone itself must have an appropriately coarse grain-size distribution in order for the filter zone to function as a capillary barrier.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.5

INTERROGATORY STATEMENT(S): Page 3-3 includes this statement: "The candidate thick covers include capillary break, biointrusion, and bioturbation barriers that make the waste less accessible to plant roots after closure of the facility." Please explain how the proposed cover-system design 1 and design 2 include effective capillary barriers.

BASIS FOR INTERROGATORY: It is not apparent to the DRC how any effective capillary breaks or barriers are included in the proposed design. There are no specific details provided of capillary breaks or barriers per se.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 16 of Neptune and Company, Inc. (2012) says, "Lateral drainage layers have high saturated hydraulic conductivities to promote lateral flow and have characteristics similar to capillary barriers."

Please revise and clarify this statement so that it is more fully consistent with current scientific and engineering knowledge concerning drainage or filter layers and capillary barriers.

BASIS FOR INTERROGATORY: While both drainage layers and capillary barriers have high saturated hydraulic conductivities, important differences between these two entities exist.

In general, "a capillary barrier system consists of a layer of fine material overlying a coarse layer under a deep top soil", and its purpose consists of keeping as much moisture in the deep top soil as possible (Kampf and Montenegro, 1997). It is not necessary for a layer underlying the capillary barrier to have low permeability. Calculation of the effects of a capillary barrier system on movement of water within it in general assumes unsaturated (partially saturated) flow. Flow of water in a capillary barrier system is generally driven by potential gradients in water having negative pressure (or positive suction). This has a large impact on flow of water. In unsaturated flow, a gravel may potentially have a greater resistance to water movement than a clay.

By contrast, a lateral drainage layer generally consists of a layer of coarse, high-permeability material overlying a layer of fine, low-permeability material, and its purpose consists of conveying water away from the point of drainage from topsoils or other soils above. Its purpose, unlike that of a capillary barrier, is not to help retain moisture in overlying soils. Conventional drainage system calculations typically assume saturated gravity flow, where flow is from water with higher hydraulic head to water of lower hydraulic head, with all of the water having positive pressure. In saturated flow, coarser-grained materials, such as gravels, generally have higher hydraulic conductivities, or less resistance to flow, than do finer-grained materials, such as clays.

Multiple coarse layers in a capillary barrier system may exist. For example, the Hanford capillary barrier consists of a series of coarse layers in which each deeper layer has a hydraulic conductivity greater than that of the layer above it.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

11.0 HYDRAULIC CONDUCTIVITY, INFILTRATION AND FLOW

SECTION: 2.2

INTERROGATORY STATEMENT(S): Page 12 of the PA describes silty clay Radon Barrier material, saying, "Upper Radon Barrier: This layer consists of 12 inches of compacted clay with a low hydraulic conductivity. This layer has the lowest conductivity of any layer in the cover system. This is a barrier layer that reduces the downward movement of water to the waste and the upward movement of gas out of the disposal cell. Lower Radon Barrier: This layer consists of 12 inches of compacted clay with a low hydraulic conductivity. This is a barrier layer placed directly above the waste that reduces the downward movement of water."

Page 39 of the PA says, "Upper Radon Barrier: The engineering design specification for a maximum hydraulic conductivity is 5×10^{-8} cm/s (4.32×10^{-3} cm/day) for this clay barrier."

Page 39 also says: "Lower Radon Barrier: The engineering design specification for a maximum hydraulic conductivity is 1×10^{-6} cm/s (8.64×10^{-2} cm/day) for this clay barrier."

In addition to the Upper and Lower Radon Barriers, the surface layer and evapotranspiration layer are considered in the PA model to consist of silty clay materials.

The PA model makes no attempt to consider any changes in hydraulic conductivity of these low-permeability soils subsequent to embankment construction.

Upper and Lower Radon Barriers should be constructed having the soil hydraulic conductivities given in the engineering design specifications described above but the soil hydraulic conductivities should be modeled over the long-term as being in the range of 8×10^{-6} to 6×10^{-4} cm/s. This complies with NRC guidance for long-term cover-system hydraulic conductivity values (Benson et al., 2011). Please conduct a sensitivity analysis in the PA model using the following three values for long-term cover-system silty-clay hydraulic conductivity: 8×10^{-6} cm/s, 6.9×10^{-5} cm/s and 6×10^{-4} cm/s.

SUMMARY OF BASIS FOR INTERROGATORY: In a recent NRC guidance document, NUREG/CR-7028, Benson et al. (2011) demonstrate that low-permeability soil layers in alternative cover systems typically increase in hydraulic conductivity over several orders of magnitude over relatively short periods of time after construction (i.e., several years). The guidance given by the NRC is to design and model systems with these anticipated increases of hydraulic conductivity built into the design as much as possible. As they say, "Performance assessments should consider changes in engineering properties that are likely to occur . . . " This is not currently done in the proposed PA plans, which assume static hydraulic conductivity values over time. The PA needs to address modeling of cover systems with dramatically increasing values of hydraulic conductivity occurring within a relatively short time after construction as taught by Benson et al. (2011).

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: It is noted that the PA model currently employs temporally constant saturated hydraulic conductivity values for the Surface Layer, the Evapotranspiration Layer, the Upper Radon Barrier and the Lower Radon Barrier. At present, changes over time in saturated hydraulic conductivity for the cover-system soil layers do not appear to be explicitly accounted for in the PA.
This assumption of static hydraulic conductivity values is inconsistent with available experimental data for numerous alternative cover systems, which show that the majority of those tested over time intervals of up to nine years after construction experience substantive increases in hydraulic conductivity occurring relatively shortly after construction, i.e., within a few years (Benson et al., 2011). In some cases, these increases in hydraulic conductivity are more than four orders of magnitude. Among other causes believed to be responsible for increased cover soil hydraulic conductivity following construction are the following:

- Frost heave, frost cracking and freeze-thaw cycles (e.g., Benson and Othman, 1993; Benson et al. 1995). These can cause dramatic increases in hydraulic conductivity of engineered clayey soils. Dramatic increases in hydraulic conductivity have been observed after as few as three separate soil freeze-thaw cycles (Othman et. al., 1994, p. 241)
- Wet-dry cycling and desiccation fracturing (e.g., Suter et al., 1993; Benson et al. 1994)
- Root intrusion and other forms of biointrusion (e.g., Waugh et al., 1999, Dwyer 2003)
- Distortion (Benson et al., 2011)

Accordingly, Benson et al. (2011) indicate that cover-system designs must account for these changes, which, in less than a decade, result in substantial changes in cover system soil properties, a process which they term pedogenesis. The changes in properties are the result of macropore formation. As explained in Benson et al. (2011):

> Over the service life of a final cover, the hydraulic properties of earthen layers evolve due to the formation of soil structure in response to natural processes such as insect and animal burrowing, plant root growth, freeze-thaw cycling, wet-dry cycling, and distortion (Chamberlain and Gow 1979, Beven and Germann 1982, Benson and Othman 1993, Benson et al. 1995, Albrecht and Benson 2001). These processes create cracks, fractures, and other larger-scale features that are generally referred to as macropores. Formation of macropores alters the network of pores controlling retention and movement of water in the field, which is reflected in changes in the hydraulic properties (e.g., Ks and SWCC).

Later they say,

> The findings from this study have demonstrated that the properties of earthen and geosynthetic materials used in final covers change over time in response to interactions with the surrounding environment. . . Alterations in cover materials should be expected. . . . Performance assessments should consider changes in engineering properties that are likely to occur, and employ performance predictions based on the equilibrium state rather than the as-built condition.

While silty clays in the Surface Layer, the Evapotranspiration Layer, the Upper Radon Barrier and the Lower Radon Barrier are expected to be somewhat similar in composition to the native soils located outside the embankment, the silty clays intended for use in the various layers of the proposed ET cover system may differ from those in native in-place soils in the following ways:

- The soil emplaced in the cover system will be inclined with respect to the horizontal by four degrees on top slopes and twenty degrees on side slopes; because this differs from a nearly horizontal slope in native soils, there will be different stresses and strains, which, over time, may affect hydraulic conductivity
- The inclination of the soil emplaced in the cover system will also tend to subject the soil in this surface layer to storm-related water flow velocities greater than flow velocities experienced by water flowing over flatter, native-environment soils; and this will affect erosional processes and thus, hydraulic conductivity
- The soil emplaced in the cover may be compacted to a different degree than the native soil, which will affect hydraulic conductivity
- The soil emplaced on the top of the cover as proposed for design purposes will contain 15% gravel not present in the native soil, which will affect erosion and hydraulic conductivity; however, other soils in the cover system may contain the same amount of gravel, or even less than that
- The cover-system soils may be vegetated by different grasses, forbs and shrubs, depending on soil characteristics, slope, compaction and water availability, and they may support a different plant coverage, than native soils, which will in turn affect hydraulic conductivity
- The cover-system soils, because of all of these factors, will likely be subject to different amounts and types of biointrusion by plant roots and by animals, which will in turn affect hydraulic conductivity
- The cover-system soils will overlie or underlie layers having different characteristics than those found in native soils (e.g., the 18-inch-thick frost protection layer containing cobbles and boulders up to 18 inches in diameter, and the waste itself), which will influence adjacent soils and affect over time the cover-system soil characteristics, including hydraulic conductivity
- The cover-system soils, because of their being part of the embankment, will be affected by differential settlement over time and will therefore be subject to different tensile strains and amounts of distortion than native soils, which will in turn affect hydraulic conductivity
- Any thin but highly compacted low-permeability layers found in native soil (such as which appear at a few excavations made on site to limit infiltration and greasewood

rooting) will be broken up during clay mining and will not remain intact in soils emplaced on the cover; this may have major implications for plant-root biointrusion and impacts on soil hydraulic conductivity and cover-system hydraulics: others have noted that plant-root biointrusion into cover-system soils may increase hydraulic conductivity values by orders of magnitude

The DRC does not accept the premise that post-construction changes in surface-layer soil properties at the Clive site can be expected to be minimal or non-existent. This argument is not supported by data in the PA, and it is not in accord with published data in peer-reviewed journals, which show significant changes in soil hydraulic conductivity taking place within several years of construction in nearly all alternative cover-system soils studied.

The fact that the current modeling efforts and the proposed design in the PA do not account for changes in soil hydraulic conductivity after construction inherently implies that initial soil material properties remain constant over time. Static maintenance of these properties over time is highly unlikely considering the many processes that can potentially disturb the soil in the proposed cover system. Impacts from natural processes cannot be avoided. Hydraulic conductivities tend to increase greatly within a few years of construction. Benson et al. (2011) state

> For covers of typical thickness (< 3 m), the saturated hydraulic conductivity of earthen barrier and storage layers will increase over time in response to processes such as wet-dry and freeze-thaw cycling, with larger increases occurring in layers having lower as-built saturated hydraulic conductivity. Increases will occur until the saturated hydraulic conductivity is in the range of approximately $8x10^{-8}$ to $6x10^{-6}$ m/s.
>
> The changes occur regardless of climate, cover profile, or placement condition. Designers should acknowledge that these changes in properties will occur and select materials and placement conditions that result in earthen barrier and storage layers that have as-built saturated hydraulic conductivities within $8x10^{-8}$ to $6x10^{-6}$ m/s.

The proposed cover at the Clive site as planned in the PA has a cover thickness of 1.4 to 1.7 meters (6 inches + 6-18 inches + 18 inches +12 inches +12 inches = 54 to 66 inches = 4.5 to 5.5 feet). This is much less than the upper limit of applicability criterion expressed in the quotation above of 3 meters (~10 feet), so the statement by Benson et al. (2011) is applicable to the Clive site. Benson et al. (2011) state that, for such soils, "the *saturated hydraulic conductivity* of earthen barrier and storage layers *will increase over time* in response to . . . " various processes [emphasis added]. To re-emphasize, "the saturated hydraulic conductivity . . . will increase over time." So, an assumption that the saturated hydraulic conductivity of the upper layer of soil in the cover-system will not change over time cannot be accepted by the DRC. This approach is not consistent with observations made by experts of many different cover system materials over extended periods of time.

Benson et al. (2011), after stating that changes in the soils will indeed occur, provide a range of saturated soil hydraulic conductivity values (8×10^{-8} to 6×10^{-6} m/s) said to be equilibrium values expected for cover-system soils. This range is equivalent to 8×10^{-6} to 6×10^{-4} cm/s. The geometric mean of this range is 6.9×10^{-5} cm/s. Proposed PA plans indicate (as is discussed later in this document) that the upper radon barrier clay is to be assigned a hydraulic conductivity value about 1,400 times less than this geometric mean value. The DRC cannot accept the values for hydraulic conductivity assigned to cover system soils in the current PA model as representing hydraulic conductivities for long periods of time (e.g., a decade or more).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 42 of Neptune and Company, Inc. (2012) says, "not including the effect of soil crusts on infiltration will overestimate the actual net infiltration rate at the site."

Please revise or remove the statement. Alternatively, justify it.

BASIS FOR INTERROGATORY: The concept expressed here is not proven. It should not be included as a statement in the PA text without qualification or modification. It is surmised that the presence of soil crusts created by dispersion of soil particles during rainfall may indeed, at a very small scale, reduce hydraulic conductivity, increase runoff and therefore tend to decrease infiltration at the soil/air interface. However, the same soil crusts may also reduce evaporation, the principle means in the Great Salt Lake Desert by which water in soil is removed, thus tending by itself to increase infiltration. Moreover, cracking of clay at the surface due to desiccation or freeze-thaw activity of soil crust may create widespread polygonal openings in the soil crust that permit relatively large fluxes of infiltration, tending to reverse the effects on infiltration previously mentioned.

The relative reductions or increases of rates of infiltration and evaporation due to these processes are believed to be unknown. Thus, it does not seem possible to say which effects, if any, are dominant. It is considered possible, until proven otherwise, that, on a percentage basis, evaporation may be reduced as much as infiltration is at the soil/air interface, or even more so. Thus, it cannot be said with certainty that failing to account for the effects of the formation of soil crusts in modeling will necessarily increase modeled values of net infiltration.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 46 of Neptune and Company, Inc. (2012) says, "Average annual fluxes are small."

Please re-do the model with appropriate hydraulic conductivities, which will undoubtedly make average annual fluxes greater.

BASIS FOR INTERROGATORY: As previously discussed, long-term hydraulic conductivities in the current PA model are orders of magnitude greater than those recommended by NRC guidance (Benson et al., 2011). They must be dropped by orders of magnitude, which will correspondingly reduce average annual fluxes. The conclusion about average annual fluxes given above, therefore, appears to be flawed and is not accepted by the DRC.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

12.0 AIR EXPOSURES

SECTION: 3.1.1

INTERROGATORY STATEMENT(S): Pages 3-1 and 3-2 say, "that after final placement of the waste and closure of the Embankment with a rock armored cover, the facility design prevents any further migration of radioactivity through the air pathway. Analysis of the longevity of the alternate evapotranspirative cover designs, which provide equivalent isolation of waste from the atmosphere, also demonstrates that no such air-related doses are projected following closure and institutional control."

As discussed earlier, there is significant concern that the cover system as proposed will suffer from erosion. Should erosion be substantial, waste could be exposed to the atmosphere. Accordingly, please do a complete analysis of air exposures associated with windblown transport of bulk waste particles exposed at the site via erosion.

BASIS FOR INTERROGATORY: As previously mentioned, the statement above is not applicable to the Clive site in the context of the current PA, since the statement refers to "rock armor" protecting against migration of radioactive particles via air. Rock armor is not proposed in the current PA for the top slope nor for the bulk of the side slope.

The statement about air-related doses is also in need of revision or removal. Releases of contaminated waste particles to air can potentially occur under conditions in which gullies erode down into bulk waste. The potential for this at Clive is documented elsewhere within this Interrogatory. As documented by Abt et al. (1994), five of 11 reclaimed mine sites in the Western U.S. having gullies had them with depths in excess of 5.5 feet. That is as deep as or more deep than the proposed cover-system soil thickness of 4.5 to 5.5 feet at Clive. Gully formation may lead to subaerial exposure of bulk waste, and the potential for either "migration of radioactivity through the air pathway" as winds pick up waste particles and disperse them, or ingestion. This could lead to exposure of humans and animals in the environment. Accordingly, there is a need for a complete air exposure analysis, as well as an analysis of exposure to radioactivity via soil ingestion.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

13.0 OTHER MODELING ISSUES

SECTION: 2.3.1

INTERROGATORY STATEMENT(S): Page 2-10 states, "the soil:plant ratio was only used where actual measured soil K_d values are not available, and the published K_d value from the soil:plant ratio was decreased by two orders of magnitude to be conservative. The radionuclide K_d values used in this site-specific Performance Assessment are listed in Table C-4 of Appendix C." Relative to these comments, the DRC requests two items of information: (1) the names of the specific nuclides for which soil:plant K_d values were utilized, and (2) justification for the use of soil:plant K_d values in models for site contaminant transport.

BASIS FOR INTERROGATORY: It is important for the DRC to know the names of the specific nuclides for which soil:plant K_d values were utilized. The PA does not appear to provide justification for the use of soil:plant K_d values, with multiplication by an apparently arbitrary factor, as soil:water K_d values in the model for site contaminant transport.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.5

INTERROGATORY STATEMENT(S): On Page 3-8, it states, "Also, longitudinal dispersivity in the unsaturated and saturated zones was set at a larger value than that suggested by RESRAD default values (where larger values of longitudinal dispersivity reduce the potential arrival time of contaminants at the Point of Compliance well)."

Please reveal the value of longitudinal dispersivity in the saturated zone used in the model. Please also re-run the model with the suggested or default dispersivity value in the RESRAD model, or with another value chosen on a scientific basis and conservatively estimated, or else justify the use of the dispersivity value previously selected for use.

BASIS FOR INTERROGATORY: While setting the longitudinal dispersivity at a larger value than suggested does indeed reduce the modeled arrival time of contaminants (assessed at a given threshold concentration), it also will reduce the modeled concentrations of contaminants released as a slug or a pulse in areas at and near the advective front. With a continuous, uniform release of contamination, on the other hand, setting the longitudinal dispersivity at a larger value than suggested will decrease modeled values of contaminant concentrations behind the advective front until near steady-state concentrations are attained closer to the source. Neither of these undesirable results is considered conservative.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): Page 30 of Neptune and Company, Inc. (2012) says that "in this case the combination of climate and cover layer properties may maintain flow in the cover system as one-dimensional." This result is in contrast to that for the current, approved design, which is modeled as having two- or three-dimensional flow since it employs rock armor or rip rap cover, as well as two underlying drainage layers. It is said in the report that 18 to 19 percent of infiltrated precipitation is expected to be removed from the cover system in this current, approved design by lateral conveyance through the upper drainage layer. Another statement made is "with more water removed from the upper layers of the covers it is less likely that water saturations at depth could increase to the point where the filter layer would laterally divert water."

The Licensee needs to revise and upgrade its model to be consistent with NRC guidance and improved assumptions, rerun the model, determine the fractional flow removed laterally from the drainage or filter system design (Design 2), and then assess whether or not a drainage or filter system design would be beneficial for actual construction. Doing so will be necessary to meet requirements found in applicable rules and regulations and guidance listed below. Specifically, please run the model using the geometric mean of the range of anticipated hydraulic conductivity values defined by Benson et al. (2011) in the NRC guidance for clay layers in the radon barrier. Also, please use the lowest and highest values in that range as bounding values in sensitivity and uncertainty analyses. When modeling, also include all other modeling approaches and parameter changes requested in this Interrogatory, unless not using them is first negotiated with the DRC in writing. Please evaluate modeled drainage of water into the waste and the groundwater system using (i) no drainage or filter layer, and (ii) a drainage or filter layer comparable in performance to that in the old design. Assess the difference in drainage occurring as a result, and the need for modeling conducted using two or more dimensions.

SUMMARY OF BASIS FOR INTERROGATORY: A recent NRC guidance document (Benson et al., 2011) states that cover-system soil hydraulic conductivity values tend to increase over time (e.g., in less than a decade) and that equilibrium values of hydraulic conductivity should be used for cover-system soils. Preliminary analysis shows that values in this range are generally much, much greater than the hydraulic conductivity value currently assigned in the PA model to the upper radon barrier. The PA model does not assume that this value changes over time. This, in the opinion of the DRC, is a serious deficiency. Likewise, other soil layers, including the surface layer and the evaporative zone layer, are assigned very low hydraulic conductivities. Because of the use in the PA of these very low to extremely low hydraulic conductivity values over the 10,000 year modeling period, the model does not appear to properly account for flow within the cover system. Also, a need exists to change the way that boundary conditions are set up in the model, as discussed elsewhere in this document. Other assumptions additionally require modification.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Although current modeling, which assumes very low hydraulic conductivities for some of the layers in the ET cover system, indicates minimal lateral drainage, the PA model and its associated parameter values are shown elsewhere in this document to be substantially flawed. The PA model parameter values do not account for, among other things, increases in hydraulic conductivity in cover-system soils after soil placement. These increases in hydraulic conductivity can result from freeze-thaw activity, wet-dry cycling, animal biointrusion, plant biointrusion, distortion and erosion, as well as other factors. Benson et al. (2011) noted that, for initially low-permeability cover materials in tested alternative cover systems, increases of hydraulic conductivity over time of two to four orders of magnitude occurred over the course of a decade or less. They say, consequently,

> For covers of typical thickness (< 3 m), the saturated hydraulic conductivity of earthen barrier and storage layers will increase over time in response to processes such as wet-dry and freeze-thaw cycling, with larger increases occurring in layers having lower as-built saturated hydraulic conductivity. Increases will occur until the saturated hydraulic conductivity is in the range of approximately $8x10^{-8}$ to $6x10^{-6}$ m/s.
>
> The changes occur regardless of climate, cover profile, or placement condition. Designers should acknowledge that these changes in properties will occur and select materials and placement conditions that result in earthen barrier and storage layers that have as-built saturated hydraulic conductivities within $8x10^{-8}$ to $6x10^{-6}$ m/s.

Since the design cover system has a thickness of less than three meters, the advice given above by Benson et al. (2011) applies. Benson et al. (2011) predict that increases in hydraulic conductivity will occur for sites in general until the hydraulic conductivity reaches 8×10^{-8} m/s to 6×10^{-6} m/s. This is equivalent to a range from 8×10^{-6} cm/s to 6×10^{-4} cm/s. Use of a geometric mean is usually considered optimal for an average of log-normally distributed values. Hydraulic conductivities in natural porous media tend to be log-normally distributed. The geometric mean of end-point hydraulic conductivity values in the range of 8×10^{-8} to 6×10^{-6} m/s is approximately 7×10^{-7} m/s, which is equivalent to 7×10^{-5} cm/s.

Modeling in the PA ignores the likelihood of earthen materials used in construction having hydraulic conductivity values that increase in value above initial values at the time of construction. Modeling in the PA employs static values of hydraulic conductivity for proposed design cover-system soil layers as low as 5 x 10^{-8} cm/s (i.e., for the upper radon barrier). This is only 0.0007, or 0.07%, of the geometric mean of values given by Benson et al. (2011).

Other needed changes in model approaches and parameter values are identified in this Interrogatory. Incorporation of these may indicate a need for running a two- or three-dimensional model.

Models must be run using more realistic long-term hydraulic conductivity values for the upper radon barrier. The geometric mean value of the Benson et al. (2011) range should be approximately 1,400 times the value currently used in modeling for the upper radon layer. When this is done, model results will change. Flows will be greater. With these modeling changes, it is much more likely that flow will be recognized as being two- or three-dimensional and that a drainage layer may be necessary in final cover-system design and construction.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Pages 31 and 32 of Neptune and Company, Inc. (2012) show conceptual cross-sectional diagrams for the numerical models used in the PA to assess whether horizontal components of flow exist through the side slopes of the cover system. These conceptual schematics show no-flow boundaries existing on seven of the eight sides of four model layers. That's all except one on the downgradient side of either the frost protection layer or the filter zone, depending on the model used. These no-flow boundaries are shown in the conceptual diagram as being vertical. Upslope boundaries are shown as being stacked vertically. Downslope boundaries also appear to be stacked vertically. There is no downslope termination of layers shown horizontally against the cell liner or the protective liner cover, as is depicted in design plans.

Please re-model flow using more realistic model-layer geometries and boundary conditions at the downslope and upslope boundaries of each layer so as to more accurately represent field conditions. Alternatively, provide justification for the existing geometry and boundaries.

SUMMARY OF BASIS FOR INTERROGATORY: A model is presented in the modeling report that purportedly demonstrates that flow in the side-slope cover system is essentially vertical, i.e., without significant lateral components of flow. However, the model is not set up with realistic geometries or boundary conditions. It does not accurately represent field conditions, and it does not prove that flow is essentially vertical. The conceptualization of how and where water enters and leaves the system is critical to the development of an accurate model.

One layer of the model, the Frost Protection Layer, has a downslope boundary shown in the conceptual diagram on Page 31 entitled "Seepage Face Boundary". A seepage face boundary is a boundary type that, in models in general, represents the interface between the lateral end of a fluid-filled porous medium and the atmosphere. In design drawings, however, the Frost Protection Layer, unlike its depiction in the conceptual model, is not exposed at its downslope end to the atmosphere. It is instead buried beneath other soil layers, and it terminates against the cell's relatively impermeable clay liner system at depth. The appropriate downslope boundary for this layer is therefore not a seepage face boundary but rather either a no-flow boundary or a connection to the cell liner (below which might be a free drainage boundary). This contact with the cell liner (which may potentially be a no-flow boundary) is not vertical but rather horizontal or sub-horizontal.

The model is currently constructed with all of its layers set up such that they terminate at the same lateral distance from the center of the modeled sideslope section. Seven of the eight ends of the four model layers are shown terminated by no-flow boundaries. This results in a stacked series of vertical no-flow boundaries for the package, four on one side, and three on the other. But, in actual design drawings, the downslope ends of the layers in the proposed cover design do not all terminate at the same lateral distance from the center of the sideslope as each other, as is conceptualized in the model. Instead, in the design drawings, the layers all terminate downslope at different distances from the center, the no-flow boundaries or contacts that they have with the cell liner are horizontal, and they do not line up with each other vertically (see Energy*Solutions* 02112013 - ET Cover Design - RML Renewal Briefing.pdf). Each layer instead terminates downslope against the cell's clay liner, or the protective liner cover above it. No layer is exposed to the atmosphere. The PA model conceptualization, which does not depict the proposed cover system this way, is therefore faulty.

The artificial imposition of vertically oriented no-flow boundaries at nearly all ends of soil layers in the cover system tends to drive water down vertically in the model. There appears to be no justification for the use of these boundaries as they are currently set up, either downslope or upslope. Without these artificially imposed vertical no-flow boundaries in the model, predicted water flow paths would be different than those currently described in the PA.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The DRC has concerns about the model intended to evaluate lateral flow as it is currently depicted in the conceptual schematic. The set of comments directly below addresses concerns having to do with the choice of vertically oriented no-flow boundaries at seven of eight lateral ends of the modeled layers, the model geometry which artificially imposes vertically stacked no-flow barriers for various layers, and the artificially imposed seepage boundary imposed on the downslope end of the Frost Protection Layer (in design 1).

In the Neptune and Company, Inc. (2012) report, vertically oriented no-flow boundaries are artificially imposed on the sides of all model cover-system layers except on the downgradient side of the frost protection layer, which has a seepage-face boundary. This artificial imposition of vertically oriented no-flow boundaries on the other layers does not seem to be consistent with the physical realities of actual cover system layers to be found at the site. Neither does artificially imposing a seepage face boundary at the downslope end of the Frost Protection Layer.

In design drawings, the Frost Protection Layer, unlike its depiction in the conceptual model, is shown at its downslope end to be not exposed to the atmosphere. It rather is buried beneath other soil layers, and it terminates against the cell's clay liner at depth. The appropriate downslope end of this layer, unlike that depicted in the model, is therefore not a seepage face boundary (such as one that might be in contact with the atmosphere) but a no-flow boundary (bounded by a cell liner or its protective layer) or simply a contact oblique with the cell liner. Furthermore, this contact is not vertical but horizontal or sub-horizontal.

The model is also constructed with all layers set up so that they terminate (vertically) at the same lateral distance from the center of the modeled sideslope section. This is inappropriate. The downslope edge of each actual layer is shown in design drawings to terminate horizontally against the horizontal liner or the horizontal protective cover layer, near to and below the ditch. Any model boundary should therefore be horizontal, not vertical. The contacts with the liner system are staggered horizontally. The evaporative zone layer terminates against the liner or protective cover layer about 3.0 to 4.6 meters (10-15 feet) closer to the center of the ditch than does the lower radon barrier. Large variations in hydraulic conductivity are expected to exist between some layers. This would likely be the case, for example, between the Frost Protection Layer (containing up to 16-inch-diameter boulders) and the Upper Radon Barrier (a clay treated so as to render it relatively impermeable). Any saturated flow within the more-permeable layers in a model with appropriately set up geometrical relationships and boundary conditions, even in isotropic soils, should therefore be predominantly semi-parallel to the bedding planes and the layers, rather than vertically through them. This is according to the tangent law of refraction. Tangent laws of flow also apparently apply to unsaturated flow (e.g., see Miyazaki, 2005). The fact that soils tend to be anisotropic, with much greater hydraulic conductivity parallel to bedding than perpendicular to bedding, would also tend to accentuate these flow trends. Thus, flow at high-K-contrast boundaries should be very close to 20 degrees with respect to the horizontal, and flow will not appear to be either vertical, or perpendicular to bedding planes.

Additionally, upslope boundaries should not be treated as no-flow boundaries. In actual design and construction, the upslope boundaries of side-slope layers at Clive are in hydraulic contact with top-slope layers. Any flow from a 20-degree-sloping upgradient portion of a sideslope will have a large lateral component of flow. Even flow from the topslope will have a large lateral component of flow. The top-slope layers receive abundant precipitation and are sloped down to the side-slope layers, the top-slope layers are intimately connected hydraulically to the side-slope layers, and the top-slope layers potentially contain water having horizontal components of hydraulic gradient. This would allow for some downslope flow into the side-slope region having a 20 degree slope. The flow near this "boundary" would not be 100% vertical, as it is currently forced to be by the artificially imposed no-flow boundaries currently used in the model. There should be no barrier to lateral components of flow at the upslope boundaries in the model. The Licensee may wish to consider whether constant-head or constant-flux boundaries might be more appropriate for these boundaries.

The artificial imposition of vertically oriented no-flow boundaries on layers in the model tends to direct flow throughout the modeled region in a direction parallel to the no-flow boundaries. In this model, flow is purportedly vertically downward. The model is said to be intended in part to demonstrate whether vertically downward flow could or would occur in an actual constructed cover system. But flow is constrained by force of the model's vertically oriented no-flow boundaries at seven of eight layer ends to be essentially vertical – no lateral flow in or out of the ends of those layers is in fact possible in the model. This influences flow throughout the entire region. In other words, the model results tend to be forced by model design to indicate vertical flow. This is what the model is supposed to prove. But it does not.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): The proposed model cross-sectional schematics on Pages 31 and 32 of Neptune and Company, Inc. (2012) show that a no-flow boundary, in addition to the no-flow boundaries at the ends of the surface layer, exists over approximately the downslope 23% (2.1 meters, or 7 feet) of the top of the modeled 9.1 meter-long (30-foot-long) surface layer.

This no-flow boundary along the surface does not correspond with physical conditions to be realized in the field once construction plans are implemented. Re-do the model to remove the artifice of imposing a no-flow boundary over the lower 2.1 meters, or seven feet, of the top of the surface layer. Also, fix other problems with the way the model is set up. Alternatively, provide justification for imposing this boundary.

SUMMARY OF BASIS FOR INTERROGATORY: There is no valid physical justification for placing a no-flow boundary over the downslope 23% of the top of the surface layer as presently configured. This is an artifice that, along with other model issues, causes the model to produce non-viable results. Also, the presence of rip rap on the downslope 9.8 meters (32 feet) or so of the surface above the evaporative zone is predicted to have adverse effects on evaporation on that part of the cover system, with a consequent tendency toward increased infiltration. This is not captured in current PA modeling.

There are a number of reasons why flow might not be detected at the observation point in the model as it is set up, even when a lateral flow of water might actually be occurring through or under the location of the observation point. The lack of observed flow in the model at the observation point does not necessarily indicate a lack of flow through the frost protection layer or the filter zone.

The DRC requires modifications in the setup of the model. Only by properly setting up the model can correct results be drawn from runs of the model that will help meet the requirements of the rules and regulations listed below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: There appears to be no physical justification for placing a no-flow boundary over the downslope 23% (2.1 meters, or 7 feet) of the top of the surface layer. There appears to be no valid physical reason to assume that this region of the upper surface of the surface layer is impermeable to flow, whereas the remaining 77% of the top of the surface layer is permeable to flow.

The artifice of placing a no-flow boundary over the downslope region of the upper surface of the surface layer was ostensibly done by Neptune and Company, Inc. (2012) to help make a point during modeling work. The idea presumably was to demonstrate a purported lack of lateral flow. In model results, no flow was noted at the observation point located below this no-flow boundary, so it is assumed by Neptune and Company, Inc. (2012) that there must not be any lateral flow. This is a faulty assumption, and the hoped-for conclusions are not demonstrated by the modeling. Reasons for this will be described shortly.

There are other potential reasons for a lack of flow being noted at this observation point located below the artificial no-flow boundary at the surface. First, as previously mentioned, artificially emplaced vertical no-flow boundaries located at seven of eight ends of the four layers in the modeled realm tends to drive nearly all infiltrated water vertically downward. Flow lines near vertical no-flow boundaries generally tend to be parallel to the no-flow boundaries (i.e., vertical). Other flow lines in the region will, in general, tend to be parallel to the flow lines near the no-flow boundaries (i.e., vertical) unless constrained otherwise by features not now seen in the model.

Second, at the base of the lower radon barrier, flow through the base of the system is not blocked at all. A no-flow boundary is not present. So, in combination with other hydraulic constraints, this tends to make flow in the model appear to go vertically downward.

Third, the presence of the no-flow boundary placed over the downslope 23% of the top, or upper surface, of the surface layer excludes all surficial entry of precipitation over that no-flow boundary, starting seven feet away from the layer's end. This means that even should some of the flow near the upslope edge of the no-flow boundary have a lateral flow component, evidence of that flow would not likely be picked up by an observation point located distantly near the opposite edge of each layer.

The modeled section is approximately 9.1 meters (30 feet) long (see Page 37). From the cross-sectional schematics on Pages 31 and 32, it appears that approximately 23% (2.1 meters, or 7 feet) of the top of the surface layer is blocked from infiltration of water due to the presence of the artificially imposed surficial no-flow boundary. While it is not revealed in the text, it appears from the diagrams in the PA that the observation point (the green circle in the schematics) is about 0.3 meters (1 foot) from the downslope seepage face boundary. This means that the closest lateral distance between the edge of the no-flow boundary and the observation point is about 1.8 meters (6 feet, or 72 inches).

In the design with the six-inch-thick evapotranspiration layer, the minimal total thickness of soil above the observation point is 0.53 meters (21 inches). This means that if a drop of water entering into the modeled sideslope package of soil at the upslope edge of the upper-surface no-flow boundary is to ever reach the observation point, it must travel parallel to the strata within the layers 1.8 meters (72 inches) while traveling perpendicular to the strata only 0.53 meters (21 inches). This means that the angle of travel with respect to a perpendicular to the strata must be at least $\tan^{-1}(72/21) = 74$ degrees, or, with respect to a line parallel to the strata, at most, 16 degrees. That is an absurdly excessive requirement that must be met in order for lateral components of flow to be acknowledged in the model.

Any drops of water entering as infiltration into the modeled sideslope soil package farther away from the observation point than this 1.8 meter (72-inch) distance do not have a chance of being detected in the model unless their flow direction is even more close to parallel to the strata than that of the first drop. Any drops of water hitting the modeled sideslope package closer to the observation point than the 1.8 meter (72-inch) distance cannot enter the package at all, due to the location of the artificially imposed no-flow boundary on top of the surface layer blocking their entry. Somewhat similar considerations with different numerical values hold for scenarios with greater thicknesses, e.g., 0.31 meters (12 inches) or 0.46 meters (18 inches) of frost protection layer.

Fourth, in Figure 7 for design 1, the observation point in the model appears to be located about half-way across the frost protection layer. This means that, if the head of water in the frost protection layer was such that it did not reach all of the way up to the model cell containing the observation point, no flow would be detected at all during modeling. Depending on model cell size, there could be, however, relatively fast water flowing laterally out of the modeled realm through the frost protection layer at a depth of water less than the base of the model cell nearly half way across. However, any flow would not be observed in model results, unless some of that water happened to be in the model cell containing the observation point.

The frost protection layer is modeled as being 0.46 meters (18 inches) thick. It is not known how large is the model cell containing the observation point. Assume, for the moment, that it is 0.05 meters (2 inches) thick, with 0.20 meters (eight inches) of frost protection layer cells above it, and 0.21 meters (eight inches) of frost protection layer cells below it. So, if water is present in and flowing through the lower 0.15 meters (6 inches), say, of the frost protection layer, it would not be detected at all at the observation point. Yet this could represent a significant flux of water. Actual heights of water in the frost detection layer not detected by the model at the observation point are not known, as calculations depend on cell size.

Fifth, as described below, the hydraulic conductivity for each layer is presumed to be modeled as being isotropic, whereas it most likely is anisotropic. This can have a large impact on ratios of vertical to horizontal flow components. This is explained in more detail in the section below.

Sixth, in the actual construction design, the downslope edge of each proposed cover-system soil layer does not have a vertically oriented no-flow boundary, but rather, the layer extends down to meet a horizontal no-flow boundary (i.e., the two-foot-thick clay liner, and/or the one-foot-thick liner protective cover – see Energy*Solutions* "Clive Facility" Class A Embankment, Sections and Details, 1 of 2, Clive, Utah). This means that the frost protection layer, the evapotranspiration layer, and the surface layer do not have any radon barrier material beneath them at the point where they meet the clay liner or liner protection cover. While the clay liner could ostensibly be simulated as a no-flow barrier, it is uncertain as to whether the liner protective cover would be sufficiently impermeable to be considered a no-flow boundary.

Seventh, in the final Energy*Solutions* "Clive Facility" Class A Embankment, Sections and Details, 1 of 2, Clive, Utah drawing, there is a section covered by a relatively impermeable layer of clay as well as by a ditch rip-rap layer. This section is noted as the "ditch transition zone" at the toe of the cover system. It is identified in the drawing as being approximately 4.3 meters (14 feet) wide. There is also an additional 5.5 meters (18 feet), approximately, of "evaporative zone" upslope, which also is covered by ditch rip rap. This ditch rip rap appears to be approximately 0.30 to 0.45 meters (1.0 to 1.5 feet) thick. As previously discussed in this document, a layer of rip rap this thick is likely to diminish evaporation and also increase infiltration tremendously. None of this is accounted for in the model described in the PA.

Similar arguments, with different calculated numbers, also apply to the design 2 model.

To summarize, there is no valid physical reason to have a no-flow boundary at the lower 2.1 meters (seven feet) of the surface layer. The presence of rip rap on 9.7 meters (32 feet) or so of the surface above the evaporative zone is predicted to have adverse effects on evaporation on that part of the cover system, with a consequent tendency toward increased in infiltration. These effects are not captured in current PA modeling.

Also, there are a number of reasons why flow might not be detected at the observation point in the model as it is set up, even when a lateral flow of water might actually occur through or under the location of the observation point. The lack of observed flow in the model at the observation point does not necessarily indicate a lack of flow through the frost protection layer or the filter zone. There are several reasons why this may occur. The model can be developed better so as to actually indicate whether flow has a horizontal component, and, if so, how much.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): The conceptual model for the proposed cover system as described on Pages 30 through 32 of the Neptune and Company, Inc. (2012) report appears to assume isotropic conditions for soils, wherein values of components of hydraulic conductivity in the x, y and z directions in the model are equivalent to each other. No mention is made in the text of any anisotropy having been modeled.

Please re-run the model without the assumption of isotropicity. Assume reasonable ratios of horizontal to vertical conductivity (K_x/K_z) ranges. Please also perform sensitivity and uncertainty analyses.

SUMMARY OF BASIS FOR INTERROGATORY: The proposed model ignores anisotropy in the modeled layered soil layers. Anisotropy is typically found in layered soils, whether found in nature, or compacted on an embankment. Anisotropy is the condition in which the relevant hydraulic conductivity, or ease with which fluid flows in the soil, depends on the modeled direction of flow. Typically, soils have much higher hydraulic conductivity values in a direction parallel to the plane of bedding (usually in a near-horizontal direction) than perpendicular to bedding (usually in a near-vertical direction). The DRC expects that, due to the placement of the soil layers in the proposed cover system, some amount of anisotropy will be present. Failure to account for this anisotropy in PA modeling is likely to skew model results. Among other things, the failure to account for anisotropy will tend to make flow in the model appear to be more vertically oriented than it actually is. The model must be re-done to account for the likely influence of anisotropy. It would be appropriate for the Licensee to conduct uncertainty and/or sensitivity studies on this topic, since it is uncertain how much anisotropy in the different soil layers exists, and it is not clear *a priori* to what extent the actual anisotropy will affect lateral components of flow. Accounting for anisotropy is essential to obtaining accurate model results that will help protect human health and the environment as required by the rules and regulations listed below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: In most natural subsurface soils, hydraulic conductivity is highly anisotropic, rather than isotropic. Hydraulic conductivity in the plane of an earth layer, or parallel to the bedding planes of that layer, is often one or more orders of magnitude greater than the hydraulic conductivity perpendicular to that layer, or perpendicular to the layer's bedding planes. This is indicated in a large number of publications. For example, Fitts (2002) states

> Granular sediments like sands and sedimentary rocks like sandstones may be isotropic on a very small scale, but due to lenses and layering they are anisotropic when a large scale is considered. For larger scales, the ratio of horizontal to vertical conductivity K_x/K_z can range from less than 10 to more than 100 in layered soils and rocks.

Guidance for RESRAD from Argonne National Laboratory (undated) states:

> Because of the usually stratified nature of unconsolidated sedimentary soil materials, soils are usually anisotropic. Within an anisotropic geological formation, the vertical component of the saturated hydraulic conductivity is usually smaller (one to two orders of magnitude) than the horizontal component.

Batu (2006) says "It is a well-known fact that vertical hydraulic conductivity may be 1 to 3 orders of magnitude less than horizontal hydraulic conductivity, depending on the type of formation."

The current model ignores anisotropy in the modeled soil layers. In an engineered setting, anisotropy is not likely to be as extreme as in nature, but it nonetheless needs to be accounted for. Failure to account for anisotropy in modeling in the PA skews model results. Among other things, the failure to account for anisotropy will tend to make flow in the model appear to be more vertically oriented than it actually is.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Figure 8 (which purports to represent "daily precipitation") on Page 35 of the Neptune and Company, Inc. (2012) report shows many data points over a 100-year period with precipitation varying between 1.0 and 2.0 centimeters (0.4 to 0.8 inches). The average value, although not easily decipherable from the figure, appears to be in the range of 0.5 centimeters (0.2 inches).

Please explain, justify, or fix the data provided. If the model is affected, then please fix the model.

BASIS FOR INTERROGATORY: If this were daily precipitation, then an average value of 0.5 centimeters (0.2 inches) would represent 0.5 centimeters/day (0.2 inches/day), or 183 centimeters (1.83 meters, 6.00 feet, or 72 inches) of water falling per year as precipitation. Yet yearly precipitation is supposed to be only about 8.62 inches/year (0.22 meters/year -- see Page 2-2 of the PA).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 39 of Neptune and Company, Inc. (2012) states, "The saturated hydraulic conductivity of the filter layer had to be reduced to a value of 864 cm/day for the 2-D model in order to reach model convergence."

Please re-do the model using the Meyer et al. (1996) hydraulic conductivity of 86,400 cm/day. It is not acceptable to the DRC for the Licensee to artificially reduce modeled hydraulic conductivity for the filter layer 100-fold without first attempting other model modifications; the performance of the filter layer is critical to making decisions about the performance of cover-system design. What other approaches can be taken to attain model convergence (e.g., changing time steps, changing spatial discretization, etc.) without artificially reducing hydraulic conductivity of an important component of the model?

BASIS FOR INTERROGATORY: Table 4 on Page 40 of Neptune and Company, Inc. (2012) shows "filter zone" (filter layer) hydraulic conductivity to be 86,400 cm/day. An artificial reduction by two orders of magnitude to attain model converge was done. This is unacceptable, since one of the primary reasons of running the model appears to be to show whether or not lateral drainage would occur through the filter and whether or not the filter was necessary. The current model appears to show that the filter does not confer much greater benefits than no filter may be attributable, at least in part, to the artificially reduced hydraulic conductivity. However, the biggest problems appear to be related to boundary conditions imposed on the model.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 43 of Neptune and Company, Inc. (2012) says that "zero water flux was recorded through the seepage faces."

Page 45 says, "The results of these 2-D simulations demonstrate that water flow in the cover system for both designs is predominantly vertical with no significant horizontal component."

These conclusions are not justified. Please re-do the modeling with more appropriate boundary conditions and model assumptions. Alternatively, justify the existing modeling results.

BASIS FOR INTERROGATORY: As previously described, the model was set up inappropriately, (1) with 23% of the cover (closest to the seepage faces) blocked with regard to infiltration, (2) with hydraulic conductivity of layered soils in the modeled realm inappropriately assumed to be isotropic, and (3) with no-flow boundaries artificially imposed at all but one downslope ends of the soil layers involved. Thus, with results only from the current model, the conclusion given above that zero water flux was recorded through the seepage faces is essentially meaningless. The conclusion about no significant horizontal component of flow is also without justification.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): On Page 50 of Neptune and Company, Inc. (2012), it is said in regard to RESRAD-OFFSITE that "the runoff coefficient was set at a value of 0.99."

The value for Cr, the runoff coefficient, used in the model and described in the text appears to be high. Please change it so that it appropriately represents physical processes at the site. This will, of necessity, also force change of the evapotranspiration coefficient value used in the model.

SUMMARY OF BASIS FOR INTERROGATORY: The value for Cr appears to be too high based on Cr values for relatively low-permeability materials such as asphalt typically used by experts in surface hydrology and civil engineering.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: A definition for the runoff coefficient is given in a manual for data collection and application in RESRAD codes. The primary author of the manual is Dr. Yu, the developer of RESRAD-OFFSITE code (Yu et al., 1993):

> The average annual runoff coefficient, Cr, is the fraction of the average annual precipitation that does not infiltrate into the soil and is not transferred back to the atmosphere through evapotranspiration. The runoff coefficient represents the fraction of the precipitation, in excess of the deep percolation and evapotranspiration, that becomes surface flow and ends up in either perennial or intermittent surface water bodies.

The average annual runoff at Clive is not likely to be as high as 99% of precipitation. Even asphalt, which is relatively impermeable, is customarily assigned a runoff coefficient somewhere in the range of 0.75-0.95%. This use of 99% for a runoff coefficient in RESRAD is inconsistent with other model results described in the PA. The HYDRUS 2/3-D model predicts zero runoff over the simulation period (although it is granted that the program most likely greatly underpredicts runoff – but that does raise questions about the viability of the model in this application). A 99% value for Cr would only be appropriate for a nearly uniform, impermeable soil.

As shown in photos provided in a past section, the native clay at the surface at Clive is not uniform and impermeable. Instead, surface macropores, such as polygonal fractures or cracks in drier clays, tend to develop, along with erosional features such as rills and gullies. Shrinkage cracks are expected to increase permeability and infiltration and decrease runoff at the start of a precipitation event until the cracks fill with water or close due to clay expansion. The flow of water into and from these cracks is called bypassing. This is not accounted for in the current model. Bronswijk (1988) refers to clayey soils that have shrinkage cracks and says,

> "The introduction of shrinkage characteristics in addition to water retention and hydraulic conductivity curves into simulation models makes it possible to calculate accurately water balance, subsidence and cracking of clay soils. The present method of dynamic partitioning of rainfall into matrix and crack infiltration simulates bypass flow and resulting rapid rises in groundwater table satisfactorily. Bypass flow is of great importance in a clay soil. Especially in the case of high-intensity rain on dry clay soil, a large part of the infiltrating water is transported quickly to the groundwater table."

Jarvis and Leed-Harrison, P.B. (1990) say,

> It is now well known that the presence of macropores (e.g. old root channels, earthworm burrows, cracks and fissures) allows rapid nonequilibrium flow of soil water, a process variously termed bypassing, preferential flow or simply channelling (Bourns, 1981; Beven and Germann, 1982). Such flow processes are particularly important in clay soils (Leeds-Harrison et al., 1982), since the hydraulic conductivity of the textural porosity may be negligible.

Because Clive site surface clays have abundant shrinkage cracks, as well as other macropores, infiltrated water is expected to drain down into the cover system soils faster and deeper compared to drainage in otherwise similar clays with no cracks or other types of macropores. Macropores discussed here and elsewhere in this document are likely to cause decreased runoff and increased infiltration compared to what the model currently predicts. Among the processes associated with formation and/or flow through macropores are shrinkage crack drainage, frost-heave damage, wet-dry cycling, distortion, plant biointrusion, and animal biointrusion of cover-system soils.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 60 provides results of current modeling efforts. It states, "Iodine-129 did not reach the groundwater well within the 10,000-year time frame." Since iodine-129 is assumed to be conservative, it is concluded in the text that no radionuclide breaks through to a point of compliance within the 10,000-year time frame.

For protection of human health and the environment, and to comply with the rules and regulations listed below, please revise model input for long-term cover-system clay soil hydraulic conductivity in accordance with NRC guidance in Benson et al. (2011), re-run the model, and re-design the cover system for the site in order to provide for needed reductions in risk to human health and the environment. Please describe the changes in the text.

SUMMARY OF BASIS FOR INTERROGATORY: Results above are not valid if hydraulic conductivities of the upper radon barrier increase over a decade to values two to three orders of magnitude greater than the hydraulic conductivity value used in the model. Benson et al. (2011) indicate that hydraulic conductivities of low-permeability soils in a cover should be expected to increase by two to three orders of magnitude over a relatively short time. This may lead to estimated times for breakthrough of at least some radionuclides at the point of compliance at the site of less than 500 years. For protection of human health and the environment, and to comply with the rules and regulations listed below, please revise model input for long-term hydraulic conductivity in accordance with NRC guidance in Benson et al. (2011), re-run the model, and re-design the cover system for the site to provide for needed reductions in risk to human health and the environment.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The validity of the result referenced in the statement quoted above depends on whether the assumptions made in the current model are accurate. If the assumptions are not accurate, then the result is not valid. Movement of Iodine-129 in groundwater in the model is assumed to not be retarded, since Iodine-129 has an assigned K_d value in the model of zero. The fact that Iodine-129 does not break through at the point of compliance within 10,000 years is taken in the PA to indicate that no radionuclide will reach the point of compliance within this time frame.

Breakthrough of Iodine-129 to the point of compliance is said in the PA to take between 12,500 and 15,000 years. This very long time that it takes for Iodine-129 to travel to the point of compliance in the model has little to do with time of transport in the groundwater system. As can be inferred from previous comments elsewhere in this document, lateral transport in groundwater to the point of compliance of a conservative solute takes only about 26 years for travel of 90 feet to a point of compliance. The PA says 60 years. Either way, it is seen that close to 100% of the time required for solute to breakthrough at the point of compliance in the PA model (between 12,500 and 15,000 years) is associated with migration of a solute through the vadose zone, rather than the saturated zone. Time associated with migration nearly all entails time when the solute is located in the waste, the unsaturated zone below the waste, or the capillary fringe.

So, a radionuclide atom, ion or molecule, or a drop of water containing the radionuclide, is supposed to spend approximately 12,500 to 15,000 years in the vadose zone, moving through some or all of the 23 meters (87 feet) of contaminated zone (see Page 53 of the PA) as well as 4.23 meters (14 feet) of vadose or unsaturated zone below that (see Page 55 of the PA). This means that concerns about the validity of modeling most likely should focus on parameters and equations involving transport in the vadose zone.

The velocity of travel through the vadose zone (considering a single contaminant atom, ion or molecule in the contaminated zone) is thus considered in the model to be as low as (14 feet)/(15,000 years) = 0.00093 feet/year (0.00028 meters/year), or as high as (87 + 14 feet)/12,500 years = 0.0081 feet/year (0.0025 meters/year). The first velocity means that it takes a radionuclide atom, ion or molecule nearly 1,100 years to travel one foot (0.3 meters). The second velocity means that it takes a radionuclide atom, ion or molecule 120 years to travel one foot (0.3 meters).

Based on hydraulic considerations, the earthen layer that is primarily supposed to slow the speed of travel of infiltrated water and the radionuclides contained in it down to these extremely low speeds is the upper radon barrier. The upper radon barrier consists of Unit 4 clay. The upper radon barrier has the lowest hydraulic conductivity of any layer of the cover system. Its hydraulic conductivity is also presumably lower than the hydraulic conductivities of the waste or the vadose zone below the waste. The upper radon barrier resides in the shallow subsurface with only 0.76 to 1.1 meters (2.5 to 3.5 feet, or 30 to 42 inches) of soil above it, depending on design selection, based on currently proposed design plans.

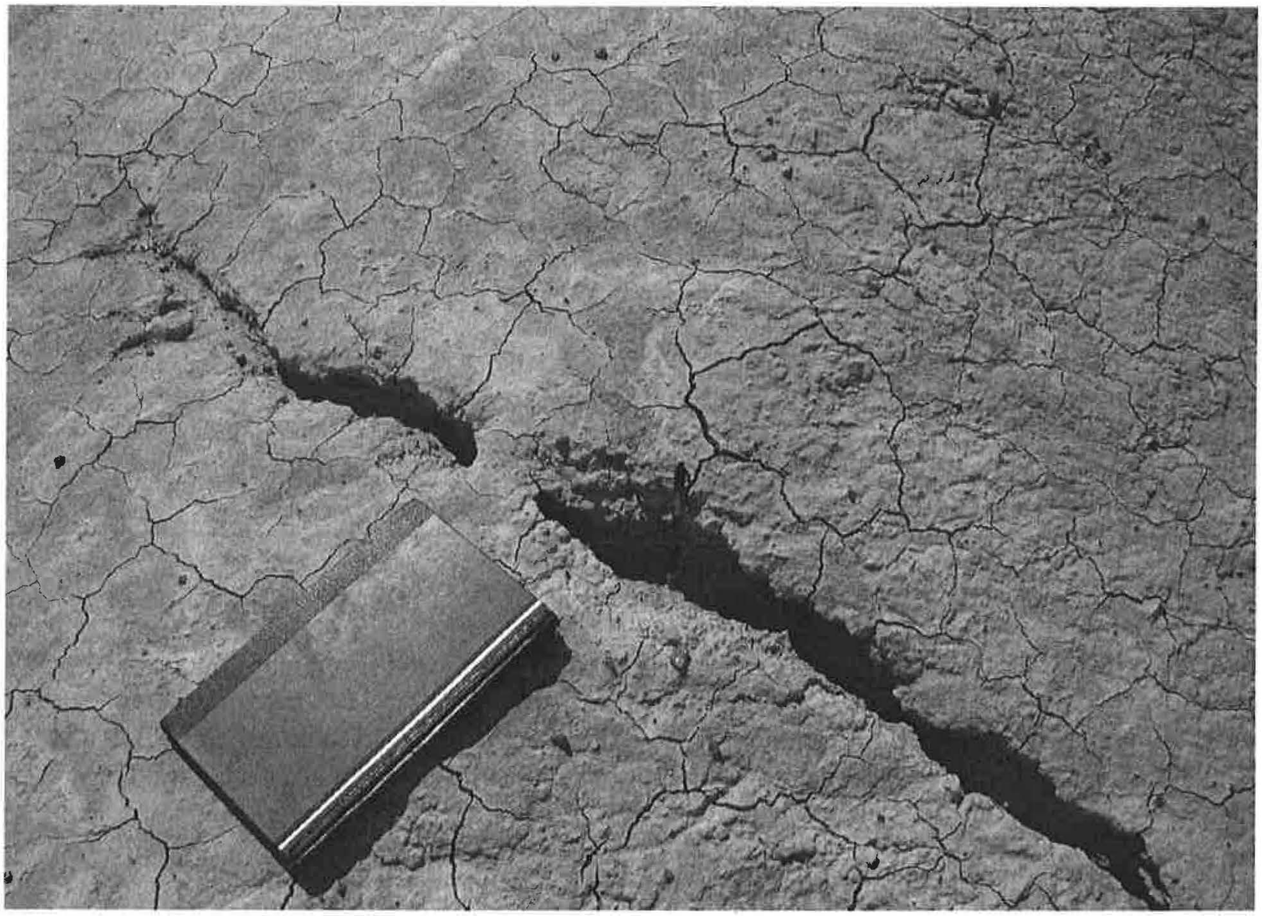
At 0.76 meters (30 inches), the cover system soil in the cover test cell in 2004 was at below freezing temperatures at times. It was frozen even when the temperature at that time was nearly 11 degrees greater than the lowest temperature recorded over the last several decades.

At a depth of 1.1 meters (42 inches), temperatures fairly close to freezing were recorded in 2004. In the coldest of all months, based on historical records over the last several decades, below-freezing temperatures are likely to be reached at a depth of 1.1 meters (42 inches), as well.

What this means is that, with the proposed cover-system design options employing only six inches (0.15 meters) of evaporative zone, below-freezing temperatures could potentially reach 12 inches (0.30 meters) into the upper radon barrier in coldest years. These would be likely to affect the hydraulic conductivity of the upper radon barrier over time, since ground freezing tends to disrupt soil and increase hydraulic conductivity over time.

Freeze-thaw activity, frost heave with accompanying desiccation, wet-dry cycling, distortion, plant biointrusion and animal biointrusion each have potential to disrupt the upper radon barrier, leading to its fracture or to other physical or chemical damage. Once damaged, the upper radon barrier, and layers above it, cannot act as the gatekeepers that they are currently envisioned to be in the model in slowing down the vertically downward migration of draining infiltrated water that will pick up radionuclides and eventually flush them down into the groundwater system.

So, does it take 120 to 1,100 years for water to travel one foot through the near-surface clays at Clive? In an imaginary, hypothetical world described in a model, maybe yes. In a real world,



where clays may look like that shown above not only at the surface, but possibly, to some extent, at depth, the answer is likely no.

NRC guidance (Benson et al., 2011) indicates that low-permeability soils in a real-world environment can be expected to be modified by natural causes, with an accompanying increase of hydraulic conductivity of two or more orders of magnitude, over relatively short periods of time (e.g., less than a decade). Applying this guidance to the site at Clive, it means that velocities of infiltrated water flowing vertically downward through the cover-system soil and then into the waste and vadose zone can likely be expected to be increased by two or more orders of magnitude compared to what has been modeled thus far. Velocity of fluid flow in soils is generally considered to be proportional to hydraulic conductivity.

If infiltrated water flows at a rate of approximately 100 times as great as currently modeled rates used for the PA analysis, then net infiltration flux would likely be on the order of 100 x (7.43 x 10^{-4} to 9.86 x 10^{-4} inches/yr), or 0.074 to 0.099 inches/yr. This is more than double the value of net infiltration calculated by Whetstone Associates (2011) through the original cover-system design. Water may flow even at rates closer to 1,000 times as great as currently modeled. Either figure suggests likely breakthrough of many different radionuclides at the point of compliance within a much shorter time frame, e.g., within a 500-year time frame (see Page 60 of the PA). It is noted on Page 60 in the PA that if Whetstone Associates (2011) values for infiltration are used, then iodine-129 breakthrough occurs between model year 500 and model year 1000. When infiltration is more than double the Whetstone Associates (2011) values, then breakthrough is expected to occur before the time bookended by model year 250 and model year 500.

However, if the Licensee accepts the Benson et al. (2011) recommendations regarding proper design hydraulic conductivities for cover-system soils, which, on average, are an additional order of magnitude lower than those just considered in the paragraph above, then transport velocities will likely be another order of magnitude faster than that described above, with breakthrough at the point of compliance accordingly occurring much earlier than in 500 years.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 60 of Neptune and Company, Inc. (2012) provides results of current modeling efforts. It states, "Iodine-129 did not reach the groundwater well within the 10,000-year time frame." Since iodine-129 is assumed to be conservative, it is concluded in the text of the PA that no radionuclide breaks through to a point of compliance within the 10,000-year time frame.

However, iodine-129 does not appear to be the most conservative radionuclide with respect to transport in groundwater (i.e., it does not appear to have the lowest distribution coefficient, or K_d, value). After upgrading the groundwater transport model to reflect more accurate assumptions and data, please change the model to follow, at a minimum, the most conservative radionuclide solute. If that solute is found to break through to the above mentioned groundwater well within 10,000 years, then examine all other radionuclide solutes that may break through within 10,000 years. Alternatively, justify the current model approach.

SUMMARY OF BASIS FOR INTERROGATORY: Whetstone Associates (2011) provides distribution coefficient values for selected radionuclides in Table 27. The distribution coefficient reflects the extent to which a dissolved radionuclide or other solute in groundwater is slowed down with respect to the average velocity of the groundwater, due to sorption of the radionuclide on aquifer or soil solids. The lower the distribution coefficient, the faster the solute tends to move. It is a conservative practice, then, to consider the solute that is fastest, or that has the lowest distribution coefficient, during modeling. In Table 27, values of K_d for several radionuclides (tritium, and strontium and technetium isotopes) are listed as being lower than that of Iodine-129 (I-129). 16 additional radionuclides have been modeled in the past as being more conservative than I-129. I-129 thus does not appear to be the most conservative radionuclide based on the information from Table 27.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Whetstone Associates (2011) provides K_d values for selected radionuclides in Table 27. In that table, values of K_d for several radionuclides are lower than the K_d value of Iodine-129 (I-129). The K_d value for I-129 given in

Table 27 notes is said to have come from Bingham Environmental testing. The initial value that Bingham Environmental assigned to K_d was 0.7 L/kg. However, the lowest slope of the curve was only 0.12 L/kg. In response to an interrogatory, the recommended overall K_d value was revised to 0.46 L/lg. This compares with literature values ranging from 0.04 to 81 L/kg.

In Whetstone Associates (2011) Table 27, there are three radionuclides or radionuclide isotopes or isotope families listed having K_d values, based on reports from the literature, less than the K_d value of I-129, i.e., with K_d values less than 0.46 L/kg. These radionuclide isotope families or isotopes include tritium (0.04 L/kg), strontium (0.05 L/kg) and technetium (0.11 L/kg). There are 16 additional radionuclide isotopes or isotope families listed with K_d values less than 0.46 L/kg, based on some highly conservative Whetstone Associates (2011) estimates.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 61 of Neptune and Company, Inc. (2012) refers to www.conservationphysic.org/atmcalc/atmoclc2.pdf, from which several equations used in the model are obtained. Please find another reference for the equations, as the current reference contains errors that reduce its credibility. Please also correct the equation for saturation vapor pressure in the PA so that its units are equivalent on both sides of the equation. (The numerical value of the equation is correct; the units provided in the equation are incorrect.)

SUMMARY OF BASIS FOR INTERROGATORY: The Web page from which the equations are derived contains a number of scientific errors. The equation obtained therefrom, which is used in the PA, is not balanced in terms of units on the left- and right-hand sides. Please correct the equation in the PA and provide a better reference for it. This will enhance the credibility of the analysis made in compliance with the rules and regulations referenced below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The Web page to which reference is made in the PA is of too dubious accuracy to use as a reliable reference. For example, it says, under the heading "Water vapour concentration"

> p = nRT/V
>
> where p is the pressure in Pa, V is the volume in cubic metres, T is the temperature in degrees Kelvin (degrees Celsius + 273.16), n is the quantity of gas expressed in molar mass (0.018 kg in the case of water), R is the gas constant: 8.31 Joules/mol/m^3.

So far, just in this one paragraph, several mistakes are made. First, n should be the quantity of gas expressed in moles, not the number of grams per mole, or molar mass. The former is a standard approach; the latter would result in inconsistent units as well as incorrect numerical values. Second, R should be expressed as 8.31 J/mol-K, not Joules/mol/m^3. Again, there are problems with incorrect units. Third, molar mass for water is 0.018 kg/mol, not 0.018 kg.

From this point on, rather than use equations from the Web site, which appears to be of dubious value as a reference, the physics underlying an equation for water vapor concentration will be derived from first principles rather than relying on the Web site. The result will then be compared with the result on the Web site and in the PA.

To convert water vapor pressure to water concentration in g/m^3, the $p = nRT/V$ equation is first rearranged as follows:

$$n/V = p/RT$$

Because n = mass/M, where M is molar mass in g/mol, and mass is expressed in grams,

$$mass/(M*V) = p/(RT)$$

so that C, concentration in terms of grams per m^3, can be expressed as

$$C = mass/(V) = pM/(RT)$$

Since 1 Pa = 1 joule/m^3, M for water is 18.015 g/mol, and T (in degrees Kelvin) equals T_c, the temperature in degrees Celsius, plus 273.16, it follows that

$$C = (2.167\ g\text{-}K/J)p/T$$

or

$$C = (2.167\ g\text{-}K/J)p/(T_c + 273.16)$$

When the saturation water vapor pressure is used, then the concentration becomes the saturation concentration of water (in g/m^3) at the temperature chosen:

$$C_{sat} = (2.167\ g\text{-}K/J)p_{sat}/(T_c + 273.16)$$

where C_{sat} is the saturation concentrations, and p_{sat} is the saturation water vapor pressure. It is noted that, after appropriate cancellations are made, the units are the same on either side of the equation (g/m^3). It is also noted that this expression differs from the version in the PA, wherein C_{sat} is incorrectly expressed as

$$C_{sat} = \{VP_{sat} \times 0.002166) / (T + 273.16)\} \times 1000\ g/kg$$

wherein T is defined as temperature in degrees Celsius, and V does not represent volume, as it does conventionally, but rather it is intended to be part of the symbol used for saturation water vapor pressure, i.e., VP_{sat}. The expression above for C_{sat} in the PA is incorrect because the units on the left side of that equation are inconsistent with the units on the right side. The units on the right-hand side of the equation are equal to (Pa)(g)/(K-kg), which are not equivalent to units for C_{sat} of g/m^3.

One Pa is equal to one Joule/m^3. A Joule has SI units of (kg-m^2)/s^2. So, the units on the right-hand side of the incorrect equation shown above are equal to (kg-m^2-g)/(s^2-m^3-K-kg), which, when simplified, become (g)/(s^2-m-K). These units are not equal to g/m^3 on the left-hand side of the equation, and thus the units on the right-hand side are not correct.

Therefore, while the PA equation gives an answer numerically equivalent to the answer given by the correct C_{sat} equation derived in this comment and shown above, the units in the PA equation are incorrect, and the Web page used as a reference for the equation contains multiple inaccuracies.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Sensitivity analyses in Neptune and Company, Inc. (2012) are limited in number, in the range of variables examined, and in quality. A sensitivity analysis is the evaluation of how changes in input parameter values affect model output. Uncertainty analysis is not carried out in the document.

SUMMARY OF BASIS FOR INTERROGATORY: The U.S. NRC (2000) emphasizes the importance of including both sensitivity and uncertainty analyses in performance assessments for low-level radioactive waste. The Neptune and Company, Inc. (2012) document does not address uncertainty analyses. Sensitivity analyses included therein are sparse, not focused on parameters of greatest importance, and, in some cases, potentially misleading. Please provide appropriate uncertainty and sensitivity analyses to help protect human health and the environment, following the guidance of U.S. NRC (2000), Benson et al. (2011) and the rules and regulations referenced below.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The U.S. NRC (2000) emphasizes the importance of having both sensitivity and uncertainty analyses in performance assessments for low-level radioactive waste. They state, "Sensitivity and uncertainty analyses are integral parts of the LLW performance assessment process, and are often used to assist in interpreting results and to optimize strategies for building confidence in compliance demonstrations." The Neptune and Company, Inc. (2012) report does not address uncertainty analyses. Sensitivity analyses are not conducted in any depth. In-depth sensitivity analysis is needed.

What analyses are conducted in the Neptune and Company, Inc. (2012) document do not focus on the most critical parameters. Great uncertainty exists for values of a number of model parameters, e.g., hydraulic conductivity, especially when performance of embankments must be considered over periods of decades, centuries and millennia. In addition, the sensitivity of modeled results (e.g., time to radionuclide breakthrough and time to peak concentration) to values of model elements such as boundary conditions and to parameters such as long-term hydraulic conductivity and evaporation rate need to be quantified. Key uncertainties and sensitivities need to be identified.

On Page 34 of Neptune and Company, Inc. (2012), reference is made to the plant "soil cover fraction", or SCF. A statement is made on that page that "The final estimate for SCF was 18 percent. The sensitivity of the modeled net infiltration rate to this estimate is evaluated in Section 5.4.2." Yet Section 5.4.2 simply says, "Separation of potential soil evaporation and potential transpiration described in Section 5.3.1 was done using a soil cover fraction (SCF) of 0.18 estimated from vegetation surveys. This value corresponds to a leaf area index of 0.4 which is low when compared with literature values of 1 for sparse vegetation cover (Varado et al. 2006)." No discussion is given of the sensitivity of modeled net infiltration to SCF, except to say that, in the case of no vegetation, the infiltration rate with an evaporative zone thickness of six inches was 1.02 x 10^{-3} inches per year, an increase of 3.5 percent over the naturally vegetated state. No discussion is made of other values, particularly values larger than 0.18, which could be occasioned through planting of plants on a nutrient-amended cover, as is often done at other sites having alternative cover systems.

Page 48 is said to include a sensitivity analysis for the surface and evaporative layers in terms of the influence of soil properties by using a single "coarser-grained material" for comparison to the native Unit 4 clay from the site. The soil selected is a hypothetical soil with characteristic parameters with values representing mean values based on a relatively large number of actual samples. The hypothetical soil has itself a relatively high clay content, which tends to keep its hydraulic conductivity low. The clay grains within the soil tend to infill pores amidst the larger silt and sand grains, blocking more porosity and causing the soil to have relative low hydraulic conductivity. There is so much clay in this hypothetical soil, in fact, that it would be classified agriculturally as a clay loam (Colorado State University Extension, 2012). In the reference in the Neptune and Company, Inc. (2012) report to the database from which the hypothetical soil selected has characteristics listed, the soil is also called a clay loam (Carsel and Parrish, 1988). So, in the sensitivity analysis said to be examining the impact of different soil properties, the report chooses to compare a silty clay from the site with a clay loam rather than with a coarser-grained soil such as medium or coarse sand.

The hypothetical clay loam soil is said in the Neptune and Company, Inc. (2012) report to have 35 percent clay, 35 percent silt, and 30 percent sand. The actual values given in the reference (Carsel and Parrish, 1988) are somewhat different: 32.6 percent clay, 37.6 percent silt, and 29.8 percent sand. The hypothetical soil is reported in the Neptune and Company, Inc. (2012) document to have a hydraulic conductivity of 6.24 cm/day, which the DRC finds to be equivalent to the published Carsel and Parrish (1988) hydraulic conductivity of 0.26 cm/hr, which is in turn is found to be equivalent to 7.72 x 10^{-5} cm/s. So, despite it containing sand, this hypothetical soil has a hydraulic conductivity value falling in a range more typical of silts than, say, a coarser-grained soil such as medium or coarse sand. A medium sand, for instance, tends to have a hydraulic conductivity in the range of 9 x 10^{-5} to 5 x 10^{-2} cm/s, which is not only greater than that of the Neptune and Company, Inc. (2012) example but is up to up to three orders of magnitude greater (see Domenico and Schwartz, 1991). The sensitivity analysis fails to utilize more than a single soil having different properties from the design soil, and the extent of the difference in terms of hydraulic conductivity is relatively minor. The design soil has a hydraulic conductivity of 4.46 cm/day compared with a hydraulic conductivity for the hypothetical comparison soil of 6.24 cm/day, which is only a 40 % increase. The differences in consequences are thus relatively minor, but still significant: a nearly three-fold increase in long-term drainage of infiltrated water. By comparison, a medium sand might have a hydraulic conductivity of 4,340 cm/day (equivalent to 5 x 10^{-2} cm/s), which would be a 97,209 % increase. The sensitivity analysis thus does not begin to capture the full range of possible changes in model results arising from changes in a given soil characteristic (e.g., hydraulic conductivity).

In Table 9, on Page 52, it is said that the evapotranspiration rate used in the RESRAD-Offsite model is "modified to match the HYDRUS infiltration rate." However, the infiltration rate in HYDRUS is assumed to be controlled largely by the upper radon barrier clay layer, which is presumed in the Neptune and Company, Inc. (2012) report to always have, throughout the entire a hydraulic conductivity of 5 x 10^{-8} cm/s. The hydraulic conductivity of 5 x 10^{-8} cm/s presumed in the report to be permanently characteristic of this layer is tremendously lower than the lowest hydraulic conductivity that it is said should be assumed in a cover system soil according to NRC guidance. NUREG CR-7028 (Benson et al., 2011) indicates that the lowest hydraulic conductivity value that should be used in modeling infiltration through a cover system soil is 8 x 10^{-6} cm/s. This is one to two orders of magnitude greater than the value used in the Neptune and Company, Inc. (2012) model. The range of hydraulic conductivity values that NUREG CR-7028 says can be used goes as high as 6 x 10^{-4} cm/s. If a value in the middle of the range is selected, then it would be about three orders of magnitude greater than the value of saturated hydraulic conductivity assumed for the upper radon layer in the cover system of the Neptune and Company, Inc. (2012) model. If a value at the high end of the range is chosen, then the ratio extends to about four orders of magnitude. The fact that the Neptune and Company, Inc. (2012) hydraulic conductivity value assumed is likely several orders of magnitude smaller than that advised by Benson et al. (2011) in NUREG CR-7028 tends to result in the Neptune and Company, Inc. (2012) model greatly underestimating how much infiltration will percolates down into the waste and the groundwater zone over the long term.

On the same page in the Neptune and Company, Inc. (2012) report, Page 52, a little (very little) playing around with model inputs is done. A value of 0.036 inches per year of infiltration is entered, as in the Whetstone Associates (2011) model for contaminant transport with infiltration through the top slope of the embankment, a six-inch Type-B filter and rip rap. Pertaining to breakthrough of radionuclides at the point of compliance well, it is said, "using the Whetstone top slope infiltration rate of 0.036 in/yr (0.91 mm/yr), breakthrough at the well occurs between 500 and 1000 yr." This is using an infiltration rate 36 times greater than that used in the Neptune and Company, Inc. (2012) document (0.0251 mm/yr). Usually, as in Darcy's law, the relationship between flow rate and hydraulic conductivity is essentially linear for a given water saturation. Thus, if hydraulic conductivity in an upgraded Neptune and Company, Inc. (2012) model is assumed to be two to three orders of magnitude greater than that in the existing model, then it can be assumed that breakthrough will be indicated to occur fairly rapidly compared to that in the Neptune and Company, Inc. (2012) model.

However, running a model after arbitrarily selecting only a single new value for a model parameter is not much of a sensitivity analysis. Usually, a range of values is considered. The DRC recommends assessing infiltration rates using three hydraulic conductivity values, one at each end of the range advised by Benson et al. (2011) and one in the middle.

The contaminated zone b parameter is modified in RESRAD-OFFSITE (see Page 54). A value of 5.3 for a silty loam texture is modified to 4 and 11 in waste and unsaturated zones, with one change in each of two model runs, but this does not change breakthrough time and results in only small changes in dose. It's evident that the model results are relatively insensitive to changes in the b parameter.

As described on Page 55, the sensitivity-analysis change of the unsaturated zone hydraulic conductivity (assigned in the model to be 227 m/yr) over a range of 0.001 m/yr to 1000 m/yr "does not alter the result of no breakthrough at the well in the 10,000-year modeling period." This is understandable: the uppermost value of the range applied (1000 m/yr) is only 4.4 times the assigned value of 227 m/yr. This is not a large change in a sensitivity analysis involving so uncertain a model parameter as hydraulic conductivity, especially when Benson et al. (2011) have demonstrated that it is typical for fine-grained unsaturated-zone soils in alternative covers for hydraulic conductivity to increase in value over time by several orders of magnitude, even after a time period of only several years to a decade after construction. But the real problem here is that the infiltration rate, taken from the Hydrus infiltration rate, is already assigned an extremely low value, and it is so extremely (and unrealistically) small that changing unsaturated zone hydraulic conductivity does not result in substantial changes noted for radionuclide breakthrough.

The unsaturated b parameter is modified in RESRAD-OFFSITE (see Page 56). A value of 5.3 for a silty loam texture is modified to 4 and 11 in waste and unsaturated zones, with one change in each of two model runs, but this does not change breakthrough time and results in only small changes in dose. It's evident that the model results are relatively insensitive to changes in the b parameter.

A RESRAD-OFFSITE internal sensitivity analysis involving "selection among 3 variations of longitudinal dispersion and retardation characteristics" is said to not affect results. However, this is an ambiguous statement, since, based on prior modeling experience, any change in longitudinal dispersion and retardation should affect results. Perhaps what is meant is that the results do not seem to be materially affected.

Finally, on Page 72, the model was run modeling either concrete or sand as soil with no material change in model results.

In summary, there is no substantive uncertainty analysis in the Neptune and Company, Inc. (2012) report. Model sensitivity analysis that exists is poorly designed and cursory. Model results are most likely to be most affected by cover-system soil hydraulic conductivity. Values used for the lowest-permeability layer in the Neptune and Company, Inc. (2012) model are likely several orders of magnitude too low for estimating long-term results.

Please address sensitivity and uncertainty analysis with regard to models, their parameters and data used in the Neptune and Company, Inc. (2012) report. Some discussion of or allusions to these topics is already given in other portions of this document. If a deterministic value is chosen for a parameter, then this value must be demonstrated to be highly conservative, based on all available knowledge, and its use in the model then justified. The intent is to provide suitable quantitative information to guide evaluation of model results for the purpose of helping to protect human health and the environment. Please follow the guidance of U.S. NRC (2000), Benson et al. (2011) and the rules and regulations referenced below.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-8(4)(b); UAC R313-25-8(4)(d); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); Benson et al. (2011)

14.0 INADVERTENT INTRUDER ANALYSIS

SECTION: 1.3

INTERROGATORY STATEMENT(S): On Pages 1-2 and 1-3 of the PA, it speaks of U.S. NRC staff, and then states,

> In particular, staff recognized that current disposal at the Clive facility includes engineered barriers and increased depths that provide significant protection for an inadvertent intruder. Specifically, staff stated in their recommendation, "The staff's preliminary independent analysis indicates that current practices at . . . disposal facilities may safely accommodate an increase in the amount of disposed waste at or just below the Class A limits" (NRC, 2010).

The DRC would like to provide additional context directly from the NRC (2010) document so as to more fully clarify the meaning and intent of the statements given above.

BASIS FOR INTERROGATORY: On Pages 7 and 33 of the NRC (2010) document, it says, speaking of NRC staff,

> The staff would also issue interim guidance to *Agreement States* on how to evaluate proposed disposal of large quantities of blended waste until the rulemaking is completed. The guidance would recommend a case-by-case evaluation of blended waste for each site that plans to accept this type of waste for disposal. *Factors such as intruder protection, the need for mitigative measures, and homogeneity would need to be evaluated by the appropriate regulator.* The staff's preliminary independent analysis indicates that current practices at existing disposal facilities *may* safely accommodate an increase in the amount of disposed waste at or just below the Class A limits. [Emphasis added.]

The DRC desires to emphasize important context in connection with the quotation that the NRC "staff's preliminary independent analysis indicates that current practices at . . . disposal facilities may safely accommodate an increase in the amount of disposed waste at or just below the Class A limits." This context would include the statements by the NRC that this quotation is addressed to agreement states in general, that blended waste would need to be evaluated on a "case-by-case basis . . . for each site that plans to accept this type of waste for disposal", and that "factors such as intruder protection, the need for mitigative measures, and homogeneity would need to be evaluated by the appropriate regulator."

On pages 18 and 19 of the NRC (2010) text, it says

> Currently, LLRW disposal facility licensees meet additional requirements, beyond the minimum disposal requirements of 10 CFR 61, (e.g., requirements addressing waste stabilization, disposal depth, or engineered barriers) that ensure that an inadvertent intruder is protected from waste at or just below the Class A limits. For example, an *operating facility in Utah* plans to dispose of waste near the Class A limit at more than 5 m (16 ft) depth, which would significantly limit the amount of waste an intruder would be expected to encounter, because 5 m (16 ft) is deeper than typical residential construction depths. *This facility also plans to dispose of waste near the Class A limit in containers, rather than as bulk waste*, which would help to maintain a recognizable waste form, thereby limiting the expected intruder exposure. A new facility *in Texas* disposes of all commercial LLRW, including Class A waste, as containerized, rather than bulk waste. The facility is required by Texas regulation (30 TAC §336.730(b)(3)) to dispose of all containerized waste more than 5 m (16 ft) below the top surface of the cover or with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years. As previously discussed, disposal at greater than 5 m (16 ft) is expected to significantly reduce exposure of an inadvertent intruder. Similarly, an intruder barrier lasting 500 years would protect an intruder by allowing radioactive decay of short-lived radionuclides, which are expected to dominate the ion-exchange resins that represent the majority of Class B/C waste amenable to blending. The staff's preliminary independent analysis indicates that *current practice at these, and possibly other, disposal facilities may* safely accommodate an increase in the amount of disposed waste at or just below the Class A limits. *Site-specific intruder analyses could be used to confirm protection of individuals from inadvertent intrusion at these sites.*

It is seen here that, with respect to "the staff's preliminary independent analysis," the U.S. NRC (2010) indicates that (i) this analysis is only preliminary, not final, (ii) safe accommodation of an increased amount of blended waste *may* occur (implying that disposal will not inherently, automatically or necessarily be safe), but, before that is determined, conditions must first be evaluated by an appropriate regulator, (iii) the waste to which the NRC is specifically referring consists of deeply buried containerized, not bulk waste, and (iv) site-specific intruder analysis could be used to confirm the safety of disposing of blended waste. It is noted that the previous quotation, the one on Pages 7 and 33, states that "intruder protection . . . would *need* to be evaluated by the appropriate regulator."

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); U.S. NRC (2010)

SECTION: 1.4.1

INTERROGATORY STATEMENT(S): Also under R313-15-401: Periods of Performance, on Page 1-3, reference is made to the time frame for modeling of protection of a hypothetical inadvertent intruder. The Licensee is requesting a modeling period of 1,000 years. However, the duration for the period of performance acceptable to the DRC is 10,000 years.

BASIS FOR INTERROGATORY: A period of performance for inadvertent intruder analyses shall be 10,000 years, consistent with a letter of agreement by the DRC (see the DRC letter dated December 12, 2011) and with the proposal made by the NRC in the Federal Register 72997, Vol. 77, No. 236, published Friday, December 7, 2012 (FR, 2012). Separate analysis will be needed for the cover system, which is proximate to bulk waste, and for blended and processed resin-bead waste.

There are several reasons for separate analyses. For example, in a future on-site residence of an inadvertent intruder in which the basement barely penetrates the radon barrier of the proposed cover system, external exposure to radiation from blended or processed waste buried at depth in the containerized waste facility (CWF) would likely be minimal or negligible due to the depth of burial, irrespective of time. On the other hand, external exposure to radiation from shallow bulk waste may be significant, even over a relatively short period of time. Thus, an inadvertent intruder analysis for external exposure to radiation from the blended and processed waste in the CWF would likely have different results than an inadvertent intruder analysis involving external exposure to radiation from bulk waste lying directly beneath the newly proposed cover system.

However, that would also depend on the design of the cover system. A very thick cover system might not be penetrated at all by a basement, and an intact radon barrier within it might provide adequate protection against external exposure. On the other hand, a relatively thin cover system, as is currently proposed in the PA, most likely would be penetrated by a constructed basement, such that external exposure could be relatively high.

The extent of exposure would also depend on the potential pathway of exposure, the length and nature of that pathway, the types of radionuclides involved, and their activities. For example, unsaturated transport of vapor-phase radionuclides (e.g., carbon-14, tritium, iodine-129, krypton-85, and/or radon-222) via diffusion through the bulk waste could potentially be significant under both scenarios. However, under the bulk-waste scenario in which the efficacy of the cover system is being evaluated, the associated transport times might be relatively fast. By contrast, under the scenario involving blended and processed waste in the CWF, the times for transport of relevant radionuclides via diffusion might be relatively slow, perhaps thousands of years. However, depending on the types of radionuclides and the activities involved, it is possible that the exposure to radiation from gases from the blended and processed waste might be higher than exposure to radiation from gases from the bulk waste.

The licensee asserts that currently no time frame is promulgated by the Board for modeling of protection of an inadvertent intruder. While the Licensee in the PA proposes a timeframe of 1,000 years, based on several precedents described in references cited by the Licensee, this value differs from the modeling timeframe agreed upon by the DRC and from the recently proposed NRC time frame for intruder analysis. The DRC requires adjustment of the time frame proposed by the licensee to a longer period more likely to capture peak doses, or justification in depth for curtailing the period of performance to the short time requested.

State of Utah rules regarding radioactive waste disposal are typically based on Federal regulations. Among these is 10 CFR Part 61. The requirements of 10 CFR Part 61 were promulgated in the early 1980's. In the original EIS for 10 CFR Part 61, the focus was on isotopes with short half-lives. An assumption was made at that time that the types of radioactive wastes accepted for disposal at low level waste facilities would be primarily composed of isotopes with short half- lives and would contain very small quantities of isotopes having long half-lives. At the current time, the NRC and Agreement States have recognized that there are larger quantities of isotopes with long half-lives being accepted for disposal at low level waste facilities. Therefore, peak doses at points of exposure for many radionuclides advected in groundwater, moving via vapor transport through bulk waste, or transported by other pathways may occur well after 1,000 years, and inadvertent intruders who may inadvertently be exposed to the waste through any pathway must also be protected against these.

While ES requests that an inadvertent intruder analysis portion be shorter, the PA cover-system modeling proposed by ES has a duration of 10,000 years. This longer period of time is needed to better assess peak doses, which require consideration in assessing potential impacts on inadvertent intruders. That is also the modeling period for protecting an inadvertent intruder specified in NRC-proposed amendments to 10 CFR 61.10. In the Federal Register 72997, Vol. 77, No. 236, published Friday, December 7, 2012 (FR, 2012), the following proposed language is presented:

> II. Discussion
> The NRC is proposing to amend its regulations, in part 61 Title 10 of the Code of Federal Regulations (10 CFR), ''Licensing Requirements for Land Disposal of Radioactive Waste,'' to require new and revised site-specific analyses and to permit the development of criteria for waste acceptance based on the results of these analyses. . .
>
> These changes would revise the existing site-specific analysis for protection of the general population to include a 10,000-year compliance period (i.e., performance assessment); ***add a new site-specific analysis for the protection of inadvertent intruders that would include a 10,000-year compliance period and a dose limit (i.e., intruder assessment)*** . . . [emphasis added]

In addition, a 10,000-year period of performance, or compliance period, is consistent with what the DRC has required of the licensee in a letter to Dan Shrum of Energy*Solutions*, dated

December 12, 2011. In this letter, Rusty Lundberg, then Executive Secretary and now Director of the DRC, wrote:

> The Executive Secretary is requesting that EnergySolutions re-evaluate the existing PA or **conduct a new PA that meets updated standards for conducting performance assessments. At a minimum this would include**, but is not limited to **prediction of** nuclide concentrations and **peak dose** (at the time peak dose would occur) using updated dose conversion factors, and a suggested **model timeframe of 10,000 years**, as well as any need to **revisit / update the waste source term, receptor, and exposure pathways**[emphasis added].

Inadvertent intruder analysis is basically a stylized approach to assessing, under various scenarios, exposure and consequent risk to one or more receptors via one or more exposure pathways. Potential receptors might be residents, long-term workers at a facility, or short-term construction workers drilling a well or constructing other infrastructure on site. Use of modeled exposure and dose data provide assurance that an inadvertent intruder will not receive doses above limits or, alternatively, that changes in cover-system and waste-disposal design will be made so as to limit exposures. The period of performance for a site-specific model is based on the requirements described in this review. The period of performance shall be consistent with the specified NRC and DRC model timeframes of 10,000 years. This may provide sufficient time for significant transport of many radionuclides via advection in groundwater or through diffusion in air spaces through soil or rock and for expected peak doses to occur.

Also, impacts to model outcomes resulting from changes in the waste source term as requested in this review should be investigated. Concentrations in various environmental media available to receptors including inadvertent intruders during this timeframe should be evaluated through various potential exposure pathways. These should include groundwater, soil ingestion, plant uptake, animal uptake, and air pathways. All potential exposure pathways should be considered. Appropriate radionuclides should be evaluated. For example, under the air exposure pathway to a basement that has breached the radon barrier portion of the cover system, diffusion through air-filled pore space in waste should be considered for all relevant vapor-phase or air-carried radionuclides, which may include one or more of the following in their vapor-phase or air-carried forms: carbon-14, tritium, iodine-129, krypton-85, and radon-222. Modeling should either be conducted using a full uncertainty analysis or using the most conservative parameter values. Sensitivity analyses for all critical model parameters, including hydraulic conductivity, should be undertaken. An analysis should be made of potential radioactive exposure, including doses received, of all receptors including inadvertent intruders.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); FR (2012)

SECTION: 1.4.2.2

INTERROGATORY STATEMENT(S): Page 1-5 claims that "UAC R313-25-20 requires assurance of protecting individuals from the consequences of inadvertent intrusion *into disposed waste*" [emphasis added]. Please revise this statement to make it consistent with UAC R313-25-20. An analysis of site-specific inadvertent intrusion as defined in UAC R313-25-20 is also needed.

BASIS FOR INTERROGATORY: UAC R313-25-20, entitled Protection of Individuals from Inadvertent Intrusion, actually states:

> Design, operation, and closure of the land disposal facility shall ensure protection of any individuals inadvertently intruding into the disposal site and occupying the site or contacting the waste after active institutional controls over the disposal site are removed.

Thus, this rule is not limited to individuals inadvertently intruding "*into disposed waste*", as implied or stated in the PA. The rule is broadly applicable to "individuals inadvertently intruding ***into the disposal site*** *and* **occupying the site** *or* contacting the waste after active institutional controls over the disposal site are removed" [emphasis added]. So, an individual simply intruding into the disposal site and occupying it after active institutional controls over the disposal site are removed, whether or not that individual actually contacts the waste, constitutes an instance of inadvertent intrusion.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-18; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007); U.S. NRC (2010)

SECTION: 1.4.2.2 (cont'd)

INTERROGATORY STATEMENT(S): Page 1-6 of the PA says that "NRC staff acknowledges that licensees are *not* expected to perform intruder dose analyses. . . " [emphasis added].

This statement, standing alone, is somewhat misleading; it must be placed within its proper context to convey its full intent. The NRC staff actually states that exceptions to this general principle do occur, and that, in fact, separate "intruder scenario analyses may be necessary" in certain situations. In the opinion of the DRC, this is one of these situations. The reasoning is provided below.

The DRC requests that the Licensee submit separate intruder scenario analyses for the site as needed. For example, one scenario might be for drilling, one might be for building and habitation of residences with basements penetrating the base of the radon barrier, and one for industrial activities on the site. Alternatively, the licensee must demonstrate why these separate scenarios do not need to be conducted.

BASIS FOR INTERROGATORY: The DRC requires that the Licensee submit separate intruder scenario analyses for the CAW. The CAW, as proposed, will contain both "large-scale blended waste", buried deeply, and bulk LLW waste, buried under, and proximate to, the proposed cover. This requirement for separate intruder scenario analyses is supported by the NRC statement quoted below that "separate intruder scenario analyses may be necessary in cases where the projected waste spectra are fundamentally different from those considered in the technical analyses supporting any Part 61 draft environmental impact statement."

It says specifically on Page 1-14 of the U.S. NRC (2000),

> Separate intruder scenario dose analyses are not envisioned to be included in an LLW performance assessment. Rather, 10 CFR 61.13(b) requires that "...analyses of the protection of individuals from inadvertent intrusion must include demonstration that there is reasonable assurance the waste classification and segregation requirements will be met and that adequate barriers to inadvertent intrusion will be provided...."
>
> That being said, *separate intruder scenario analyses may be necessary in cases where the projected waste spectra are fundamentally different from those considered in the technical analyses supporting any Part 61 draft environmental impact statement* (DEIS – see NRC, 1981) [emphasis added].

The "projected waste spectra" for LLW blended and processed on a large scale and containing many radionuclides at or close to the Class A limits "are fundamentally different from those considered in the technical analyses supporting any Part 61 draft environmental impact statement." Application of this principle to disposal of large-scaled blended waste at the Clive facility is evident when considering the following from U.S. NRC (2011b):

> The NRC did not consider the disposal of significant volumes of waste at one of the classification limits during the original development of the Part 61 waste classification system. Instead, in the analysis supporting the development of the waste classification system, NRC staff assumed that not all of the waste encountered by an inadvertent intruder would be present at the classification limits. The staff assumed that any waste at the classification limit would be mixed with a significant amount of waste with radionuclide concentrations far below the classification limit. Thus, a waste stream that is blended so that a significant fraction of the waste that an inadvertent intruder could encounter is at or near the Class A limit is different from the waste that NRC considered in the original analysis.

Additional support for the DRC decision to require separate intruder scenario analyses comes from this statement by the U.S. NRC (2010):

> These changes would ensure continued safety by requiring that disposal of large-scale blended waste is subjected to a site-specific intruder analysis as part of the overall performance assessment of a disposal facility.

It is the finding of the DRC that disposal of large-scale blended and processed waste at the Clive facility requires site-specific intruder analysis. In order to meet applicable State of Utah UAC rules protecting the general public and inadvertent intruders, intruder scenarios for various types of intrusions at the site must be analyzed, and separate intruder scenario analysis reports must be submitted as required to evaluate the different scenarios. This extends beyond short-term drilling to cover also the building and long-term habitation of residences as well as the long-term activities association with industrial operations on the site, possibly far into the future, but within the 10,000 year period of time in which peak dose will be assessed by modeling. Drillers, residents and workers may all receive different radiation doses depending on the duration and type of contact that they have with contaminated groundwater, soil or other media. Analyses will be different depending on whether the focus is on blended and processed resin waste deeply buried in the CWF, or on bulk waste lying under, and in close proximity to, the newly proposed cover system being evaluated in the PA.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-18; UAC R313-25-19; UAC R313-25-20.

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000), U.S. NRC (2010), U.S. NRC (2011b).

SECTION: 2.1.10

INTERROGATORY STATEMENT(S): On Page 2-4, under Groundwater, the text says that groundwater at the site has high salinity and, "as a consequence, is not suitable for most human uses (NRC, 1993)." Please revise the statement in the PA to acknowledge the possibility, however likely or unlikely it is to happen, that both shallow and deep groundwater not contaminated by radionuclides at the site can be treated to remove its high salinity, and that the initial high salinity of the water before treatment per se therefore does not bar people from drinking treated groundwater or using it for other purposes.

SUMMARY OF BASIS FOR INTERROGATORY: There is abundant evidence showing that groundwater with high salinity can be used as potable water for residents at a site if the water is first desalinated. Of course, there has to be sufficient economic incentive for this to actually happen. Communities in northern Utah currently enjoy drinking water that, at some places in the aquifer from which it is produced, has very high salinity, and which has to be desalinated. There is little reason why, if groundwater at Clive remains uncontaminated, residents could not use it once it was treated. The water is a potential resource that, if uncontaminated, may have value within the next 10,000 years.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: While the PA statement may be true for *untreated* groundwater on site, it is not beyond the realm of possibility that deep, and perhaps even shallow, groundwater at the site uncontaminated by radionuclides could be *treated* to make it relatively fresh. One way to do that would be via reverse osmosis (RO), solar distillation, or some other desalination process. RO treatment units are readily available. The treated groundwater could then be used as potable water, or water for industrial or agricultural purposes, if desired. The reject water could be evaporated in the sun.

Similar processes are undertaken at numerous desalination plants around the world, where seawater, having high concentrations of total dissolved solids (TDS) (e.g., about 86% of that at Clive), is routinely treated in order to provide potable water for people to drink or for other purposes. The United States Geological Survey (USGS) states that, in 2002, "there were about 12,500 desalination plants around the world in 120 countries." Important uses of desalination are found in the Middle East and in North Africa, and there is also significant use in California and Florida (http://ga.water.usgs.gov/edu/drinkseawater.html). Desalination is unquestionably somewhat expensive, and it would not be expected to be done on a large scale in or near the Great Salt Lake Desert unless there was some sufficient economic incentive for people to do it there. A possible economic incentive that could potentially arise in the future in the area would be the discovery of economically valuable hydrocarbon or non-fuel mineral resources, with subsequent exploration and production or mining.

Regionally, treatment by reverse osmosis, multi-stage flash distillation, or electrodialysis to remove undesirable salts is being done to provide drinking water for cities. By way of example, Kennecott Copper Utah desalinates groundwater highly impacted by sulfates and other salts to provide drinking water for West Jordan, South Jordan, Riverton and Herriman. Some of the associated wells in the supply aquifer have historically contained very high salt concentrations (e.g., >30,000 ppm; see Kennecott Utah Copper | Environmental Restoration Group, 2012). A number of desalination plants exist in California. Another desalination plant exists in Yuma, Arizona.

It is important to conserve potential groundwater resources that, while not likely to be economically useful at the current time, may well be useful over the next 10,000 years, or even over the next 100 years. An inadvertent intruder in the future would by definition not have knowledge that any radionuclide-contaminated groundwater, whether deep or shallow, was contaminated by radionuclides. Treatment via reverse osmosis (RO) or other means would concentrate radioactivity into reject water. Reverse osmosis treats only a fraction of the water (e.g., 20% for a residence) to make it clean; the contaminants are transferred into the reject water (e.g., the other 80%), where they are thus concentrated. The reject water, if used for other purposes or disposed of near a residence, could provide an ongoing and increasing source of radioactivity leading to higher rates of exposure to the residents. The inadvertent-intruder residents would not be aware of their exposure to this radioactivity. This would be unacceptable.

Even if the residents were aware of the presence of radioactivity, their use of in-home RO would not necessarily diminish external exposure during resident proximity to the untreated water as it comes into the home and as it is collected as reject water with concentrated contamination subsequent to treatment. The cost of disposing of radioactive reject water would also likely be prohibitively expensive – much, much higher than the cost of using RO within the home on uncontaminated groundwater. For these reasons, it would be important not to contaminate the groundwater as a potential resource.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1

INTERROGATORY STATEMENT(S): It is stated on Page 3-1 of the PA that the assumption "that a member of the general public would build a residence near the edge of the Clive site and use local groundwater for potable needs is extremely unreasonable." The DRC disagrees. The DRC asks the Licensee conduct assessments of inadvertent intruder-resident and other scenarios with the probability of intrusion being considered to be greater than zero.

SUMMARY OF BASIS FOR INTERROGATORY: The DRC does not accept the argument "that a member of the general public would build a residence near the edge of the Clive site and use local groundwater for potable needs is extremely unreasonable." With an appropriate economic incentive to do so, people in the future could easily build homes on or near the site, and they could produce deep, or perhaps even shallow, groundwater from wells and desalinate it to produce potable water. Energy*Solutions* itself has considered drilling for deep groundwater for use on site, and it spent money performing studies to evaluate that possibility. Another option is that people could truck potable water in. Yet another option for supplementing supplies of drinking water would be rainwater harvesting.

It would be contrary to the DRC's mission of protecting human health and the environment from radioactive contamination as described in the rules, regulations and guidance below to dismiss the possibility of an inadvertent intruder building a residence on the site at some point in the future.

Also, it is not only home residences that need to be considered as places where people might reside, at least for part of the day, on the site. It is possible that in the future someone might choose to locate an industrial facility on the site, or commence resource exploration or production activities on site, unaware of its past history or the presence of radionuclides. The time that employees might spend on the site each day might then be eight to twelve hours.

Recent NRC documents state that the probability of inadvertent intrusion in inadvertent-intruder analyses should be considered to be one. The DRC thus requires that the Licensee conduct inadvertent intruder-resident analyses.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Under current conditions, with what is known by the general public about the Clive disposal facility and its operations today, it would generally be considered unreasonable for a member of that public to build a residence on or near the Clive site and use local groundwater for potable water needs. However, in projecting out modeling of risk for hundreds, or even thousands of years, such a scenario is not out of the question, particularly if the resident has no knowledge of prior use of the site.

The choice to live in that area would largely depend on there being a suitable economic incentive. If, for example, major hydrocarbon or mineral reserves are discovered centuries from now in the area, and people are involved in exploration, prospecting, developing or mining but are not aware of the buried radioactive waste at the site, then it would be conceivable that someone might build a residence or an office on or near the site to make it easier to explore, prospect, produce or mine on or near the site. This could result in inadvertent exposure to radioactivity. Exploration for resources is, in fact, considered a scenario for inadvertent intrusion. This is found in a proposal "to amend Part 61 to Title 10 of the Code of Federal Regulations to require low-level radioactive waste disposal facilities to conduct site-specific analyses to demonstrate compliance with the performance objectives in Part 61, which would enhance the safe disposal of low-level radioactive waste" (NRC, 2011a), since this speaks of inadvertent intruders engaged in "resource exploration".

While highly saline groundwater is not generally preferable as a raw source to produce drinking water, it is feasible that an individual, a family or a community of people, could use highly saline groundwater as a source of water and run it through a reverse osmosis (RO) system or another system involving current or future desalination technology to produce potable water for drinking and other uses. Such processes are used, in fact, to obtain fresh drinking water from seawater in a number of nations on the earth, and within a number of states in the United States. Use of desalination processes on or near the site could potentially be cheaper or more convenient than hauling sufficiently large amounts of water from locations long distances from the site. Reject water, as long as it is not radioactively contaminated, could be evaporated in the desert to reduce the volume to that of the formerly dissolved mineral constituents.

It is far better to ensure that the groundwater at the site is not contaminated by radionuclides than to assume that it could be treated safely and at reasonable cost. Handling of radioactively contaminated fluids during and after treatment by inadvertent intruders entails risk. Cost of treatment of radioactively contaminated reject water would also be expected to be extremely high. For this reason, protection of on-site and near-site groundwater from radioactive contamination in or near the Great Salt Lake Desert is vital.

There is potential for a future community of individuals having sufficient economic reason to do so to drill deeper on or near the site in search of fresher water recharged from the mountains to the east and passing under the desert in sediments at depth. The potential for a well screened several hundred feet below the surface to produce fresher water at sufficiently high rates to make it a viable water-production system already exists. The Licensee (Envirocare of Utah at the time) authorized studies in 2005 involving numerical modeling to assess the potential impact on the water table in shallow water-bearing soils of drilling a well on or near the site and pumping groundwater from the deeper regional Great Salt Lake Desert aquifer at a depth of 550 to 600 feet at a rate of 200 gallons per minute (Whetstone Associates, Inc., 2005). If pumped continuously at that rate, this would supply 288,000 gallons per day. Flow at that rate could sustain local industrial activities or provide drinking water for a small community. The fact that the Licensee has considered drilling for water on or near the site implies that the general public, given appropriate economic incentives to live or work on the site, might do the same.

Moreover, industrial activities might be undertaken on the site, leading to exposure of unaware workers for eight to twelve hours per day. Energy*Solutions* is an industrial facility already present on the site, and other companies have built industrial facilities nearby. This attests to the possibility of people in the future residing on the site for part of the day during working hours. Excavations might also be made for purposes of resource recovery (e.g., fill materials, or fuel or non-fuel mineral resources).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.3

INTERROGATORY STATEMENT(S): On Page 3-2 of the PA, it is stated, "The primary site characteristics that prevent public exposures via the groundwater pathway are the very poor groundwater quality at the site, the low population density, arid meteorology, and the low yield of the aquifers. The groundwater is not potable because of its very high concentration of dissolved salts. This characteristic alone prevents any consumption of the water by humans or livestock." Please modify the text to acknowledge that, while factors exist that make consumption of untreated groundwater highly unlikely, it is possible that, at somewhat high cost, the water can be treated via reverse osmosis or other desalination technology to be made potable, and that storage of contaminated groundwater prior to its treatment and storage or disposal of contaminated reject water after treatment could lead to human or animal exposure.

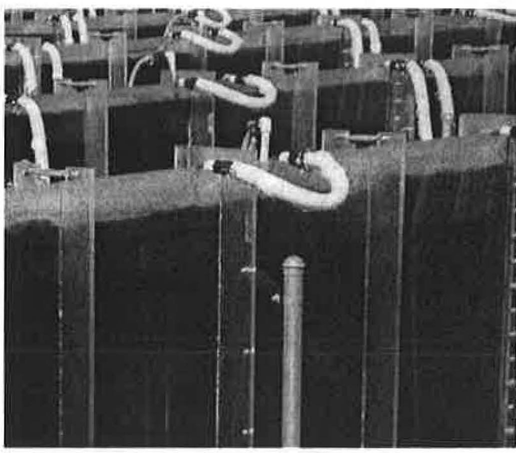
BASIS FOR INTERROGATORY: The DRC agrees that, prior to treatment, the groundwater at the site is not potable, and that its consumption without prior treatment is highly unlikely. For this reason, exposure to radioactivity via ingestion of untreated groundwater is not a likely scenario.

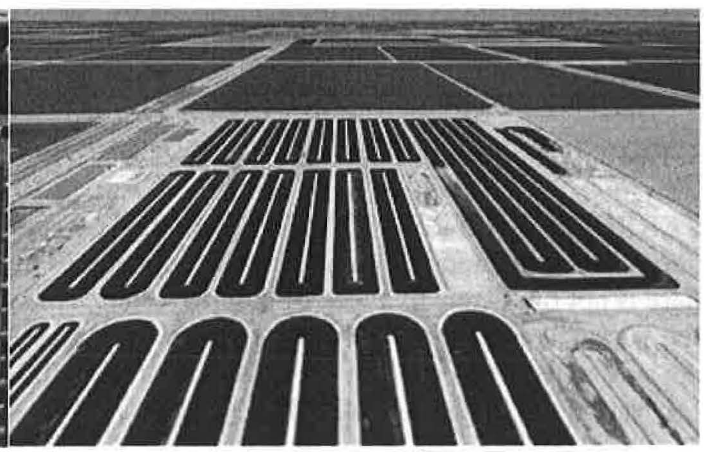
However, it is not true that that the very high concentration of dissolved salts in groundwater actually "prevents any consumption of the water by humans or livestock" and "prevents public exposures" if the water is being treated prior to use. If very high salinity in water pumped from the ground prevented consumption of that water, then people in West Jordan, South Jordan, Riverton and Herriman in Utah would not be drinking the water from their faucets every day. But they do. The highly saline water in the wells supplying their potable water is first treated by RO, and then it becomes potable.

Any untreated, radioactively-contaminated water stored in a residence, an outside tank or some other constructed feature on the Clive site could serve as a source of external exposure. Once treated by RO or other desalination technology, the water could be consumed by animals or people, so consumption in general is not prevented. Presumably treatment of the raw water would remove most radionuclides, minimizing exposure by ingestion. However, the radionuclides would be transferred to reject water (usually, in the home, about 75-95% of the total amount of water supplied), and the reject water would then have an increased concentration of radionuclides, which could result in external exposures.

Exposure to radioactivity by inadvertent intruders thus could occur if (1) untreated groundwater was pumped from the ground and then stored in tanks in or near residences prior to its treatment, or (2) pumped groundwater was treated, e.g., by reverse osmosis, with the reject water having increased concentrations of radionuclides then being stored or disposed of on site in close proximity to people or animals. Storage in indoor tanks after pumping of groundwater by inadvertent intruders would be expected, especially with groundwater being pumped from wells with low well yields. Such storage would most often be indoors to prevent freezing of water during the winter. Some RO systems have built-in storage tanks. Indoor storage could result in external exposures. Reject water could also constitute a source of radionuclide exposure. Reject water in a desert area without a community sewer system might be disposed of just outside of a home, where water would evaporate, but where radionuclides might remain in the soil. That also could result in external exposures.

There are other activities other than residing in a home that could in the future draw people to the site at Clive and lead to potential public exposure. Industrial activity is one already mentioned. Another, for example, would be construction and operation of high-tech algal farming units making use of saline water available in the desert.





Several up and coming technologies currently being developed involve growing of algae in saline water in covered tanks on algae farms located on relatively inexpensive desert lands that otherwise do not lend themselves to agriculture. Development of desert algae farms could lead to future use of the site for this purpose by inadvertent intruders. The algae, depending on species and processing, can be useful for biofuel, human food, animal feed, industrial feedstocks, pharmaceuticals and supplements. The saline groundwater at Clive, especially that which is deep, could potentially be used to provide the medium needed for growing select algae under saline or hypersaline conditions, areas currently being researched and viewed with much promise. Periodic regulation of salinity water in covered tanks could be achieved using uncontaminated RO-treated groundwater. Currently, it is anticipated that commercial biofuel production from algae is several decades away; however, the expectation is that algae will provide much in the way of biofuel and food in the future.

Arid meteorology conditions may limit recharge of groundwater systems, and usage of groundwater may be limited by how quickly the groundwater can be pumped and treated. There are places where people obtain their water from low-yield water-bearing units, but it is generally true that large population centers do not tend to develop where the only local source of water is from a low-yield water-bearing unit. The geometric mean horizontal saturated hydraulic conductivity of the Unit 3 and Unit 4 water-bearing unit (i.e., the shallow aquifer) is reported to be only 6.16×10^{-4} cm/s (Whetstone Associates, Inc., 2011a). This value, however, is not outside the range of values of hydraulic conductivity of geologic units that in some places in the world supply groundwater, at relatively low rates, to be sure, to individuals or small groups of people. More pertinent, however, is the concept that, despite the arid environment, people could pump saline groundwater at far greater rates from the deeper Great Salt Lake Aquifer, and then treat it for drinking or other uses. There are numerous ways that the deeper aquifer could be contaminated if the shallow groundwater is first contaminated.

Photos: Vertical bioreactor at Sandia test facility, https://share.sandia.gov/news/resources/news_releases/images/2013/Tom_Aaron_John-McGowank.jpg; California facility, http://www.pnnl.gov/news/release.aspx?id=859

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.2

INTERROGATORY STATEMENT(S): Page 3-4 states, "For purposes of demonstrating performance, it is important to note that occupation of the site by inadvertent intruders after site closure is not likely due to a lack of natural resources in the area, particularly a lack of potable water. As such, contacting the waste after site closure by an onsite resident is *highly unlikely* due to the lack of natural resources (no reason to drill or dig) and the design of the embankment cover system . . ." [emphasis added].

Pages 3-9 and 4-1 state strongly, "there are *no* credible intrusion scenarios" [emphasis added].

The DRC does not accept the licensee's claim and asks the licensee to justify that "there are credible intrusion scenarios." Reasons given by the Licensee for an inadvertent intrusion not being worthy of any consideration are not considered valid by the DRC. For example, the argument that people cannot live on or occupy the site due to a perceived lack of potable water is not valid. Please revise the language in the PA to better reflect current relevant knowledge; please also conduct appropriate inadvertent intruder scenario analyses.

SUMMARY OF BASIS FOR INTERROGATORY: The Licensee here assesses the probability of inadvertent intrusion as being essentially zero, saying, "there are no credible intrusion scenarios." However, approaching the subject in this way contravenes documented statements found in recent NRC documents. The NRC states that an inadvertent intruder assessment must *not* consider the probability of inadvertent intrusion occurring as being less than one. What must be assessed, then, is the consequence of intrusion, not whether intrusion happens at all. And, in contravention of assumptions made in the PA by the Licensee, the DRC finds the potential for future intrusion by someone constructing a residence on site to be greater than zero, such that inadvertent intruder scenarios should be considered.

A commonly repeated thread throughout the PA is that no one would or could build and live in a residence at or near the site because no fresh groundwater is locally available. This is a very weak argument. People can truck fresh water in. People can harvest rainwater. People can treat deep, or even shallow, saline groundwater to make it potable. The weakness of the arguments in the PA can be illustrated with regional data. For example, in Utah and several adjoining states, approximately 30-40% of the Navajo people (90,000 to 120,000 people) regularly bring in potable water from distant sites within 55 gallon drums in pickup trucks, traveling many miles each way. People in some cities of northern Utah obtain drinking water from what originally is saline groundwater when pumped but what is then treated by RO to make it potable. People at the Clive site in the future could also drill groundwater wells, produce saline groundwater from the wells, and treat the groundwater.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The assumption that no credible intrusion scenarios exist for the Clive site is *not* an acceptable assumption for the PA. The NRC (2011a), in a recent document, says, in fact, that "the intruder assessment ***must assume*** that *an inadvertent intruder occupies the disposal site after closure and engages in activities that unknowingly expose the intruder to radiation from the waste . . .*" [emphasis added].

This is corroborated by comments by Dr. Michael Ryan reported in minutes of a meeting by the NRC Advisory Committee on Reactor Safeguards (ACRS), taken by Widmayer (2011):

> Risk-Informing Analysis – Member Ryan expressed several times that *the likelihood of the inadvertent intruder retains its probability of 1.0*, as it did in the original Part 61 analysis, meaning the probability of inadvertent intrusion is not really considered and all the discussion and evaluations only concerns the consequences of the actions [emphasis added].

The NRC (2012a) further states in another recent document,

> An inadvertent intruder assessment typically does ***not*** *consider a probability or likelihood of less than one of the inadvertent intrusion occurring*. Rather, the assessment assumes reasonably conservative scenarios that could occur and evaluates the radiological consequences that could be experienced by individuals who might actually intrude onto the disposal site if active and passive controls and societal memory were lost (NCRP, 2005; IAEA, 2008).
>
> Therefore, an intruder assessment typically is *based on the assumption that the intruder directly contacts the disposed waste*" [emphasis added].

While leaving open the possibility of a licensee submitting a justification that "*might* be considered" by the NRC arguing that certain types of inadvertent intrusion are unlikely, using, by way of illustration, the example of an area without viable sources of groundwater, the NRC requires that such exceptions be justified so as to provide reasonable assurance of the claims before they are fully considered. The DRC likewise requires this of its licensees. So far, the Licensee for the Clive site has not demonstrated to the DRC with reasonable assurance that a paucity of easily available potable water, or the salinity of the existing groundwater supply, means that one or more persons cannot build a residence, or would not build a residence, at or near the Clive site in the periphery of the Great Salt Lake Desert if and when a suitable economic incentive occurs.

The argument that the site cannot be inhabited in the next 10,000 years because of a claimed lack of potable water is not valid. In the Navajo Nation in Utah and nearby states, for example, it is estimated that 30 to 40 percent or more of homes do not have potable water nearby, but they rely on water hauling over long distances to meet basic survival needs (St. Bonaventure, undated; 21st Navajo Nation Council, 2010; U.S. DOI, 2012). Thirty to 40 percent of the Navajo Nation represents 90,000 to 120,000 people.

Another option for supplementing meager water resources is rainwater harvesting from a roof. A roof entailing 1,000 square feet, coupled with more than eight inches of precipitation per year, can presumably capture more than 670 cubic feet of water per year. That's equal to 4,989 gallons. That is equivalent to 13.7 gallons per day. That water can be filtered or run through a reverse osmosis device to produce potable water. If filtered, nearly all 13.7 gallons would be useable.

Again, while not likely, future occupation of the site by an inadvertent intruder is clearly possible given a sufficiently motivating economic incentive. This could involve, for example, exploration for or production of valuable hydrocarbons from the area, or mining of valuable non-fuel mineral resources on or near the site, such as gold. Additionally, other resources, such as geothermal resources, might be explored for or developed. In conjunction with any of these activities, water wells could be drilled and water could be produced (even as Energy*Solutions* once proposed to do from a depth of about 550-600 feet on the site several years ago), and the produced water, even though initially saline, could be desalinized, e.g., by reverse osmosis. Accomplishing desalination would not really be a question of technical feasibility, since this is a technology that is well-developed, but only a question of whether desalination would be justified economically.

While economic mineral or other resources on or near the site may not currently be apparent, they may exist in the future, and this may be cause for future exploration, production or mining activity on or near the site. This may justify setting up infrastructure on site and desalinating water produced from depth.

For many years, the Bakken Shale in Montana and North Dakota and parts of Canada was not considered a viable petroleum exploration and production target, and it was largely ignored. That changed around 2008, however, with the advancement of more sophisticated rock fracturing and horizontal drilling techniques and practice. Today, the Bakken Shale is a highly sought after oil exploration and production target. The formation is currently producing 660,000 barrels of oil per day. North Dakota currently has the lowest unemployment of any state (~3%).

Housing in areas of North Dakota with lots of Bakken Shale oil activity is hard to come by. One article describes the problem as follows (WCAX.com, 2012):

> "Oil workers are flooding the state for jobs and finding no where to live.
>
> The modern day "gold rush" has left oil companies scrambling for suitable housing . . . the new workforce must find houses for their families first.
>
> Right now, the majority of workers are crammed into small man-camps that are crowded, poorly insulated, expensive and temporary . . ."

This is but one of many possible examples of areas in the U.S. where it was once thought that few, if any, recoverable valuable natural resources existed, but where recoverable valuable natural resources were later discovered and exploited profitably. Accompanying an associated boom is often a shortage of places to live, and it is not inconceivable that people might inadvertently seek any empty area for a temporary or long-term man-camp or other habitation.

Such is a possibility for Clive. It is not certain that there is a lack of natural resources in the area; it may be that only that these resources are not yet discovered and exploited.

There is thus no justification for the DRC or the Licensee failing to consider that construction of a residence at the Clive site could indeed take place, and that water resources could be obtained in support of that residence. Therefore, this scenario must be considered.

The Utah Board of Radiation Control has issued to the Licensee a directive to demonstrate that it will protect public health and safety (including that of inadvertent intruders) to prescribed limits, with "reasonable assurance." This is consistent with 10 CFR 61.13(b):

> "Analyses of the protection of individuals from inadvertent intrusion must include demonstration that there is reasonable assurance the waste classification and segregation requirements will be met and that adequate barriers to inadvertent intrusion will be provided."

It is also consistent with 10 CFR 61.23(c),

> "The applicant's proposed disposal site, disposal site design, land disposal facility operations (including equipment, facilities, and procedures), disposal site closure, and post-closure institutional control are adequate to protect the public health and safety in that they will provide reasonable assurance that individual inadvertent intruders are protected in accordance with the performance objective in § 61.42, Protection of individuals from inadvertent intrusion."

Therefore, in supporting this Board directive, the DRC requires that the Licensee conduct an inadvertent intruder-resident analysis for the site.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.2 (cont'd)

INTERROGATORY STATEMENT(S): Page 3-4 says, "Several design features provide the required protection. Overall features include:

- Site isolation and the resultant lack of nearby residential population;
- Embankment cover systems (rock armored rip-rap, evapotranspirative bioturbation/biointrusion); and
- Granite markers"

As previously mentioned, "rock armored rip-rap" (listed as a "design feature" above) does not exist in the preferred proposed designs shown in the PA. Please modify the text accordingly.

Also, please identify where the granite markers will be placed, and what, if anything, will be written on them, and in what language(s).

BASIS FOR INTERROGATORY: As previously explained, no "rock armored rip-rap" (listed as a "design feature" above) exists in the proposed preferred designs shown in the PA. Granite markers are of value only if they are placed appropriately in the embankment and if the words written on them mean something to those who discover the markers.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX A

INTERROGATORY STATEMENT(S): Appendix A of the PA is entitled "Regulatory Basis for Selecting Reasonable Inadvertent Intruder Scenarios". Page A-2 of this appendix notes that the NRC associates the meaning of "reasonable assurance" with the meaning of "reasonable expectation." Page A-2 states that the NRC defined the term "reasonable" in the fourth point of 10 CFR 63.304, as "discouraging the modeling of unreasonably-extreme physical situations in the performance assessments".

The Licensee applies this line of thinking on Page A-5 of the appendix, where it says,

> 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 unpotable 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 Report's site-specific Performance Assessment.

Please correct the foregoing statements to make them accurate, or else defend and justify them.

SUMMARY OF BASIS FOR INTERROGATORY: 10 CFR 63.304 does not prohibit modeling of extreme physical situations and parameter values, but actually enjoins use of a full range of defensible and reasonable parameter distribution values. The fourth point of 10 CFR 63.304 states that reasonable expectation "focuses performance assessments and analyses on *the full range of defensible and reasonable parameter distributions* rather than *only* upon extreme physical situations and parameter values." In the opinion of the DRC, the assumption by the Licensee of no credible inadvertent intrusion scenarios over the next 10,000 years represents an extreme assumption; it does not consider and analyze the full range of defensible and reasonable potential intruder-resident scenarios.

The reasons given for excluding the inadvertent intruder-construction scenario as being unreasonable are not viewed by the DRC as having suitable justification. Lack of historical habitation at a particular site does not preclude future habitation of the site. As populations grow, the trend is that habitations are being built farther and farther from centers of conventional large cities. The existence of non-potable groundwater on site, while decreasing the likelihood of local settlement and residence, does not prevent it, since water can be trucked in, rainwater can be harvested, and/or non-potable water produced from wells can be treated via desalination technology to make it potable. A lack of viable irrigation sources or abundant precipitation does not exclude the settling of an area if the people settling there are interested in mineral extraction or production or some other non-agricultural activity and do not plan on being directly involved in agricultural practices. To meet the rules and regulations listed below, the DRC requires the Licensee to develop an inadvertent intruder-construction analysis.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: While the NRC discourages the limiting of modeling to only extreme physical situations, such as claiming no possibility of inadvertent intrusion, the NRC does allow for the modeling of extreme physical situations. In general, it encourages development of complete, meaningful models based on a full range of defensible and reasonable parameter values. For example, 10 CFR 63.304 states, in regard to PAs,

> Reasonable expectation means that the Commission is satisfied that compliance will be achieved based upon the *full record* before it. Characteristics of reasonable expectation include that it . . .
>
> (3) *Does not exclude important parameters from assessments and analyses simply because they are difficult to precisely quantify to a high degree of confidence*; and
>
> (4) Focuses performance assessments and analyses on *the full range of defensible and reasonable parameter distributions* rather than *only* upon extreme physical situations and parameter values (emphasis added in above quotations).

For this reason, the DRC expects the Licensee to provide in its inadvertent intruder analysis and modeling "important parameters from assessments and analyses," including those that "are difficult to precisely quantify to a high degree of confidence" and, furthermore, the DRC requires the Licensee to consider "the full range of defensible and reasonable parameter distributions" and physical situations rather than rely "only upon extreme physical situations and parameter values."

In the opinion of the DRC, the assumption that that *no* one at *no* time during the next 10,000 years will *ever* dwell on the site represents an extreme assumption. It does not consider the full range of defensible and reasonable potential intruder-resident scenarios. In the opinion of the DRC, included in the full range of defensible and reasonable potential intruder scenarios would be that of explorationists, developers, producers or miners interested in the discovery of and the development of fuel or non-fuel mineral wealth potentially working on or living on the property in the future.

Human health and the environment is protected based on the applicable rules, regulations and guidance listed below when modeling work considers "important parameters from assessments and analyses," including those that "are difficult to precisely quantify to a high degree of confidence" and it accounts for a "full range of defensible and reasonable parameter distributions" and physical situations.

The analysis in the PA of the inadvertent intruder-construction scenario appears to be faulty for several reasons.

(1) The analysis discounts the potential for an intruder-construction scenario in part by making the claim that there is no historical evidence of prior residential construction at the Clive site. However, historical evidence of construction on the site itself is not required to indicate the potential for future construction on the site. What is needed, based on the NRC (2007) guidance, is that assumptions of potential inadvertent intruder activities (e.g., construction at the site) be physically reasonable and appropriate for the site, as well as consistent with regional practices and characteristics.

There is no reason to assume that, given an appropriately large economic incentive, people could not, at some point in the future, build on the Clive site. If world demand for oil, gas and other natural resources continues to rise, and if instabilities in many natural resource exporting countries create supply shortages, then it may become more economically attractive for industrial countries to focus on more-local resource exploration and production, including that in areas previously not well-explored.

The size and shape of the proposed constructed embankment at Clive is a factor that does not necessarily rule out future construction by residential builders. By way of example, a National Archives photo, #156, shows houses, many of which are built on a terrace or bench or perhaps a tailings pile, in 1876 in the boomtown Deadwood Gulch of Black Hills, South Dakota, located two states over from Utah. Many of the homes are shown built on a very large embankment, whether natural or artificial, at the base of the hillside. Today, it is not uncommon for newer homes in Utah to be built on bluffs or other raised landmasses, which, among other things, offer superior views. Thus, it is not inconceivable that someone someday could build one or more homes on an embankment in the area of the Great Salt Lake Desert, in or near Clive.

At other times, when there is sufficient economic reason, people may even choose to live in temporary shelters close to a mining claim or other place where mineral resources exist. Boomtowns often spring up in such areas. Another National Archives photo, #167, shows a mountain-valley tent town that grew up in Idaho a little over a hundred years ago.

The boomtown phenomenon is not only something from the past. In Williams County, North Dakota, a place where the Bakken Shale is currently being developed for oil production, local government recently added another six months to an existing moratorium on building "man camps". This moratorium was developed after the county had approved, in only 18 months, construction of 9,700 new beds. North Dakota is only three states over from Utah.

The Basin and Range region, in which Clive is located, has seen a general increase in resource exploration in recent years. In 2003, a new oil field, called Covenant field, was discovered in an area of Utah where economic oil production had not previously occurred. This renewed interest in the region in exploration for new oil targets. In more recent times, interest in geothermal energy resources in Utah has increased. In September, 2012, for example, the Salt Lake Tribune published an article entitled, "Utah scientists find massive geothermal hotspot in west desert." The subtitle was "Black Rock Desert basin south of Delta has a geothermal hot spot where power plants may thrive one day, scientists say." These two instances illustrate examples of discoveries in new areas where previously little or no expectation of resource development existed.

Ad hoc construction of housing in areas of prolific mineral or other resource exploration or development is not uncommon, and there is no valid reason to deny that it could someday occur at or near Clive, Utah, if geothermal or fuel or non-fuel mineral resources were to be discovered there or at some nearby area at some point in the future.

Additionally, the fact that actual, living modern people have, in historical times, made homes or businesses, and have worked or lived during much, if not all, of the daylight hours, in nearby places in Utah such as Dell, Knolls and Aragonite implies the potential for people to make a home and live in or near the Great Salt Lake Desert, in the West Desert, in or near Clive, in the future, should they be given sufficient economic incentive or other adequate motivation to do so.

Trends are for population pressures expanding the needs for water in the West Desert. This is underscored by a table entitled Present and Projected Total M&I Water Use by Basin data given in Division of Water Resources (2001). This table indicates that, by 2050, it is expected that West Desert municipal and industrial (M&I) water usage there will increase from 24,000 acre-feet/yr (in 2001) to 53,000 acre-feet/yr. This latter figure is 221% of the former.

(2) The PA analysis mentioned above lists "the extreme salinity of Clive's soils" as one reason why an intruder-construction scenario should not be considered.

While excess salinity is definitely a problem for traditional agriculture, saline water from saline soils in a desert environment is sought after by many companies engaged in algae farming. Algae farming is a line of agriculture which specifically seeks lower-cost land with warmer temperatures such as may be found in the desert. Many algae flourish in saline water. Algae farmers often envision tens to thousands of acres per facility filled with covered photobioreactors in which they may produce raw materials for various products. Products from algae farming may include biofuels, foods, fertilizers, pharmaceuticals, nutraceuticals, cosmetics and dyes. Residences of algae farmers may be built in desert environments close to places of production.

It is difficult to see why, apart from landscaping or gardening, excess salinity in soil should hinder or prevent residential construction on or near the Clive site, should there otherwise be one or more suitable incentives to build there. Having a yard of lush grass is not essential for everyone. Many people choose not to garden. In some parts of the country, the trend is toward sparse landscaping that is harmonious with a locally harsh environment. In Arizona, for example, landscaping of many new homes in the Queen Creek area near Phoenix and other nearby areas emphasizes placement of pebbles or crushed rock, along with planting and growth of a relatively small number of native plants, as ground cover as opposed to use of grass. Gardens are extremely difficult to grow unless non-native soil is imported. Many Native American yards throughout parts of Arizona consist nearly totally of natural, native flora and pre-existing native soil, unembellished by ornamental grasses, forbs or shrubs. If a garden were really important to someone at Clive, they could truck in fertile soil from another location and lay it down. But that would not be a need for some people. Although a yard consisting of aragonite clay, having greasewood shrubbery, may not appeal to all, it may not be a barrier to others who may, in the future, wish to live in or near Clive, Utah, either temporarily or permanently.

(3) As previously discussed, "unpotable groundwater" locally available may be a reason to discourage, but not prevent, some people from living in an area such as Clive, provided that there is suitable economic incentive or other motivation to live there. People can drill wells, obtain water from them and then desalinize the water. Or they can have water brought in by truck. Another option for supplementing meager water resources is rainwater harvesting from a roof or paved surface.

(4) One item listed as a reason why an intruder-construction scenario is not feasible is "the severe lack of irrigation sources." While this would hinder or prevent conventional agriculture in the area, it is not sufficient reason to exclude the potential for people to build homes in the area if they otherwise wished to do so. Not everyone is a gardener, and some people do not like having to water their yards every week. For these people, a severe lack of irrigation sources may not be

a hindrance to residing on site. Algae farmers in a desert environment would primarily use saline water, mixed at times with fresh water obtained from desalination of saline water.

(5) Likewise, "the inadequacy of precipitation to support agriculture" is not a reason to conclude that an intruder-construction scenario is not feasible. While inadequate precipitation would definitely hinder or prevent conventional agriculture in the area, it would not be sufficient reason to exclude the possibility of people building homes in the area if there is sufficient economic reason or other motivation for them to do so. Only a relatively small fraction of people living in homes in this country are currently directly involved in agricultural activities. And algae farmers using saline water in their photoreactors would not necessarily need precipitation.

The DRC does not accept the contention that the inadvertent intruder-construction scenario is not considered "reasonable" for the Clive site. Please include an inadvertent intruder-construction analysis in the site-specific Performance Assessment.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX A (cont'd)

INTERROGATORY STATEMENT(S): Page A-3 of the PA lists five bulleted quotations from NRC (2007) that refer to scenarios that are physically reasonable and appropriate for a site, as well as consistent with regional practices and characteristics. Several bulleted items refer to regional practices. These are mentioned in the PA in providing a rationale for not performing an inadvertent intruder-resident analysis. The DRC requires that the Licensee conduct inadvertent intruder-resident analyses for this site.

SUMMARY OF BASIS FOR INTERROGATORY: NRC (2007) actually applies to distinguishing high-level waste from incidental waste. Nevertheless, the points about regional practices are well taken. Regional practices pertinent to the Clive site include Navajo people in the four corners region trucking in potable water from sources far away from where they live, and desalination of highly saline groundwater in northern Utah communities to provide potable water for residents. The DRC finds that there is no valid justification for the Licensee excluding inadvertent intruder-resident analyses for the Clive site based on concepts of paucity of groundwater or of groundwater being too saline to drink.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: While the Licensee is associating this information with modeling inadvertent intruder scenarios for the Class A low-level waste disposal embankments at Clive, the information provided in NRC (2007) is actually provided for making waste determinations to distinguish high-level waste from incidental waste for material at Hanford (Washington), Savannah River Plant (South Carolina), Idaho National Laboratory (Idaho), and West Valley (New York). While there may be similarities between the two approaches, there may be differences as well.

The guidance relative to regional practices is important. One regional practice, as previously mentioned, is the use of desalination technology to make potable water to support a community. This is done for several cities in Utah affected by a groundwater sulfate plume historically having had concentrations in places greater than 30,000 ppm. Desalination is a practice that could conceivably enable people to live in the future on or near the Clive Waste Disposal Facility site, since desalination is already being regionally practiced, even within 100 miles of the site. There is no reason, therefore, to assume that a lack of potable water, by itself, should preclude a residential inadvertent intruder on the site.

Another regional practice, as previously mentioned, is the trucking in of water from relatively distant locations to provide a source of potable water. This allows for a great many Navajos in the four corners area to survive in locations where local potable water resources do not exist. Water is currently trucked to a residence about 20 miles east of the Clive facility.

There is no justification for denying that people could not live on or near the site at Clive in the future. It is a physically reasonable scenario. It is consistent with regional activities. And thus, there is no justification based on the items listed on Page A-3 for not performing inadvertent intruder analyses.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2007); U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): On Page 21 of Neptune and Company, Inc. (2012), it says, "The intruder drilling scenario is highly unlikely due to the nature of the embankment design, which as a raised mound covered with rip rap would be a very difficult place to site a drilling rig."

Please correct the statement above, or justify it.

BASIS FOR INTERROGATORY: The statement above is not correct in the current context of proposed cover-system design. The statement refers to a "raised mound covered with rip rap". Rip rap does not exist throughout most of the proposed cover system as described in the PA.

Furthermore, a raised mound would not necessarily deter siting of a drilling rig to drill a hole on the mound, if sufficient economic incentive existed for someone to drill on the mound. A road could be graded on the mound, if necessary.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): It says on Page 23 of Neptune and Company, Inc. (2012) that "Consistent with Section 4.1.1.1 of NRC (1986), the three subsequent IHI scenarios are not assessed in this report because the prospective resident will be unable to secure potable water and therefore will not initiate construction of a home."

Please assess the three subsequent IHI scenarios.

BASIS FOR INTERROGATORY: As previously described, if sufficient economic reason exists at some point for a person to build a residence at Clive, it is not at all beyond reason to imagine that person contracting a driller to locally drill to a deep source of saline water, which could then be pumped and treated via reverse osmosis or other desalination technology to make it potable. In conjunction with this, or, as an alternative, the person could have water trucked in and/or utilize rainwater harvesting approaches.

There is no valid reason to deny the possibility that someone could build a home at or near the site in the future, given sufficient economic reason to do so. While it does not appear by any means to be likely to happen under conditions, an unexpected economic incentive could serve as a driver for residential construction.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Please revise the following statement found on Page 23 of Neptune and Company, Inc. (2012). It says, "Because groundwater at the site is not potable, the groundwater exposure scenario is incomplete."

BASIS FOR INTERROGATORY: Again, saline water can often be made potable through treatment. Such treatment tends to be expensive. At present, that kind of incentive does not generally seem to exist at or near Clive. However, that could change in the future. Because the groundwater at the site can be made potable, the groundwater exposure scenario needs to be assessed. Both shallow and deep groundwater could potentially be affected by radioactive contamination under a variety of scenarios. For example, it is conceivable that, sometime during a 10,000-year period, near-surface groundwater could become contaminated, and someone could then drill an unprotected deep exploration borehole or water-supply borehole at the site, with groundwater from near the surface could flow downhole into the deeper aquifer. Similar cross-flow contamination issues between aquifers aquifers involving organic or inorganic contaminants have been relatively common in the past in the United States and elsewhere (Gass et al., 1977; Santi et al., 2005; and Landon et al., 2010).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(b)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

15.0 MISCELLANEOUS

SECTION: EXECUTIVE SUMMARY

INTERROGATORY STATEMENT(S): The PA is said on Page ES-1 to demonstrate protection of the general public through consideration of transport via the following pathways:

* atmosphere
* site soils
* groundwater
* surface water
* vegetation
* burrowing animals

The DRC finds that these pathways are not fully evaluated in the current version of the PA. Some are hardly evaluated at all. The DRC therefore requires that the Licensee reassess the potential transport associated with each of these pathways and provide a thorough response on how the Licensee will prevent or mitigate these possibilities.

BASIS FOR INTERROGATORY: Although a demonstration of protection in each of these six potential pathways of contaminant transport is necessary to meet the requirements of applicable regulations, rules and guidance referenced below, the PA generally dismisses the potential for contaminant transport to exist via any of these pathways. However, the DRC finds substantive potential for possible radionuclide contaminant transport over time through a number of these pathways. Analyses are required by Utah Administrative Code:

> Analyses demonstrating that the general population will be protected from releases of radioactivity shall **consider the pathways of air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals**. *The analyses shall clearly identify and differentiate between the roles performed by the natural disposal site characteristics and design features in isolating and segregating the wastes. The analyses shall clearly demonstrate a reasonable assurance that the exposures to humans from the release of radioactivity will not exceed the limits set forth in R313-25-19.* – UAC R313-25-8(4a)

Discussions of potential exposure pathways and risks are found throughout this set of Interrogatories in appropriate topical sections. The potential risk associated with these pathways must be evaluated, and means for preventing or mitigating this risk if model estimates for UAC R313-25-19 dose criteria are exceeded must be developed.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: EXECUTIVE SUMMARY (cont'd)

INTERROGATORY STATEMENT(S): Page ES-1 says that the

> Site-specific Performance Assessment also demonstrated that, because of the very low infiltration rates associated with the alternative cover designs, no water that infiltrates through the covers will reach the point of compliance within 10,000 years. Therefore, no class A radionuclide concentrations will arrive at the point of compliance well within the 10,000 year assessment period. As such, disposal of additional volumes of blended ion-exchange resins in excess of 40,000 ft^3 annually does not compromise the Embankment's performance and protection of the groundwater resource.

The DRC finds that there is potential for much greater infiltration than that currently modeled in the PA. The DRC therefore requires that the Licensee reassess model inputs based on requests and information contained throughout this Interrogatory, re-run the model, describe the modified model output, and revise plans and proposals for embankment and cover system design as needed.

BASIS FOR INTERROGATORY: As discussed specifically in various sections of this set of Interrogatories, there are numerous problems apparent to the DRC in the existing PA model. Once the model is modified to resolve these problems, the model will likely yield results consistent with the prediction of substantially higher infiltration rates. Substantially higher infiltration rates may in turn allow some radionuclides at the site to arrive at a point of compliance at significantly higher concentrations within the model time frame. . This would, in turn, require a much more intensive analysis of doses. In terms of actual, physical contamination, the presence of radionuclides in LLW at or near the regulatory concentration limits would potentially result in greater doses than would exist were all radionuclides in LLW at substantially lower concentrations. The existing model does not account for increased infiltration and therefore higher concentrations of radionuclides in groundwater over the modeled time period. The model therefore needs to be modified and upgraded based on the requirements of this Interrogatory, and then it needs to be re-run to determine which Class A radionuclides, if any, may arrive at the point of compliance within the 10,000-year modeling period, and at what concentrations. Once that is determined, then dose analysis can be undertaken.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 1.4.2.1

INTERROGATORY STATEMENT(S): Page 1-4 notes that NUREG-1573 states:

> As a matter of policy, the Commission considers 0.25 mSv/year (25 mrem/year) TEDE as the appropriate dose limit to compare with the range of potential doses represented by the older limits that had whole-body dose limits of 0.25 mSv/year (25 mrem/year) (NRC, 1999, 64 FR 8644; see Footnote 1). Applicants do not need to consider organ doses individually because the low value of the TEDE should ensure that no organ dose will exceed 0.50 mSv/year (50 mrem/year). (NRC, 1999, 64 FR 8644; see Footnote 1).

Please review the above quotation and revise it to make it consistent with original sources.

Additionally, this section of the PA includes a statement indicating that

> As such, this Performance Assessment does not consider organ doses individually because the low value of the total effective dose equivalent ensures that no organ dose will exceed the promulgated limitations.

Please provide information to document that even though the Licensee is using a dose limit of 500 mrem/yr, which is 20 times the dose limit of 25 mrem/yr TEDE, there is no need for the Licensee to demonstrate that the organ doses found in R313-25-402 are not exceeded.

BASIS FOR INTERROGATORY: Please note that the inclusion of the reference to (NRC, 1999, 69 FR 8644; See Footnote 1) twice in the indented quoted statement from the PA is not correct. NUREG-1573 does not include the second, repeated reference found at the end of the PA statement. Neither does Footnote 1 of 69 FR 8644 contain the statement "Applicants do not need to consider organ doses individually. . ."

In NUREG-1573, the NRC states that it is a matter of policy that the appropriate dose limit to compare with the range of potential doses represented by a whole body dose of 25 mrem/yr is 25 mrem/yr TEDE. Therefore, if applicants meet the low value of 25 mrem/yr TEDE, applicants do not need to consider organ doses individually. The low TEDE value of 25 mrem/yr should ensure that no organ dose will exceed 50 mrem/yr.

However, if the range of potential TEDE doses is increased from 25 mrem/yr (as assumed in NUREG-1573) to 500 mrem/yr (as proposed in the PA), there is nothing in NUREG-1573 that indicates that limiting organ doses listed in R313-25-402 will not be exceeded at the site.

The dose limit of 25 mrem/yr TEDE corresponds with the dose limit used in R313-15-402, "Radiological Criteria for Unrestricted Use." However, the Licensee states within this PA that they will use a dose limit of 500 mrem/yr as found in R313-15-403, "Criteria for License Termination Under Restricted Conditions." As discussed elsewhere in this document, the

Licensee cannot use a dose limit of 500 mrem/yr until the Licensee successfully demonstrates that it meets three criteria, which have not yet been demonstrated to have been met. The important point for now, however, is that the Licensee is proposing using a TEDE dose limit 20 times higher than that given by the NRC for determining that it is not necessary for a licensee to consider the dose limits for individual organs.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-15-402; UAC R313-15-403; UAC R313-25-19.

REGULATORY GUIDANCE REFERENCE(S): NUREG-1573 [US NRC (2000)]

SECTION: 1.4.2.1 (cont'd)

INTERROGATORY STATEMENT(S): After referencing a number of instances in which the Federal government has set specific dose standards, including one or more indicated as being appropriate under license termination, Page 1-6 states that the Licensee will use a 500 mrem/yr threshold for purposes of applying the performance standard for the protection of individuals.

The DRC cannot accept a 500 mrem/yr threshold without the Licensee first having followed the provisions in Utah R313-14-403.5(b) i, ii, and iii (see also 10 CFR 20.1403). Unless these provisions are followed, the dose standard is set by rule in R313-14-403 at 0.1 rem/yr (100 mrem/yr). Please either revise the threshold to the 100 mrem/yr value, or demonstrate that provisions in Utah R313-14-403.5(b) i, ii, and iii are followed.

BASIS FOR INTERROGATORY: Notwithstanding practices among various Federal agencies under different conditions, the rule for determining a specific dose standard for protection of individuals following license termination is clear for Utah facilities. It is given in UAC R313-15-403 (see also 10 CFR 20.1403) as follows:

> R313-15-403. Criteria for License Termination Under Restricted Conditions.
>
> (5) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the total effective dose equivalent from residual radioactivity distinguishable from background to the average member of the critical group is as low as reasonably achievable and would not exceed either:
>
> (a) one mSv (0.1 rem) per year; or
>
> (b) five mSv (0.5 rem) per year provided the Licensee:
>
> (i) Demonstrates that further reductions in residual radioactivity necessary to comply with the one mSv (0.1 rem) per year value of Subsection R313-15-403(5)(a) are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm;
>
> (ii) Makes provisions for durable institutional controls; and

(iii) Provides sufficient financial assurance to enable a responsible government entity or independent third party, including a governmental custodian of a site, both to carry out periodic rechecks of the site no less frequently than every five years to assure that the institutional controls remain in place as necessary to meet the criteria of Subsection R313-15-403(2) and to assume and carry out responsibilities for any necessary control and maintenance of those controls. Acceptable financial assurance mechanisms are those in Subsection R313-15-403(3).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-15-403; 10 CFR 20.1403

REGULATORY GUIDANCE REFERENCE(S): N/A

SECTION: 1.4.2.2

INTERROGATORY STATEMENT(S): On page 1-5, the PA says,

> Resin liners are placed in either the first or second layer of the CWF. The containers are placed in a honeycomb pattern of concrete silos and backfilled with sand. At some interior locations in the CWF, the containers are placed in a temporary steel silo. The silo is used to administratively ensure the honeycomb spacing pattern, including minimum distances between adjacent containers, is achieved. After the steel silo is removed, voids around the containers are filled with the sand backfill.

Please correct the statement here, as needed, as well as the statement on Page 3-6 that deals with disposal of resin, as needed, in order to make the two statements accurate and consistent.

BASIS FOR INTERROGATORY: The statement quoted above from Page 1-5 in the PA says that sand is used to backfill concrete silos or to infill voids between adjacent resin containers. By contrast, the PA says on Page 3-6 that "Blended resins are shipped in containers and not be [sic] dumped in bulk. They are disposed in its [sic] shipping container and then surrounded by CLSM."

CLSM stands for controlled low-strength material.

The Page 3-6 statement indicates that infill between resin containers is CLSM. It does not mention sand. Page 1-5 indicates that the infill is sand. There is an obvious discrepancy between the statement on Page 1-5 and the one on Page 3-6.

The DRC requests that the Licensee describe both past and current and planned practices relative to disposal of resin containers and infilling. Please describe whether disposal occurs with sand infilling, CLSM infilling, or both, perhaps in different areas or at different times. It is important for the DRC to clearly understand the nature of the disposal process in evaluating performance assessments.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-15-402; UAC R313-15-403; UAC R313-25-19.

REGULATORY GUIDANCE REFERENCE(S): NUREG-1573 [US NRC (2000)]

SECTION: 1.4.2.4

INTERROGATORY STATEMENT(S): On page 1-7, the Licensee states that NRC notes that (i) "to the extent practicable the waste should maintain gross physical properties and identify over 300 years, under the conditions of disposal", and (ii) "a site should be evaluated for at least a 500-year time frame to address the potential impacts of natural events or phenomena." In the sentence following the above assertion, the Licensee states that "a disposal site and cover design providing reasonable assurance that long-term stability will be achieved" have been implemented. Additionally, the Licensee indicates that "the best-available technology in setting design standards in the range from 200 to 1000 years is appropriate to provide site stability to the extent practicable."

In a later section of the PA, the Licensee states that the disposal embankment is designed to perform for a minimum of 500 years.

Please resolve apparent timing-related conflicts between the NRC's stated assertions that a site should be evaluated for at least a 500-year timeframe, that the disposal embankment is designed to perform for a minimum of 500 years, and that "the best-available technology in setting design standards in the range from 200 to 1000 years is appropriate." Please clarify how these statements are interrelated.

SUMMARY OF BASIS FOR INTERROGATORY: Conflicts between statements made in the PA must be resolved to remove ambiguity and potential misinterpretation within the PA. This is particularly important owing to recent changes made in the adjudicative process which require that clear and complete records be made to support license actions approved by the Director. In particular, resolution is needed of timing conflicts associated the NRC's stated assertions that a site should be evaluated for at least a 500-year timeframe, that the disposal embankment is designed to perform for a minimum of 500 years, and that the best-available technology in setting design standards in the range from 200 to 1000 years is appropriate.

APPLICABLE RULE(S) OR REGULATION(S): Not applicable. Resolution of apparent conflicts between various statements made in the PA, with further clarification of the statements' relationships, is being requested.

REGULATORY GUIDANCE REFERENCE(S): Not applicable. Resolution of apparent conflicts between various statements made in the PA, with further clarification of the statements' relationships, is being requested.

SECTION: 2.1.3

INTERROGATORY STATEMENT(S): On Page 2-2, under Temperature, it says that "data from the Clive facility from 1992 through 2011 indicate that monthly temperatures range from about -2°C (29°F) in December to 26°C (78°F) in July (MSI, 2012)." Please correct inaccurate text and data related to air temperature values for the site.

SUMMARY OF BASIS FOR INTERROGATORY: The description temperature range given above appears to be incorrect.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: MSI (2010) data shown in tabular and graphic formats in Whetstone Associates (2011) show that (i) the air temperature values indicated in the quotation above should be identified as a range of *mean* monthly air temperatures, not a range of "monthly temperatures", which range would be greater than what is presumably referred to in the PA, and (ii) the 17-year mean monthly temperature values shown in degrees Fahrenheit in this reference actually vary from, to the nearest degree, 28 degrees to 80 degrees, rather than from 29 degrees to 78 degrees, as stated in the PA. The range of mean monthly temperatures is much smaller than the range of all monthly temperatures, since the latter includes both extreme low and extreme high values, whereas the former does not. Although the corrections given here for individual mean monthly temperatures in degrees F are minor, they do extend the range of mean monthly temperatures from a mean low to a mean high by three degrees (i.e., from 49 to 52 degrees F), which represents an increase of 6%.

Understanding temperatures to which the site is exposed is important in designing for future cover systems on site. Factors that can affect the effectiveness of cover systems such as freeze-thaw conditions, bioinvasion and evaporation and transpiration through plants are all highly dependent on temperature. Accuracy in reporting temperature is important.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.1.3

INTERROGATORY STATEMENT(S): Page 3-2 says, "Additionally, the horizontal groundwater flow velocity is approximately 0.5 meters per year, resulting in groundwater travel times of approximately 60 years from the toe of the side slope region of the embankment to the Point-of-Compliance well." Please revise the statement to be more conservative in terms of estimated maximum groundwater velocities and more protective of human health and the environment as required by the rules and regulations listed below.

SUMMARY OF BASIS FOR INTERROGATORY: Groundwater can potentially move faster than indicated in the statement quoted above.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: Groundwater velocity is given for one-dimensional horizontal flow as follows:

$v = -Ki/n_e$

where v = velocity, K = hydraulic conductivity, i = hydraulic gradient, and n_e = effective porosity. Since a gradient of a quantity is the increase in the value of that quantity per unit distance, and groundwater travels in the opposite direction to the hydraulic gradient, i has a negative value in the direction of groundwater flow – hence the need for the negative sign in the equation.

Maximum estimated hydraulic gradient across what was then considered to be the Class A Cell based on measured head measurements in April, 2011 appears to have been - 1.54×10^{-3} (see Whetstone Associates, Inc., 2011b). Use of this gradient is conservative, although it is conceivable that following periods of higher than usual precipitation, hydraulic gradients may for a time be even larger than the maximum that was measured in April, 2011. Average effective porosity is assumed, for Units 3 and 4 in the area, to be 0.29 (Whetstone Associates, Inc., 2011a). As mentioned previously, the geometric mean horizontal saturated hydraulic conductivity is 6.16×10^{-4} cm/s (Whetstone Associates, Inc., 2011a; 2011b). Thus,

$v = -Ki/n_e = -(6.16 \times 10^{-4} \text{ cm/s})(-0.00154)/0.29 = 3.3 \times 10^{-6} \text{ cm/s} = 3.4 \text{ ft/yr}$

Maximum estimated hydraulic gradient should be chosen, since it is conservative. Therefore, under these conditions, flow across the 90 feet of distance from the toe of slope to the point-of-compliance well should take 26 years, rather than 60 years, on average. Since the mean hydraulic conductivity is used in the equation, the average time of travel is calculated. Some groundwater may arrive faster, and some may arrive slower. Please make appropriate revisions in the text and in the model, as well.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.4

INTERROGATORY STATEMENT(S): Page 3-7 includes the statement:

> As part of the Class A West license amendment application, Energy*Solutions* demonstrated that the disposal site, disposal site design, land disposal facility operations, disposal site closure, and post-closure institutional control plans are adequate to protect the public health and safety in that they will provide reasonable assurance of the long-term stability of the disposed waste and the disposal site and will eliminate to the extent practicable the need for continued maintenance of the disposal site through the

> compliance period following closure in accordance with the requirements of UAC R313-25.

While the existing design described in the Class A West license amendment application provides a cover design previously accepted by the DRC, the proposed design in the PA, as it is currently written, is unacceptable to the DRC. Please develop a workable cover-design plan to prevent, or minimize to the extent practicable, the potential for biointrusion, frost-heave, distortion, or erosion of cover-system soils.

BASIS FOR INTERROGATORY: As described elsewhere in this document, biological processes such as biointrusion or physical processes such as frost-heave, distortion, or erosion into the radon barriers or into both the radon barriers and the underlying waste can vitiate, mar, spoil or otherwise render ineffective the design protections for the proposed cover system design. The DRC requires that the Licensee reassess model inputs based on requests and information contained throughout this Interrogatory, re-run the model, describe the modified model output, and revise plans and proposals for embankment and cover system design as needed.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: 3.5

INTERROGATORY STATEMENT(S): It is stated on Page 3-8

> In this site-specific Performance Assessment, net water infiltration through the two alternate covers (as computed using the HYDRUS and RESRAD platforms) is projected to be several orders of magnitude lower than calculated for the traditional rock armored cover (as presented in Table C-9 of Appendix C). The new analysis also demonstrates an optimal maximum evaporative zone layer thickness of 30.5 cm (above which negligible improvement is seen with increased thickness).

And on Page 3-9, it is stated that

> The proposed disposal of large quantities (i.e., greater than 40,000 ft^3 per year) of blended ion-exchange resin waste has been evaluated in this site-specific Performance Assessment, which confirms that this waste can be disposed of safely and in compliance with all applicable regulatory requirements.

Statements above are not considered by the DRC to necessarily be accurate. Please update data and assumptions in the model, run the model with the new data and assumptions, and develop conclusions based on the updated model results. Then revise statements in the text to reflect any new findings.

SUMMARY OF BASIS FOR INTERROGATORY: Some of the conclusions made by the licensee as a result of PA modeling results are not accepted by the DRC. Modeling results are based on some inadequate or faulty data or assumptions. The models in the PA fail to account adequately for frost heave, freeze-thaw cycling, frost cracking, wet-dry cycling, desiccation fracturing, root intrusion, animal intrusion, erosion and distortion. Recent NRC guidance indicates that PA model values for hydraulic conductivity are as much as three orders of magnitude too low.

EXTENDED TECHNICAL BASIS FOR INTERROGATORY: The conclusions drawn in the above statements claim that "net water infiltration through the two alternate covers . . . is projected to be several orders of magnitude lower than calculated for the traditional rock armored cover" and that "blended ion-exchange resin waste . . . can be disposed of safely and in compliance with all applicable regulatory requirements." However, these conclusions are dependent on modeling results based on a number of assumptions, some of which are found by the DRC to lack justification. Inadequate or faulty data and assumptions must be modified to square with established facts and principles. Because of inadequate or faulty data and assumptions used in modeling, the DRC does not accept the results of the PA as it is currently developed.

As discussed elsewhere in this document, the model fails to adequately account for likely increases in proposed cover-system clay soil hydraulic conductivity over time due to frost heave, freeze-thaw cycling, frost cracking, wet-dry cycling, desiccation fracturing, root intrusion, animal intrusion, erosion and distortion. Recent NRC guidance (Benson et al., 2011) indicates that the PA model values for hydraulic conductivity are as much as three orders of magnitude too low. The model fails to adequately account for hydraulic and radon-release impacts of biointrusion by burrowing deer mice, kangaroo rats, ground squirrels, badgers, and foxes. The model does not capture likely potential biointrusion into radon barrier and waste in places by deep greasewood taproots. Design of the cover system appears to employ insufficient gravel (only 15%) in the surface-layer gravel admixture to provide for adequate erosion resistance. Experts use or propose use of much higher percentages of gravel: 25-50%, (and preferably 30-45% -- Anderson and Wall, 2010), 40% (Stenseng and Nixon, 1997), 40% (Waugh and Richardson, 1997), and 50% (Anderson and Stormont, 2005). To attain sufficient erosion resistance, it may be necessary for infilled cobbles to be used in a surface layer. Finally, the cover system fails to include within its design an effective biointrusion barrier and an effective capillary barrier (with appropriate filter criteria applied).

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20; UAC R313-25-8(4)(d); UAC R313-25-22; UAC R313-25-22; R313-25-24(4) and (6)

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B

INTERROGATORY STATEMENT(S): The PA application includes as Appendix B a document entitled, "Modeling report: fate and transport of contaminants from the Class A West Embankment and exposure to a post-closure traditional inadvertent human intruder at the EnergySolutions Clive, Utah facility" by Neptune and Company, Inc. (2012). Page 7 of that document states that "To the east and southeast, the site is bounded by the north-south trending Lone Mountains, which rise to a height of 5,362 ft amsl."

Please provide references for the name of the mountains and also the elevation that is provided. "Lone Mountain" is familiar to the DRC, but not "Lone Mountains."

BASIS FOR INTERROGATORY: The DRC is familiar with the appellation "Lone Mountain", which refers to a specific peak in a ridge east of the facility, but not the phrase "Lone Mountains."

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 7 of Neptune and Company, Inc. (2012) states "Alluvial and lacustrine sediments that fill the valley floor are estimated to extend to depths of greater than 500 ft with unconsolidated sediments ranging from 300 to over 500 ft."

Please review this text and revise it as needed.

BASIS FOR INTERROGATORY: If unconsolidated sediments range only from 300 to over 500 feet in depth, then what kind of sediments lie above 300 feet in depth? In general, sediments found in the more shallow depth range are also unconsolidated.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): On Page 8 of Neptune and Company, Inc. (2012), it says, "The site aquifer system consists of a shallow unconfined aquifer that extends through the upper 40 ft of lacustrine deposits."

Please review this text and revise it as needed to indicate that the aquifer only exists from the top of the water table (which, on average, exists at a depth of about 15 feet below normal ground surface) down to about 40 feet below normal ground surface.

BASIS FOR INTERROGATORY: The shallow unconfined aquifer, depending on location, exists from depths of about 15 feet to about 40 feet below normal ground surface and is saturated. On the other hand, the sediments in about the upper 15 feet of sediments below normal ground surface on site are not saturated, so they should not generally be described as part of the shallow aquifer. They are part of the vadose zone.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 29 of Neptune and Company, Inc. (2012) speaks of a "capacity flow rate of a drainage layer . . ." as

$$Q^{cap} = K_s * T * i$$

Please fix the description of this equation, or justify its inclusion in the PA as is.

BASIS FOR INTERROGATORY: Since dimensions of K_s are L/T, dimensions of T are L, and "i" is nondimensional, the dimensions of Q^{cap} must be L^2/T, and the description for Q^{cap} should thus be along the lines of "capacity flow rate per unit depth (or per unit distance at right angles to the plane of two-dimensional analysis for a drainage layer). . ." Please clarify in the text that this is not a three-dimensional flow rate with dimensions of L^3/T, as is commonly inferred when reading the term "flow rate" but rather two-dimensional flow rate per unit depth (distance into or out of a plane of reference) with dimensions of L^2/T.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

SECTION: APPENDIX B (cont'd)

INTERROGATORY STATEMENT(S): Page 48 of the Neptune and Company, Inc. (2012) report refers to four tested cores having "slightly less than 50 percent clay and 50 percent silt and a small percentage of clay."

Please correct the statement on Page 48 quoted above by changing the last word to "sand". Please also address the mineralogical composition of on-site silts and clays since the use of these terms in the report as quoted above does not refer to mineralogical composition but only to grain size.

BASIS FOR INTERROGATORY: The statement on Page 48 above referring to four tested cores errs in regard to its use of the phrase "small percentage of clay." The statement should read as "slightly less than 50 percent clay and 50 percent silt and a small percentage of sand."

The soil classifications in the statement above need to be understood in terms of particle grain size, not mineral composition. Generally, the mineral composition of clay-size particles of soils at the Clive site is about 65% carbonate minerals, and only about 18% clay minerals.

APPLICABLE RULE(S) OR REGULATION(S): UAC R313-25-8(4)(a) and (b); UAC R313-25-18; UAC R313-25-19; UAC R313-25-20

REGULATORY GUIDANCE REFERENCE(S): U.S. NRC (2000); U.S. NRC (2007)

16.0 SCIENTIFIC AND ENGINEERING RESEARCH REFERENCES

Abt, S., Pauley, C., Hogan, S., and Johnson, T. (1994) Gully Potential in Soil-Covered Uranium Waste Impoundments, J. Energy Eng., v, 120, p. 51–66.

Abt, S.R., Nelson, J.D., Johnson, T.L. and Hawkins, E.F. (1989) Cap stabilization for reclaimed uranium sites, Journal of Energy Engineering, v. 115, p. 109-119.

Abt, S. R., Wittier, R.J., Ruff, J.F., LaGrone, D.L., Khattak, M.S., Nelson, J.D., Hinkle, N.E., and Lee, D.W. (1988). Development of riprap design criteria by riprap testing in flumes: phase II, NUREG/CR4651, U.S. Nuclear Regulatory Commission, Washington, D.C., Sept.

Albrecht, B. and Benson, C. (2001) Effect of desiccation on compacted natural clays. Journal of Geotechnical and Geoenvironmental Engineering, 127(1), 67-75.

Albrecht, B. and Benson, C. (2002) Closure to discussions of "Effect of desiccation on compacted natural clays," Journal of Geotechnical and Geoenvironmental Engineering, 128(4), 356-360.

Albright, W.H., Benson, C.H. and Waugh, W.J. (2010) Water Balance Covers for Waste Containment: Principles and Practice, ASCE Press (August 24, 2010), 160 pp.

Anderson, J.E. and Forman, A.D. (2002) The Protective Cap/Biobarrier Experiment: A study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory, STOLLER-ESER-46, Prepared for the U.S. Department of Energy – Idaho Field Office, Idaho Falls, ID, 51 pp.

Anderson, C. and Wall, S. (2010) Design of erosion protection at landfill areas with slopes less than 10%, in Scour and Erosion: Proceedings of the Fifth International Conference on Scour and Erosion, ICSE-5, November 7-10, 2010, San Francisco, California, ASCE, November 7-10, 2010.

Anderson, C.E. and Stormont, J.C. (2005) Gravel admixtures for erosion protection in semi-arid climates, in Erosion of Soils and Scour of Foundations, Proceedings of Sessions of the Geo-Frontiers 2005 Congress, Austin, Texas.

Argonne National Laboratories (undated) Retrieved January 2012 from http://web.ead.anl.gov/resrad/datacoll/conuct.htm)

Arthur, W. J. III and Markham, O.D. (1983) Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho, Journal of Environmental Quality, v. 12, pp. 117–122.

Arthur, W.J. III, Markham, O.D., Groves, C.R. and Halford, D.K. (1986) Radiation dose to small mammals inhabiting a solid-radioactive-waste disposal area. Journal of Applied Ecology, v. 23, p. 13-26.

Arthur, W.J. III, Markham, O.D., and Groves, C.R. (1987) Radionuclide export by deer mice at a solid radioactive waste disposal area in southeastern Idaho, Health Physics, v. 52, p. 45-53.

Ayres, B., Dobchuk, B., Christensen, D., O'Kane, and Fawcett, M. (2006) Incorporation of natural slope features into the design of final landforms for waste rock stockpiles, in Barnhisel, R.I., ed., 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis MO., American Society of Mining and Reclamation (ASMR), 3134 Montavesta Road, Lexington, KY. Retrieved June 2012 from http://www.infomine.com/publications/docs/Ayres2006.pdf

Batu, V. (2006) Applied Flow and Solute Transport Modeling in Aquifers: Fundamental Principles and Analytical and Numerical Methods. Boca Raton, Florida: Taylor & Francis, CRC Press, 696 p.

Benson, C.H. (2011) CRESP DOE landfill partnership, 26 May 2011, http://srnl.doe.gov/copexchange/2011/pdfs/Benson_15.pdf

Benson, C., Abichou, T., Olson, M., and Bosscher, P. (1995) Winter effects on the hydraulic conductivity of a compacted clay. Journal of Geotechnical and Geoenvironmental Engineering, 121(1), 69-79.

Benson, C.H., Albright, W.H., Fratta, D.O., Tinjum, J.M., Kucukkirca, E., Lee, S.H., Scalia, J., Schlicht, P.D., and Wang, X. (2011) NUREG/CR-7028, Engineered Covers for Waste Containment: Changes in Engineering Properties and Implications for Long-Term Performance Assessment, Volume 1, Office of Nuclear Regulatory Research, NRC, December 2011.

Benson, C., Bosscher, P., Lane, D., and Pliska, R. (1994) Monitoring System for Hydrologic Evaluation of Landfill Final Covers, Geotech. Testing J., 17(2), 138-149.

Benson, C., Hardianto, F., and Motan, E. (1994) Representative size for hydraulic conductivity assessment of compacted soil liners. Hydraulic Conductivity and Waste Contaminant Transport in Soil, STP 1142, ASTM, West Conshohocken, PA, 3-29.

Benson, C. and Othman, M. (1993) Hydraulic conductivity of compacted clay frozen and thawed in situ. Journal of Geotechnical and Geoenvironmental Engineering, 119(2), 276-294.

Beven, K. and Germann, P. (1982) Macropores and water flow in soils. Water Resources Research, 18, 1311-1325.

Black, P., Tauxe, J., Perona, R., Lee, R., Catlett, K., McDermott, G., Balshi, M., Fitzgerald, M., Shrum, D., McCandless, S., Sobocinski, R., Rogers, V.C. (2012) Advancing Performance Assessment for Disposal of Depleted Uranium at Clive Utah, Neptune and Company with Energy*Solutions*, PowerPoint presentation found at http://www.neptuneandco.com/~jtauxe/wm12/WM2012_Blacketal_presentation_12493.pdf

Blom, P.E., Johnson, J.B. and Rope, S.K. (1991) Concentrations of ^{137}Cs and ^{60}Co in nests of the harvester ant, *Pogonomyrmex salinus*, and associated soils near nuclear reactor waste water disposal ponds, American Midland Naturalist, v. 126, p. 140-151.

Blom, P.E., Johnson, J.B. and Shafi, B. (1994) Soil water movement related to distance from three *Pogonomyrmex salinus* (Hymenoptera: Formicidae) nests in south-eastern Idaho. Journal of Arid Environments, v. 26, p. 241–255.

Bowerman, A.G. and Redente, E.F. (1998) Biointrusion of protective barriers at hazardous waste sites, Journal of Environmental Quality, v. 27, p. 625-632.

Bronswijk, J.J.B. (1988) Modeling of water balance, cracking and subsidence of clay soils, Journal of Hydrology, v. 97, p. 199–212.

Cadwell, L. L., Eberhardt, L.E. and Simmons, M.A. (1989) Animal Intrusion Studies for Protective Barriers: Status Report for FY 1988, PNL-6869, Pacific Northwest Laboratory, Richland, Washington.

Chamberlain, E. and Gow, A. (1979) Effect of freezing and thawing on permeability and structure of soils. Engineering Geology, 13, 73-92.

Chena, K-F, Lib, S. and Zhang, W-X (2011) Renewable hydrogen generation by bimetallic zero valent iron nanoparticles, Chemical Engineering Journal, v. 170, Pages 562–567.

Colorado State University Extension (2012) Estimating Soil Texture: Sand, Silt or Clayey? Retrieved 17 January, 2013 from http://www.cmg.colostate.edu/gardennotes/214.html.

Cooper, D.J., Sanderson, J.S., Stannard, D.I. and Groeneveld, D.P. (2006) Effects of long-term water table drawdown on evapotranspiration and vegetation in an arid region phreatophyte community, Journal of Hydrology, v. 325, p. 21–34.

Diaz, F., Jimenez, C.C. and Tejedor, M. (2005) Influence of the thickness and grain size of tephra mulch on soil water evaporation, Agricultural Water Management, v. 74, p. 47-55.

DRC (2011) Technical Assessment: Energy*Solutions* Proposed Disposal of Low-Level Radioactive Waste Generated by SempraSafe Treatment Process, Utah Department of Environmental Quality, Division of Radiation Control, December, 2011.

Dreeson, D.R. and Marple, M.L. (1979) Uptake of trace elements and radionuclides from uranium mill tailings by four-wing saltbush (*Atriplex canescens)* and alkali sacaton *(Sporobolus airoides*), in Proceedings of the Second Symposium on Uranium Mill Tailings Management, Fort Collins, CO, November 19-20, 1979, Geotechnical Engineering, Civil Engineering Program, Colorado State University, 18 pp.

Dwyer, S.F., Rager, R.E. and Hopkins, J. (2007) Cover System Design Guidance and Requirements Document, LA-UR-06-4715, April 2007, EP2006-0667, Environmental Programs-Environmental Restoration Support Services, Los Alamos National Laboratory, New Mexico, 170 pp. plus appendices.

Elliot, C.L., McKendrick, J.D. and Helm, D. (1987) Plant biomass, cover, and survival of species used for stripmine reclamation in south-central Alaska, U.S.A., Arctic and Alpine Research, v. 19, p. 572-577.

Energy*Solutions* (2012) Utah Low-Level Radioactive Material License (RML UT2300249) Updated Site-Specific Performance Assessment, October 8, 2012.

FR (2012) Proposed Rules, Docket ID NRC-2011-0012, Federal Register 72997, Vol. 77, No. 236, published Friday, December 7, 2012.

Fitts, C.R. (2002) Groundwater Science, Academic Press (Elsevier), San Diego, 450 pp.

Gass, T.E., Lehr, J.H., Heiss, H.W. (1977) Impact of abandoned wells on ground water. US Environmental Protection Agency,Washington, DC, Rep EPA/600/3-77-095

Goodman, P.J. (1973) Physiological and Ecotypic Adaptations of Plants to Salt Desert Conditions in Utah, Journal of Ecology, v. 61, p. 473-494.

Groenevelt, P.H., van Straaten, P., Rasiah, V. and Simpson, J. (1989) Modifications in evaporation parameters by rock mulches, Soil Technology, v. 2, p. 279-285.

Gummer, J. and Hawksworth, S. (2008) Spontaneous ignition of hydrogen literature review, Health and Safety Laboratory, Harpur Hill, Buxton, England.

Hadas, A. and Hillel, D. (1972) Steady-state evaporation through non-homogeneous soils from a shallow water table, Soil Science, v. 113, p. 65-73.

Hakonson, T. E. (1999) The effects of pocket gopher burrowing on water balance and erosion form landfill covers. J. Environ. Qual. v. 28, p. 659–665.

Hakonson, T.E. (2002) Review of Sandia National Laboratories/New Mexico Evapotranspiration Cap Closure Plans for the Mixed Waste Landfill, Prepared for Citizen Action 2/15/02.

Hakonson, T.E., Martinez, J.L. and White, G.G. (1982) Disturbance of a low-level waste burial site cover by pocket gophers, Health Physics, v. 42, pp. 868–871.

Hampton, N.L. (2006) Biological Data to Support Operable Unit 7-13/14: Modeling of Plant and Animal Intrusion at Buried Waste Sites, INEEL/EXT-01-00273 Revision 1 Project No. 23378, Idaho Cleanup Project, January 2006.

Han, S. J., and Goodings, D. J. (2006) Practical model of frost heave in clay, J. Geotech. Geoenviron. Eng., v. 132, p. 92–101.

Hancock, G., Willgoose, G., Evans, K., Moliere, D., Saynor, M. (2000) Medium term erosion simulation of an abandoned mine site using the SIBERIA landscape evolution model. Australian Journal of Soil Research, 38, 249-263.

Handley-Sidhu, S., Worsfold, P.J., Boothman, C., Lloyd, J.R., Alvarez, R., Livens, F.R., Vaughan, D.J., and Keith-Roach, M.J. (2009) Corrosion and Fate of Depleted Uranium Penetrators under Progressively Anaerobic Conditions in Estuarine Sediment, Environ. Sci. Technol., v. 43, p. 350–355.

HERD (1998) Issue: depth of soil samples used to set exposure point concentration for burrowing mammals and burrow-dwelling birds in an ecological risk assessments. Herd Ecological Risk Assessment Note, Herd Era Note Number: 1, California Department of Toxic Substances Control, Human and Ecological Risk Division (Herd), Issue Date: May 15, 1998 Retrieved May 2012 from http://www.dtsc.ca.gov/AssessingRisk/upload/econote1.pdf

Hermansson, A. (2002) Modeling of frost heave and surface temperatures in roads. Doctoral Thesis. Lulea University of Technology, Department of Civil and Mining Engineering, Lulea, Sweden.

Hermansson, A. and Guthrie, W.S. (2005) Frost heave and water uptake rates in silty soil subject to variable water table height during freezing, Cold Regions Science and Technology, v. 43, p. 128–139.

Homaee, M. and Feddes, R.A. (2002) Quantification of root water extraction under salinity and drought, Plant Nutrition, Developments in Plant and Soil Sciences, v. 92, p. 376-377.

Jain, R. K., and Kothyari, U. C. (2009) Cohesion influences on erosion and bed load transport, Water Resour. Res., 45, W06410, p. 1-17.

Jarvis, N.J., Leed-Harrison, P.B. (1990) Field test of a water balance model of cracking clay soils, Journal of Hydrology, v. 112, p. 203-218.

Johnson, T.L. (2002) Design of Erosion Protection for Long-Term Stabilization, Final Report, NUREG-1623, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, Washington, D.C.

Kampf, M. and Montenegro, H. (1997) On the performance of capillary barriers as landfill cover, Hydrology and Earth System Sciences, v. 4, p. 935-929.

Kamphuis, J.W. (1990) Influence of sand or gravel on the erosion of cohesive sediment, Journal of Hydraulic Research, v. 28, p. 43-53.

Katerji, N., van Hoorn, J.W., Hamdy, A., Karam, F., Mastrorilli, M. (1994) Effect of salinity on emergence and on water stress and early seedling growth of sunflower and maize. Agric. Water Manage. 26, 81–91.

Katerji, N., van Hoorn, J.W., Hamdy, A., Karam, F., Mastrorilli, M. (1996) Effect of salinity on water stress, growth and yield of maize and sunflower. Agric. Water Manage. 30, 237–249.

Kemper, W. D., Nicks, A. D. and Corey, A. T. (1994) Accumulation of water in soils under gravel and sand mulches, Soil Sci. Soc. Am. J., v. 58, p. 56–63.

Kenagy, G.J. (1973) Daily and seasonal patterns of activity and energetics in a heteromyid rodent community, Ecology, v. 54, p. 1201-1219.

Kennecott Utah Copper | Environmental Restoration Group (2012) South Facilities Groundwater 2011 Remedial Progress Report, April 2012, 136 pp.

Lagasse, P.F., Clopper, P.E., Zevenbergen, L.W., and Ruff, J.F. (2006) Riprap Design Criteria, Recommended Specifications, and Quality Control, NCHRP Report 568, Transportation Research Board, National Academies of Science, Washington, D.C.

Landeen, D.S. and Mitchell, R.M. (1981) Invasion of radioactive waste burial sites by the Great Basin Pocket Mouse (*Perognathus parvus*), 13 pp., in International symposium on migration in the terrestrial environment of long-lived radionuclides from the nuclear fuel cycle, Knoxville, TN, USA, 27 Jul 1981.

Landeen, D.S. (1994) The influence of small mammal burrowing activity on soil water storage at the Hanford Site, WHC-EP-0730, Westinghouse Hanford Company, Richland, Washington.

Landon, M. K., Jurgens, B. C., Katz, B. G., Eberts, S. M., Burow, K. R., and Crandall, C. A. (2010) Depth-dependent sampling to identify short-circuit pathways to public-supply wells in multiple aquifer settings in the United States, Hydrogeology J., v.18, . p. 577-593.

Lewis, R.S., Varley, T. and Schneider, H. (1919) The mineral industry of Utah, Bull. 12, Univ. of Utah, v. 10, p. 199.

Lindzey, F.G. (1976) Characteristics of the natal den of the badger, Northwest Science, v. 50, p. 178–180.

Liu, L. and Neretnieks, I. (2002) The effect of hydrogen on oxidative dissolution of spent fuel, Nucl. Technol., v. 138, p. 69–78.

Maxwell, B., Carroll, M., Waugh, J., Jordan, F. and Glenn, E. (2007) Remediation of soil and ground water using native desert phreatophytes, USA Water Quality Conference, work performed under DOE contract DE-AC01-02GJ79491.

McAdoo, J.K. and Young, J.A. (1980) Jackrabbits, Rangelands, v. 2, August 1980, p. 135-138.

McKenzie, D.H., Cadwell, L.L., Eberhardt, L.E., Kennedy, W.E.. Jr., Peloquin, R.A. and Simmons, M.A. (1982) Relevance of biotic pathways to the long-term regulation of nuclear waste disposal, NUREG/CR-2675, Pacific Northwest Laboratory, Richland, Washington.

Middle.usa (undated) http://middle.usm.k12.wi.us/faculty/taft/Unit5/westwebquest/boomtowns/

Miyazaki, T. (2005) Water Flow In Soils, Second Edition, CRC Press, 440 pp.

Nagy, K.A., Shoemaker, V.H. and Costa, W.R. (1976) Water, electrolyte, and nitrogen budgets of jack rabbits (*Lepus californicus*) in the Mojave Desert, Physiol. Zool.. v. 49, p. 351-363.

National Archives #156 (1876) "Gayville in Deadwood Gulch, Black Hills [Dak. Terr.], 1876." Log cabins under construction at the foot of a hillside. 111-SC-100863. http://www.archives.gov/research/american-west/

National Archives #167 (1909) "Tent town in a mountain valley in Idaho." By Burt L. Wheeler November 1909. 95-G-77538. http://www.archives.gov/research/american-west/

21st Navajo Nation Council (2010) Resources Committee, Navajo EPA and federal agencies meet with Rep. Waxman staffers on updates regarding Navajo uranium five year plan. Retrieved January 2013 from http://www.navajo-nsn.gov/News%20Releases/NNCouncil/Aug10/100827_Resources_Committee_Navajo_EPA_update_Rep_Henry_Waxman_staffers.pdf.

Nelson, J.D., Volpe, R.L., Wardwell, R.E., Schumm, S.H., and Staub, W.P. (1983) Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments, NUREG/CR-3397 (ORNL-5979), U.S. Nuclear Regulatory Commission, Washington, D.C.

Neptune and Company, Inc. (2011a) Biologically-Induced Transport Modeling for the Clive DU PA, 28 May 2011, prepared for Energy*Solutions*.

Neptune and Company, Inc. (2011b) Final Report for the Clive DU PA Model, version 1.0, 1 June 2011, prepared for Energy*Solutions*.

Neptune and Company, Inc. (2012) Modeling Report: Fate and Transport of Contaminants from the Class A West Embankment and Exposure to a Post-Closure Traditional Inadvertent Human Intruder at the Energy*Solutions* Clive, Utah Facility, prepared for Energy*Solutions*.

Nichols, W. D. (1993) Estimating Discharge of Shallow Groundwater by Transpiration from Greasewood in the Northern Great Basin, Water Resources Research, v. 29, p. 2771–2778.

O'Neal, G.T., Flinders, J.T. and Clary, W.P. (1987) Behavioral ecology of the Nevada kit fox (*Vulpes macrotis nevadensis*) on a managed desert rangeland, p. 443–481 in H.H. Genoways, ed., Current Mammalogy, Volume 1. Plenum Press, New York, New York.

Petrov (1976) Deserts of the World, Wiley, New York.

Reardon, E.J. (2005) Zerovalent Irons: Styles of Corrosion and Inorganic Control on Hydrogen Pressure Buildup, Environ. Sci. Technol., 2005, 39, p. 7311–7317.

Reheis, M. C., and R. Kihl (1995) Dust deposition in southern Nevada and California, 1984–1989: Relations to climate, source area, and source lithology, J. Geophys. Res., v. 100, p. 8893–8918.

Reith, C.C. and Caldwell, J.A. (1990) Vegetative covers for UMTRA project disposal cells, Jacobs Engineering Group Albuquerque, New Mexico 87108.

Ritchie, J. T. (1972) Model for predicting evaporation from a row crop with incomplete cover, Water Resour. Res., v. 8, p. 1204-1213.

Robertson, J.H. (1983) Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), Phytologia, v. 54, p. 309–324.

Salhotra, A.M., Adams, E.E. and Harleman, D.R. (1985) Effect of salinity and ionic composition on evaporation: Analysis of Dead Sea evaporation pans, Water Resour. Res, v. 21, p. 1336-1344.

Santi, P.M., McCray, J.E., Martens, J.L. (2006) Investigating cross-contamination of aquifers. Hydrogeol J., v. 14, p. 51–68.

Sargeant, A.B. and Warner, D.W. (1972) Movements and denning habits of a badger, Journal of Mammalogy, v. 53, p. 207-210.

Sejkora, K.J. (1989) Influence of pocket gophers on water erosion and surface hydrology, Ph.D. Dissertation, Colorado State Univ., Fort Collins, CO.

Schenk, H.J. and Jackson, R.B. (2002) Rooting depths, lateral root spreads and below-ground/above-ground allometries of plants in water-limited ecosystems, J. of Ecology, v. 90, p. 480-494.

Sinkov, S.I., Delegard, C.H. and Schmidt, A.J. (2010) Mitigation of Hydrogen Gas Generation from the Reaction of Water with Uranium Metal in K Basin Sludge, PNNL-19135, Prepared for the U.S. Department of Energy, Pacific Northwest National Laboratory, Richland, WA, January 2010.

St. Bonaventure (undated) Water delivery, St. Bonaventure Indian Mission and School. Retrieved January 2013 from http://www.stbonaventuremission.org/waterdelivery.htm.

Stenseng, S.E. and Nixon, P.A. (1997) Long-term cover design for low-level radioactive and hazardous waste sites as applied to the Rocky Flats environmental technology site solar evaporation ponds, in Wukasch, R.F., 1995, Proceedings of the 50th Industrial Waste Conference May 8, 9, 10, Purdue Research Foundation, Office of Technology Transfer, West Lafayette, IN, 852 pp.

Suter, G.W. (1993) Ecological Risk Assessment, 2nd Edition, CRC Press, Boca Raton, Florida, 655 pp.

Suter, G.W., Luxmoore, R.J., and Smith, E.D. (1993) Compacted soil barriers at abandoned landfill sites are likely to fail in the long term. J. Environ. Qual., v. 22, p. 217-226.

SWCA Environmental Consultants (2011) Field Sampling of Biotic Turbation of Soils at the Clive Site, Tooele County, Utah, Prepared for Energy*Solutions*, January 2011.

SWCA Environmental Consultants (2012) Vegetated Cover System for the Energy*Solutions* Clive Site: Literature Review, Evaluation of Existing Data, and Field Studies, Summary Report, Prepared for EnergySolutions, August 2012.

Tannerfeldt, M., A. Moehrenschlager, and A. Angerbjörn (2003) Den ecology of swift, kit and Arctic foxes: a review, in Sovada, M. and Carbyn, L., eds., The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Centre, University of Regina, Regina, Saskatoon, p. 167–181.

MacMillan, L. (2012) Tainted desert struggling to reclaim their health and land after decades of uranium mining, the Navajos find a strong advocate at Tufts, Tufts Magazine, Winter 2012. Retrieved January 2013 at http://forgottennavajopeople.org/.

University of Utah Research Institute (1993) Summary of X-Ray Diffraction Analysis, University of Utah Research Institute, Earth Science Laboratory, included as an attachment to a letter report on Evaluation of Long Term Permeability of Treated Clay Notice of Deficiency: Radioactive Materials License UT2300249, Envirocare Disposal Facility, Toole County, Utah, Project No. 11293, from Robert E. Edgar of Applied Geotechnical Engineering Consultants, Inc. to Steve Petersen of Envirocare of Utah, Inc., dated February 17, 1993.

U.S. Bureau of Land Management (1986) Final Environmental Impact Statement for the Jackpile-Paguate Uranium Mine Reclamation Project: Laguna Indian Reservation, Cibola County, New Mexico (Vol. 2), U.S. BLM and Rio Puerco Resource Area, and U.S. Bureau of Indian Affairs, Albuquerque Area Office.

U.S. Bureau of Land Management (2008) Handbook H-1740-2 – Integrated Vegetation Management, Bureau of Land Management, U.S. Dept. of the Interior, Washington, D.C. Retrieved November 21, 2012 from www.blm.gov/pgdata/etc/medialib/blm/wo/Information_Resources_Management/policy/blm_handbook.Par.59510.File.dat/H-1740-2.pdf

U.S. Department of Agriculture (2013) Fourwing saltbush, Atriplex canescens (Pursh) Nutt., Plant Guide, U.S. Department of Agriculture, Natural Resources Conservation Service. Retrieved February 2013 from http://plants.usda.gov/plantguide/pdf/pg_atca2.pdf.

U.S. Department of Agriculture (2009) Black Greasewood: *Sarcobatus vermiculatus* (Hook.) Torr., Plant Guide, U.S. Department of Agriculture, Natural Resources Conservation Service, Retrieved December 2012 from http://plants.usda.gov/plantguide/pdf/pg_save4.pdf

U.S. DOI (2012) Navajo-Gallup Water Supply Project Planning Report and Final Environmental Impact Statement, Reclamation: Managing Water in the West, U.S. Department of Interior, Bureau of Reclamation, Upper Colorado Region. Retrieved January 2013 from http://www.usbr.gov/uc/envdocs/eis/navgallup/FEIS/index.html.

U.S. EPA (2012) Tribal Successes and Challenges: Safe Drinking Water, Clean Waterways. Retrieved January 2013 from http://www.epa.gov/region9/tribal/success/02/water.html.

U.S. NRC (2000) A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities, NUREG-1573, U.S. Nuclear Regulatory Commission, Published October 2000.

U.S. NRC (2003) 4. Environmental impacts of construction, operation, aquifer restoration, and decommissioning activities, Environmental Review Guidance for Licensing Actions Associated With NMSS Programs, Final Report, NUREG–1748, Washington, DC. August 2003. Retrieved November 21, 2012 from http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1910/v1/ch4.pdf.

U.S. NRC (2007) NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations, NUREG-1854, Center for Nuclear Waste Regulatory Analyses, U.S. Nuclear Regulatory Commission, August 2007.

U.S. NRC (2010) Blending of Low-Level Radioactive Waste, SECY-10-0043, April 7, 2010.

U.S. NRC (2011a) Part 61: Site Specific Analyses for Demonstrating Compliance with Subpart C Performance Objectives: Preliminary Proposed Rule Language, May 2011, Retrieved February 2013 from http://pbadupws.nrc.gov/docs/ML1111/ML111150205.pdf.

U.S. NRC (2011b) Summary of existing guidance for reviewing large-scale low-level radioactive waste blending proposals, FSME-11-024, March 17, 2001. Retrieved 14 February 2013 from http://pbadupws.nrc.gov/docs/ML1104/ML110480850.pdf.

U.S. NRC (2012) Draft Branch Technical Position on Concentration Averaging and Encapsulation, Revision 1, May 2012, Washington, D.C., Retrieved January 2013 from http://pbadupws.nrc.gov/docs/ML1211/ML121170418.pdf.

Utah Division of Water Resources (2001) Population and Water Use Trends and Projections, in Utah's Water Resources: Planning for the Future, Utah State Water Plan, State of Utah, Natural Resources, Division of Water Resources.

Van Ledden, M., Van Kesteren, W.G.H., and Winterwerp, J.C. (2004) A conceptual framework for the erosion behaviour of sand/mud mixtures. Continental Shelf Research, v. 24, p. 1-11.

Ward, A.D. and Trimble, S.W. (1995) Environmental Hydrology, Lewis Publishers, 462 pp.

Waugh, W.J. (1998) Monument Valley Ground Water Remediation Work Plan: Native Plant Farming and Phytoremediation Pilot Study, Prepared by MACTEC for the U.S. Department of Energy, UMTRA Ground Water Project, August 1998, Work Performed under DOE Contract No. DE–AC13–96GJ87335.

Waugh, W.J. and Richardson, G.N. (1997) Ecology, design and long-term performance of surface barriers: applications at a uranium mill tailings site, in Committee on Remediation of Buried and Tank Wastes, National Research Council, eds., Barrier technologies for environmental management: summary of a workshop, The National Academies Press, Washington, D.C., 188 pp. Retrieved August 2012 from http://www.nap.edu/openbook.php?record_id=5539&page=54

Waugh, W.J. and Smith, G.M. (1998) Root intrusion of the Burrell, Pennsylvania, Uranium Mill tailings cover, pp. 89–108, in Proceedings: Long-Term Stewardship Workshop, CONF–980652, U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado (invited paper).

Waugh, W.J., Morrison, S.J., Smith, G.M., Kautsky, M., Bartlett, T.R., Carpenter, C.E. and Jones, C.A. (1999) Plant Encroachment on the Burrell, Pennsylvania, Disposal Cell: Evaluation of Long-Term Performance and Risk, GJO-99-96-TAR, Environmental Sciences Laboratory, U.S. Department of Energy, Grand Junction, Colorado.

Waugh, W.J., Smith, G.M., Bergman-Tabbert, D. and Metzler, D. (2001) Evolution of Cover Systems for the Uranium Mill Tailings Remedial Action Project, USA, Earth and Environmental Science Mine Water and the Environment, v. 20, p. 190-197. Retrieved May 2012 from http://www.springerlink.com.ezproxy1.lib.asu.edu/content/r1xpfdl9knnr4v56/

Way, J.G., Auger, P.J., Ortega, I.M. and Strauss, E.G. (2001) Eastern coyote denning behavior in an anthropogenic environment, Northeast Wildlife, v. 56, p. 18-30.

WCAX.com (2012) Bakken Oil Boom Creates Huge Housing Demand, Posted October 10, 2012, retrieved December, 2012 from http://www.wcax.com/story/19786504/bakken-oil-boom-creates-huge-housing-demand.

Wells, S.G. and Jercinovic, D.E. (1983) Applications of Geomorphology to Surface Coal-Mining Reclamation, Northwestern New Mexico, Chaco Canyon Country, American Geomorphological Field Group.

Whetstone Associates, Inc. (2011a) Energy*Solutions* Class A West Disposal Cell Infiltration and Transport Modeling Report, April 19, 2011

Whetstone Associates, Inc. (2011b) Revised Section 5 Excavation Infiltration Modeling report prepared for Energy*Solutions*, June 15, 2011.

Widmayer, D.A. (2011) Certification of the minutes for the meeting of radiation protection and nuclear materials subcommittee, June 23, 2011 – Rockville, Maryland, Memorandum to ACRS Members, November 22, 2011, United States Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, Washington, DC 20555-0001, http://pbadupws.nrc.gov/docs/ML1132/ML11322A156.pdf

Wildflower Center (2012) *Atriplex confertifolia* (Torr. & Frém.) S. Wats., Lady Bird Johnson Wildflower Center, The University of Texas at Austin. Retrieved November 21, 2012 from http://www.wildflower.org/plants/result.php?id_plant=ATCO

Willard, J.R.A. 1964. Biological activities of the harvester ant, *Pogonomyrmex owyheei* Cole, in central Oregon. M.S. thesis. Oregon State Univ., Corvallis.

Winsor, T.F. and Whicker, F.W. (1980) Pocket gophers and redistribution of plutonium in soil, Health Physics, V. 39, pp. 257–262.

WSDNR (2011) Ecological Integrity Assessments: Inter-Mountain Basins Greasewood Flat, Natural Heritage Program, Washington State Department of Natural Resources, Version: 2.22.201, 11 pp.

Yu, C., Loureiro, C., Cheng, J.-J., Jones, L.G., Wang, Y.Y., Chia, Y.P. and Faillace, E. (1993) Data collection handbook to support modeling impacts of radioactive material in soil, Environmental Assessment and Information Sciences Division, Argonne National Laboratory, Argonne, Illinois, April 1993. Retrieved January 2013 from http://web.evs.anl.gov/resrad/documents/data_collection.pdf.

Zhu, J-K, Hasegawa, P.M., Bressan, R.A. and Bohnert, H.J. (1997): Molecular aspects of osmotic stress in plants, Critical Reviews in Plant Sciences, v. 16, p. 253-277.