

Review of Deep Time Supplemental Analysis

White Paper

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submitted to the

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TABLE OF CONTENTS

Abbreviations and Acronyms	3
Introduction.....	4
Aeolian Deposition	4
DRC Comments on DTSA.....	7
Additional Modeling of Radon Release.....	7
References.....	18
Appendix 1: Loren Morten Memo.....	20

LIST OF TABLES

Table 1: Annual Dust Deposition Rates on Land (Goudie et al, 1997)	6
Table 2: Summary Table of Published Sedimentation Rates, Eastern Great Basin, Utah.....	15
Table 3: Summary of Calculated Ground Surface Radon Fluxes.....	17

LIST OF FIGURES

Figure 1: Knolls Dune Field and Location of the Clive Facility	5
Figure 2: Possible Paleodune Field near Clive	6
Figure 3: Deep Time Supplemental Analysis Embankment Model	8
Figure 4: Unit 3 and Unit 4 Moisture Content.....	10
Figure 5: Waste Material Diffusion Coefficient Comparison.....	10
Figure 6: Sediment Diffusion Coefficient Comparison	11
Figure 7: Radon Fluxes at the DU and Unit 3 Top Surfaces	12
Figure 8: Base Case Ground Surface Radon Fluxes	13
Figure 9: Early Lake Case Ground Surface Radon Fluxes	13
Figure 10: Comparison of Lake Sedimentation Rates	14
Figure 11: Sedimentation Case Ground Surface Radon Fluxes.....	15
Figure 12: Aeolian Deposition Case Ground Surface Radon Fluxes	16
Figure 13: Mean-Peak Ground Surface Radon Fluxes	17

ABBREVIATIONS AND ACRONYMS

AMSL	above mean sea level
Bq	becquerel
CFR	<i>Code of Federal Regulations</i>
cm	centimeter
cm ²	square centimeter
cm ⁻³	cubic centimeter
DEQ	Department of Environmental Quality (Utah)
DRC	Division of Radiation Control (Utah)
DTSA	deep time supplemental analysis
DU	depleted uranium
g	gram
km ²	square kilometer
μCi/m ³	microcurie per cubic meter
m	meter
mm	millimeter
mrem	millirem
mSv	millisievert
NCRP	National Council on Radiation Protection and Measurements
NRC	Nuclear Regulatory Commission (U.S.)
PA	performance assessment
pCi/m ² -s	picocurie per square meter per second
RESRAD	Residual Radiation
SC&A	S. Cohen and Associates (SC&A, Inc.)
sec	second
SER	Safety Evaluation Report
y or yr	year

INTRODUCTION

Based on concerns expressed by the Utah Department of Environmental Quality (DEQ) in the Draft Safety Evaluation Report (SER) dated July 7, 2014, regarding the modeling of the Federal Cell in deep time [i.e., greater than 10,000 years as required under R313-25-9(5)(a)], EnergySolutions provided a supplemental qualitative analysis for deep time. This analysis was presented in *Deep Time Supplemental Analysis for the Clive DU PA*. Clive DU PA (depleted uranium performance assessment) Model vDTSA, August 5, 2014. This white paper describes DEQ's review of the deep time supplemental analysis (DTSA).

AEOLIAN DEPOSITION

A key element in the supplemental analysis involves the assumption that aeolian deposition will occur at the Clive site, raising the general level of the land surface supposition prior to the site being intruded by a pluvial lake, which is assumed to occur sometime after 10,000 years. Current plans call for the DU waste to be buried in the Federal Cell at or below current grade level [4,272 ft above mean sea level (AMSL)]. If the pluvial lake is of sufficient depth, it is assumed that the Federal Cell embankment would be destroyed to a level consistent with the current grade of the Federal Cell plus the thickness of any aeolian deposition that occurred prior to inundation of the site by the pluvial lake. This aeolian deposition would provide a partial barrier to radon diffusion from the DU waste. An additional barrier to radon release would be sediment that deposits on the surface of the cell as the lake recedes. Thus, the question of how much aeolian deposition has occurred prior to intrusion of the site by the first pluvial lake is of considerable importance in defining the radon flux at the surface after the pluvial lake has receded to a level below the then existing land surface.

Dr. Paul Jewell, University of Utah, provided several comments on the approach to aeolian deposition taken by EnergySolutions/Neptune in the Supplemental Analysis as noted below:

The August 2014 Deep Time Supplemental Analysis (DTSA) document from Neptune contains much more accurate and up-to-date analysis of current and future aeolian deposition adjacent to the Clive site relative to documents submitted earlier in 2014. Several points should be considered going forward.

1. *Aeolian deposition is much higher during glacial and immediate post-glacial periods.* Many studies document order of magnitude changes in overall aeolian sedimentation rate between glacial and interglacial periods and this may have a bearing on the sediment that makes it to the Clive site.
2. *World class aeolian deposits are not a good analogy for Great Basin dune deposits.* The very thick loess deposits formed during the Last Glacial Maximum in China, the Nebraska Sand Hills, Mississippi River valley, and Palouse area of the Pacific Northwest U.S. are the product of sediment availability from retreating continental glaciers combined with favorable (often flat) topography and wind patterns. While the retreat of Lake Bonneville at the end of the last glacial period provided a certain amount of sediment, it really can't be compared to these other areas.

3. *Aeolian deposition rates have extreme spatial variability.* Average aeolian deposition rates need to be treated with caution. Vast portions of the Great Basin have little or no windblown sediment, whereas areas such as the Little Sand Dunes and Knolls dunes of western Utah have accumulated 10s of meters of aeolian sediment during the Holocene. The mean aeolian deposition rate of 59 cm/10,000 yr in Table 1 of the DTSA is reasonable, but a standard deviation of 5 is too restrictive. As the authors of the document point out, the Clive site could very well be overrun in the coming decades or centuries by many meters of aeolian sediment from Knolls dunes to the west of the site (see Figure 1).



Figure 1: Knolls Dune Field and Location of the Clive Facility

4. *Aeolian sediment has poor long-term preservation potential in the Great Basin.* In addition to active dune deposits, a cursory look at Google Earth shows considerable evidence of prior aeolian deposition [including possible paleodunes near the Clive site (Figure 2)]. In spite of this, virtually no aeolian material is documented in cores, such as the Burmester site (summary in Oviatt et al. 1999), or logs, such as those of the Clive pit mentioned in previous Neptune documents. Poorly consolidated aeolian materials simply do not survive the high energy shore zones of lakes or fluvial systems that, on geologic time scales, follow aeolian deposition of dry, interglacial periods. This may have a direct bearing on long-term (10^5 – 10^6 year) infiltration studies of the proposed DU burial site.



Figure 2: Possible Paleodune Field near Clive

Additional information on dust deposition was included in Interrogatory CR R313-25-8(5)(a)-18/3: Sediment Accumulation, where Table 1 was presented (Goudie et al. 1997).

Table 1: Annual Dust Deposition Rates on Land (Goudie et al, 1997)

References ^b	Location	Deposition rate	
		(t km ⁻² a ⁻¹)	(mm 1,000 a ⁻¹) ^a
<u>Sahara</u>			
<u>Mediterranean region</u>			
Löye-Pilot et al. (1986)	Corsica	4	16
Yaalon and Ganor (1975)	Israel	22–83	25–93
Goossens (1995)	Negev	15–30	10–20
Bücher and Lucas (1975)	Pyrenees	18–23	20–26
Pye (1992)	Crete	10–100	11–112
<u>Harmattan plume</u>			
Maley (1980)	S Chad	109	122
McTainsh and Walker (1982)	N Nigeria	37–181	154–203
Drees et al. (1993)	SW Niger	200	100–150
<u>USA</u>			
Smith et al. (1970)	High Plains	65–85	73–96
Péwé et al. (1981)	Arizona	54	61
Gile and Grossman (1979)	New Mexico	9.3–125.8	10–141
Muhs (1983)	California	24–31	27–35
Reheis and Kihl (1995)	California/Nevada	4.3–15.7	5–18
<u>Middle East</u>			
Safar (1985)	Kuwait	100	112
Behairy et al. (1985)	W Saudi Arabia	13–109	15–122

Table 1: Annual Dust Deposition Rates on Land (Goudie et al, 1997)

References ^b	Location	Deposition rate	
		(t km ⁻² a ⁻¹)	(mm 1,000 a ⁻¹) ^a
<i>Miscellaneous</i>			
Inoue and Naruse (1991)	Japan	3.5–6	4–7
Tiller et al. (1987)	SE Australia	5–10	6–11
Kukal (1971)	Caspian Sea	39.5	44

a Calculated on bulk density of dust of 0.89 g cm⁻³ where not derived in original reference.

b The references in this column can be found in Goudie et al. 1997.

From Table 1 it can be seen that deposits in the Western U.S. range from 5 to 141 mm/1,000 yr. The overall average is 53 mm/1,000 yr, assuming reported results are uniformly distributed within each range.

DRC COMMENTS ON DTSA

Attachment 1 to this white paper provides additional comments from the Utah Division of Radiation Control (DRC) on the DTSA. Issues of particular importance include:

- Whether the unpublished interpretation by Orviatt of pit wall samples at Clive is consistent with aeolian deposition rather than sedimentation.
- Whether the aeolian deposition rates are correctly interpreted from the sedimentation rate for the Gilbert Episode at a location between the Stansbury and Antelope Islands.
- Whether the timing for the next glacial cycle is appropriately modeled.
- Whether the DTSA will be affected by currently unresolved issues related to infiltration through the ET cover.

ADDITIONAL MODELING OF RADON RELEASE

This section describes additional modeling that was done to provide greater transparency regarding, inter alia, the issues noted above. Figure 3 shows the embankment model used to perform these deep time analyses. Briefly, when the embankment is closed (i.e., at time zero) the embankment will be as described in the design documents. Then after a long time period (i.e., more than 10,000 years), aeolian deposition will have raised the general ground level around the Clive site. Finally, a lake will return that will wash away everything above the general area ground level, including the top portion of the embankment. While the lake is present, sedimentation will occur, which would remain after the first lake has receded. The radon fluxes are calculated on the ground surface, directly above the disposed of DU.

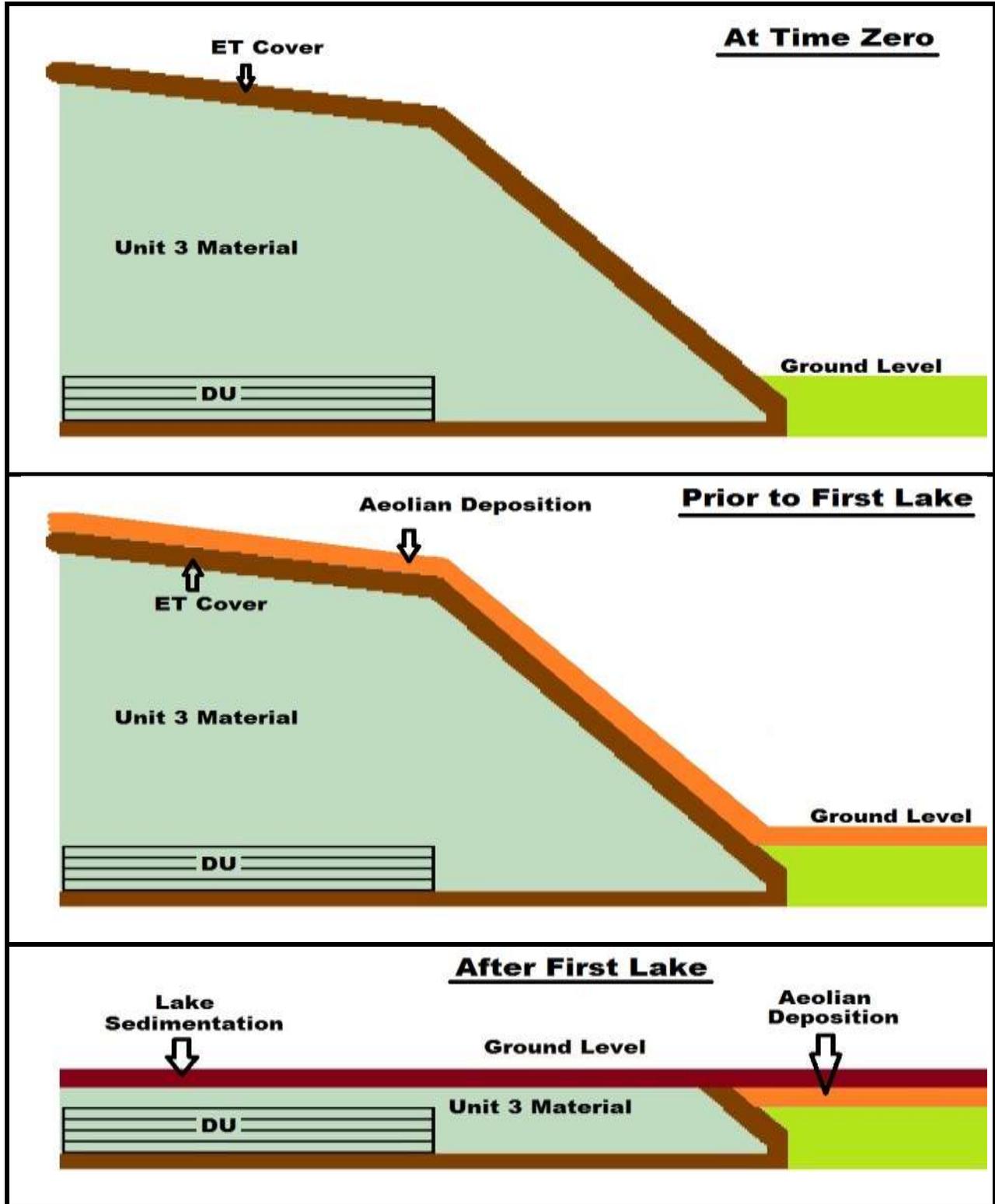


Figure 3: Deep Time Supplemental Analysis Embankment Model

Rogers and Nielson (1991) developed the following empirical expression for the radon diffusion coefficient based on 1,073 diffusion coefficient measurements on natural soils:

$$D = D_0 \Phi \exp[-6 m \Phi - 6 m^{14} \Phi] \quad (1)$$

Where: D = Radon diffusion coefficient ($\text{cm}^2 \text{s}^{-1}$)
 D_0 = Radon diffusion coefficient in air ($0.11 \text{ cm}^2/\text{sec}$)
 Φ = Total porosity (dimensionless)
 m = Moisture saturation fraction (dimensionless)
 $= \frac{M}{\Phi}$
 M = Moisture content, dry basis (dimensionless)

Instead of the Rogers and Nielson (1991) empirical relationship to calculate the radon diffusion coefficient, Neptune calculated the effective diffusion coefficient as the product of the diffusion coefficient in free air and the tortuosity, as explained in the EnergySolutions Round 2 response to Interrogatory 05.

For the DTSA, Neptune assumed that the DU layer and the embankment layers immediately above the DU layers were composed of Unit 4 material (i.e., silty clay). In the Neptune (2011) (FRV1) and Neptune (2014a) (FRV1.2), the DU layers and the layers immediately above were assumed to be composed of Unit 3 material (i.e., silty sand). A major difference between Unit 3 and Unit 4 is their moisture content distributions. Figure 4 shows that the Unit 4 moisture content (taken from DTSA, Figure 1) has a mean moisture content of 0.2559, while the Unit 3 mean moisture content is only 0.114. This is important because, as equation 1 indicates, the radon diffusion coefficient is exponentially related to the moisture content. Higher moisture contents reduce the radon flux at the surface.

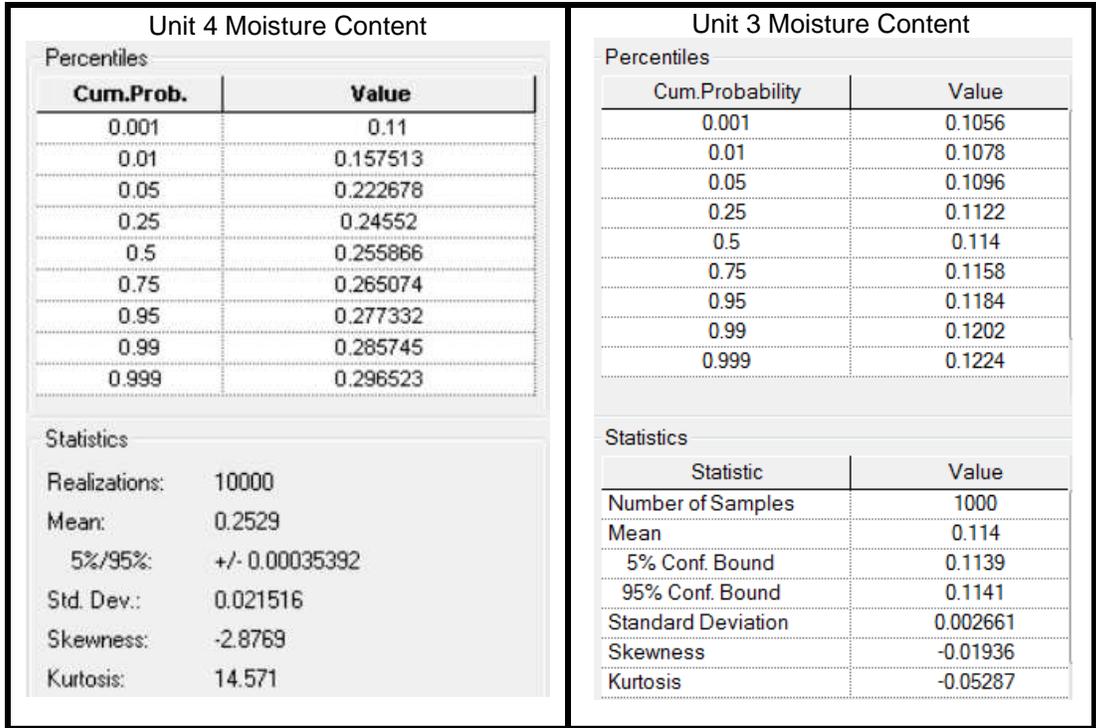


Figure 4: Unit 3 and Unit 4 Moisture Content

Figure 5 shows the EnergySolutions/Neptune- and SC&A-calculated radon diffusion coefficients used to calculate the radon flux at the DU surface. The EnergySolutions/Neptune coefficient was calculated using Unit 4 material moisture content and porosity and the Interrogatory 05 “tortuosity” equation. The SC&A coefficient was calculated using Unit 3 material moisture content and porosity and the Roger and Nielson (1991) empirical equation.

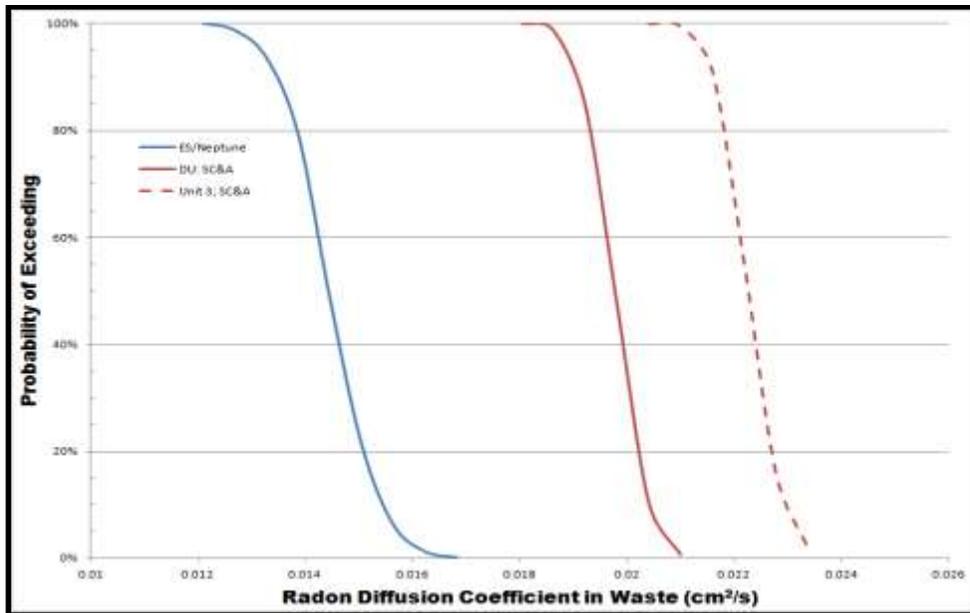


Figure 5: Waste Material Diffusion Coefficient Comparison

Figure 5 shows that at the 50% exceedance probability, the diffusion coefficients agree within less than a factor of 2, i.e., 0.014 versus 0.019 cm²/s.

Figure 6 shows the EnergySolutions/Neptune-calculated radon diffusion coefficient that was used for all material above the DU layer, including any material that remains after the bulk of the embankment has been removed by the lake and any lake deposit material. The Figure 6 SC&A coefficient uses the same parameters that EnergySolutions/Neptune used, but the Roger and Nielson (1991) empirical radon diffusion coefficient relationship was used.

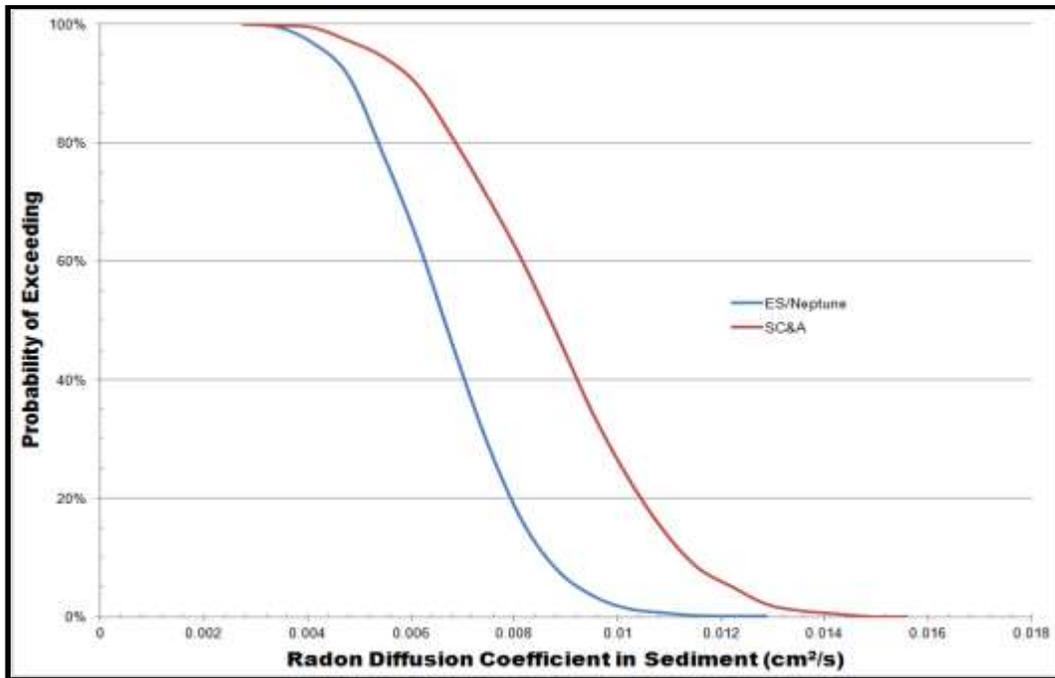


Figure 6: Sediment Diffusion Coefficient Comparison

The two approaches are in reasonable agreement—at the 50% exceedance probability, the results differ by a factor of only about 1.3, i.e., 0.006 versus 0.008 cm²/s.

Figure 7 shows the radon flux at the top surface of the DU that was calculated by both EnergySolutions/Neptune and SC&A. As expected from the Figure 5 diffusion coefficients, the SC&A-calculated flux is slightly higher than the EnergySolutions/Neptune-calculated flux, and both fluxes increase with time due to the buildup of Ra-226. These curves represent the radon flux with attenuation by sedimentation or aeolian deposition.

Figure 7 also shows the SC&A-calculated radon flux on the top surface of the remaining embankment material [EnergySolutions/Neptune did not calculate this flux, but rather assumed that all material was the same and only calculated a single flux at the ground surface (see the Figure 8 discussion)]. Figure 7 shows this flux to start out about equal to the flux on top of the DU, but as aeolian deposition accumulates resulting in more Unit 3 material remaining after the embankment is destroyed, this flux is significantly attenuated.

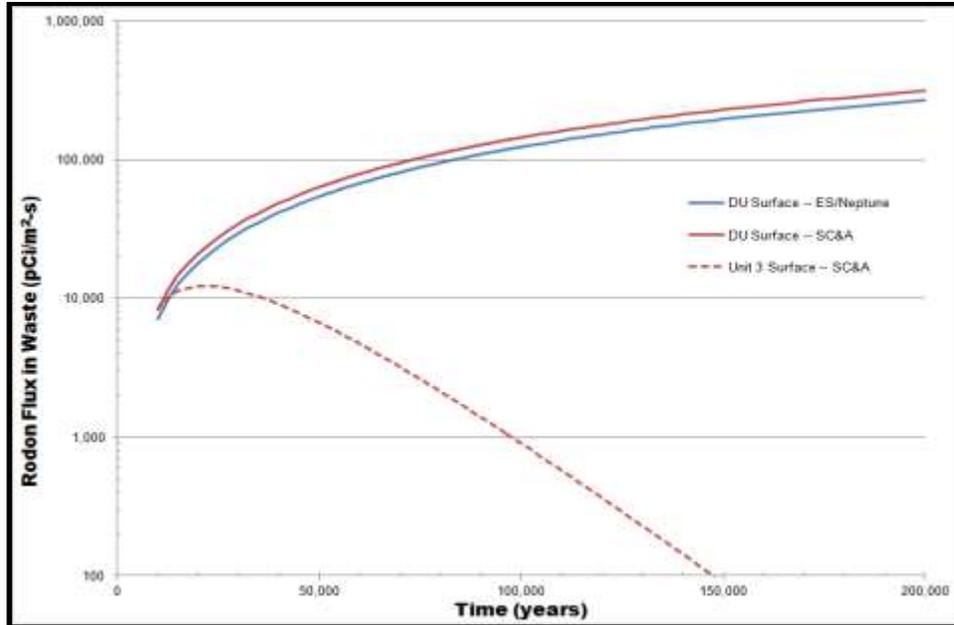


Figure 7: Radon Fluxes at the DU and Unit 3 Top Surfaces

Figure 8 shows the EnergySolutions/Neptune- and SC&A-calculated radon flux at the ground surface. The EnergySolutions/Neptune fluxes were calculated using the GoldSim “Clive DU PA Model vDTSA” file as it was delivered to DEQ/SC&A. It should be noted that the Figure 8 EnergySolutions/Neptune fluxes are identical to the mean fluxes shown in Figure 4 of the DTSA Report, with a peak of the radon flux of approximately 0.96 pCi/m²/s at about 59,250 yr. The Figure 8 SC&A radon fluxes were calculated by modifying the GoldSim file to incorporate the SC&A diffusion coefficients shown in Figure 5 and Figure 6. The Figure 8 maximum SC&A calculated flux is about 8.2 pCi/m²-s, or 8.5 times larger than the EnergySolutions/Neptune maximum flux.

As L. Morton commented (see Attachment 1), the basis for assuming that the lake does not return for the next 50,000 years is weak. It would be more conservative to assume that the lake could return at any time after the 10,000-year compliance period. The GoldSim “Clive DU PA Model vDTSA” file was adjusted to allow the return of the lake at any time after 10,000 years, and the ground surface radon fluxes re-calculated. Figure 9 shows the results. When the lake is allowed to return after 10,000 years the calculated ground surface radon flux increases by about an order of magnitude for both the EnergySolutions/Neptune and SC&A cases.

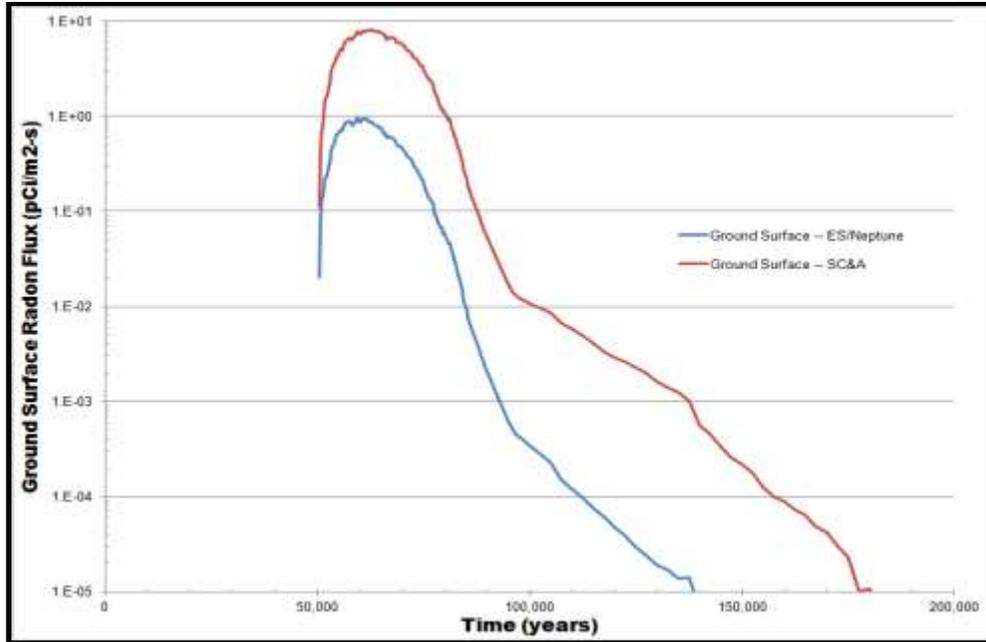


Figure 8: Base Case Ground Surface Radon Fluxes

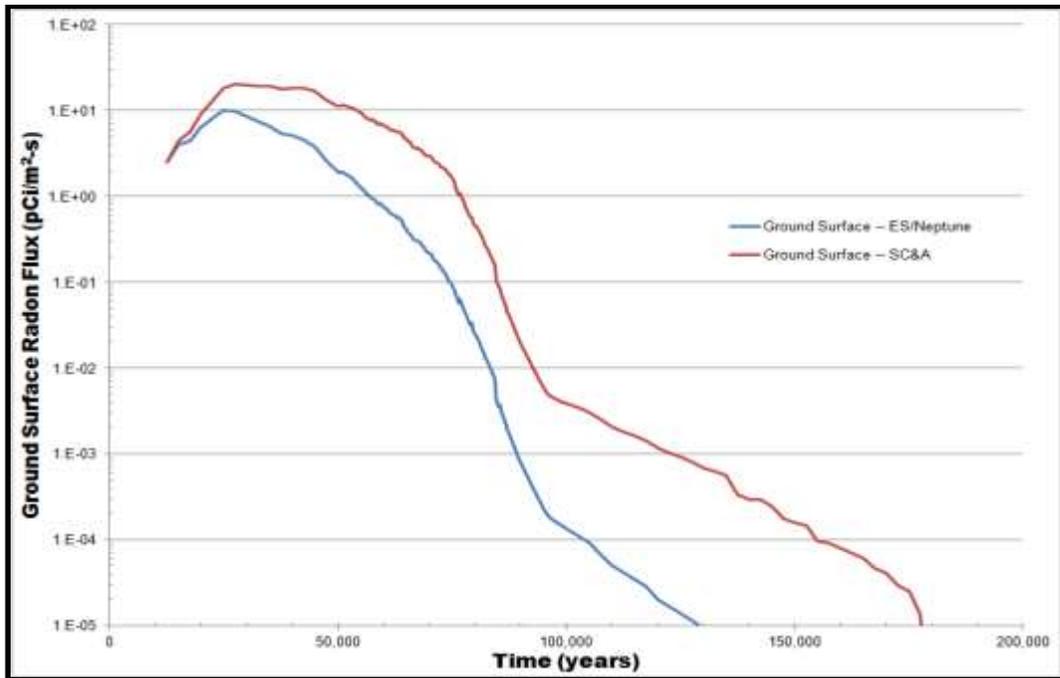


Figure 9: Early Lake Case Ground Surface Radon Fluxes

In FRV1.2, Appendix 13, Table 1, EnergySolutions/Neptune indicated that there was an intermediate lake mean sedimentation rate of 2.82 m, and a mean lake duration of 500 yrs. Combining those two parameters gives a sedimentation rate of 5.64 m per 1,000 years. Meanwhile, for the large lake, the sedimentation rate is given in FRV1.2, Appendix 13, Table 1, as 0.00012 m/yr, over 4 orders of magnitude less.

The GoldSim “Clive DU PA Model vDTSA” file was further modified by SC&A to reduce the intermediate lake sedimentation rate to an arbitrary 0.0012 m/yr, i.e., 10 times the large lake rate, and the ground surface radon fluxes recalculated. Figure 10 shows the resulting sedimentation profiles for the DTSA EnergySolutions/Neptune case and the revised lower sedimentation case. The bottom, green line in Figure 10 shows the aeolian deposition that was assumed by EnergySolutions/Neptune and used for the SC&A calculations, as well.

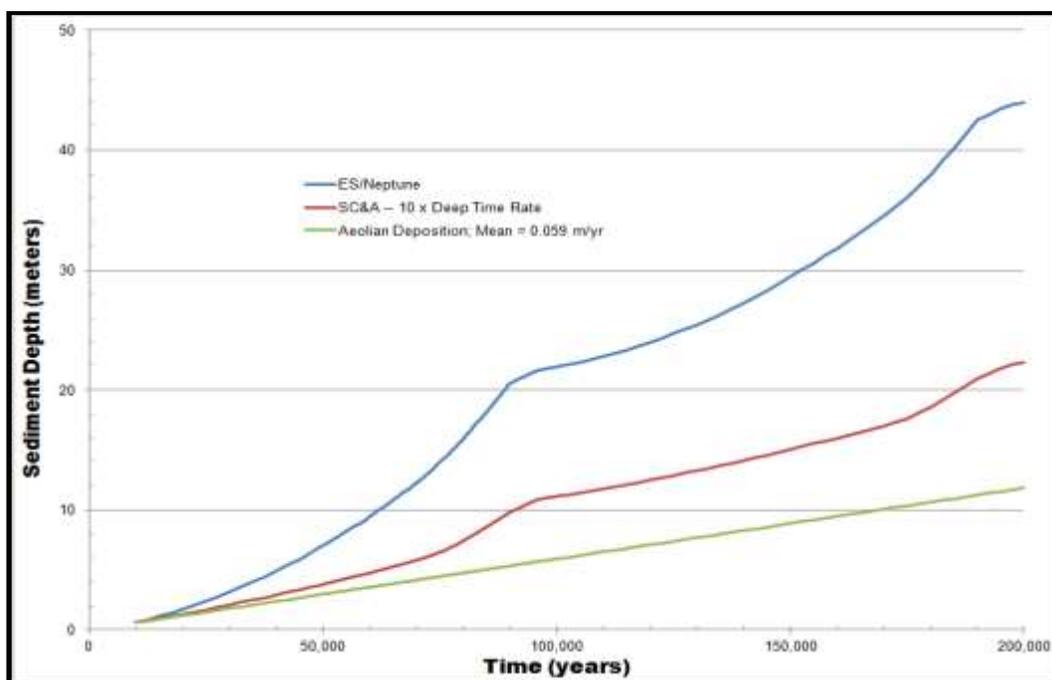


Figure 10: Comparison of Lake Sedimentation Rates

Figure 11 shows the calculated ground surface radon fluxes for both the EnergySolutions/Neptune and SC&A models using the Figure 10 SC&A sediment buildup curve (i.e., 10 × the large lake sedimentation rate of 0.12 mm/yr). In Dr. Paul Jewell’s email on the subject, he indicated that “so-called ‘intermediate lakes’ seem not to have [sedimentation] rates that much greater than the long term records.” In support of this, Dr. Jewell provided the information on Great Basin Lake sedimentation rates included in Table 2¹. From Dr. Jewell’s information, it can be concluded that a sedimentation rate of 1.2 mm/yr for intermediate lakes is likely conservative, thereby understating the radon flux.

¹ Private Communication from Dr. Paul Jewell, University of Utah, to David Back, SC&A Inc, sedimentation_rates_Aug_2014.doc.

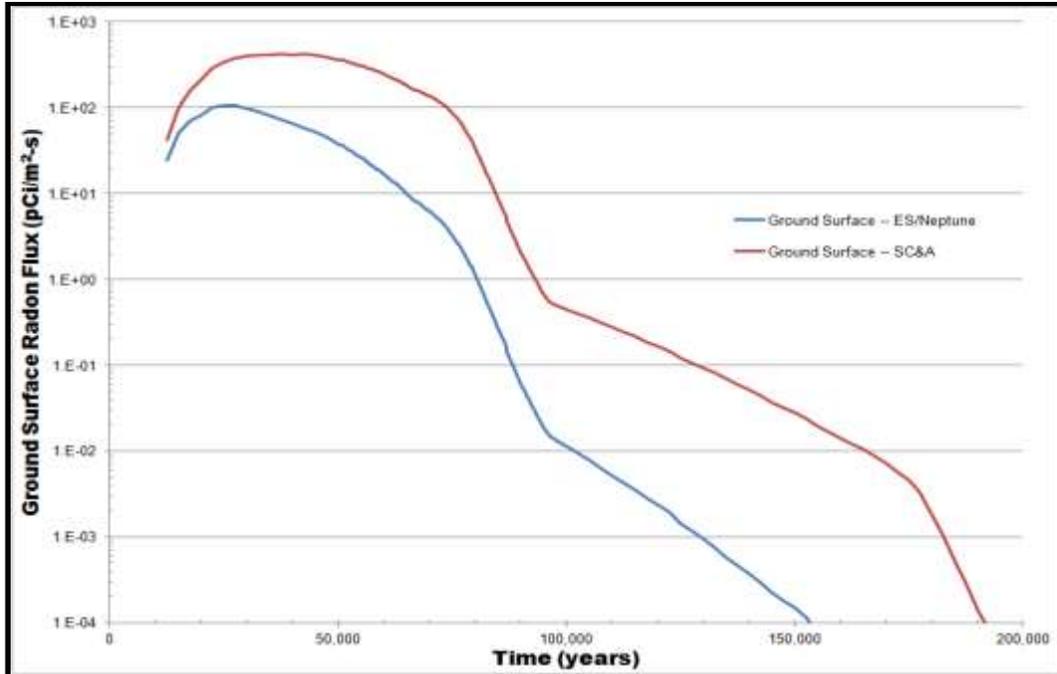


Figure 11: Sedimentation Case Ground Surface Radon Fluxes

Table 2: Summary Table of Published Sedimentation Rates, Eastern Great Basin, Utah

Lake	Period covered	Sedimentation rate (mm/yr)	Reference
Lake Bonneville and predecessors	758 kyr to present	0.12	Oviatt et al. (1999)
Blue Lake (western side of Bonneville basin)	44 kyr to present	0.18	Benson et al. (2011)
Great Salt Lake	Holocene (~11 kyr to present)	0.20-0.83	Colman et al. (2005)
Bear Lake	Holocene (~11 kyr to present)	0.3-0.8	Colman et al. (2009)
Lake Bonneville and predecessors	287 kyr to present	0.4	Balch et al. (2005)
Bear Lake	Late Pleistocene to present	0.5	Colman et al. (2009)

As stated above, there is much uncertainty regarding aeolian deposition. EnergySolutions/ Neptune based their radon flux calculation on the information provided by Oviatt, i.e., normal distribution with mean: 0.059 mm/y, and standard deviation: 0.005 mm/y. SC&A has questioned whether the Oviatt information is sufficiently “robust” to form the basis for making a licensing decision. Using the data in Table 1, SC&A developed an alternative aeolian deposition distribution, i.e., normal distribution with mean: 0.053 mm/y, standard deviation: 0.045 mm/y, minimum: 0.005 mm/y, and maximum: 0.141 mm/y based on the U.S. information provided in Table 1. Figure 12 shows that with the revised aeolian deposition distribution results in a calculated time-dependent mean ground surface radon flux of 914 pCi/m²-s.

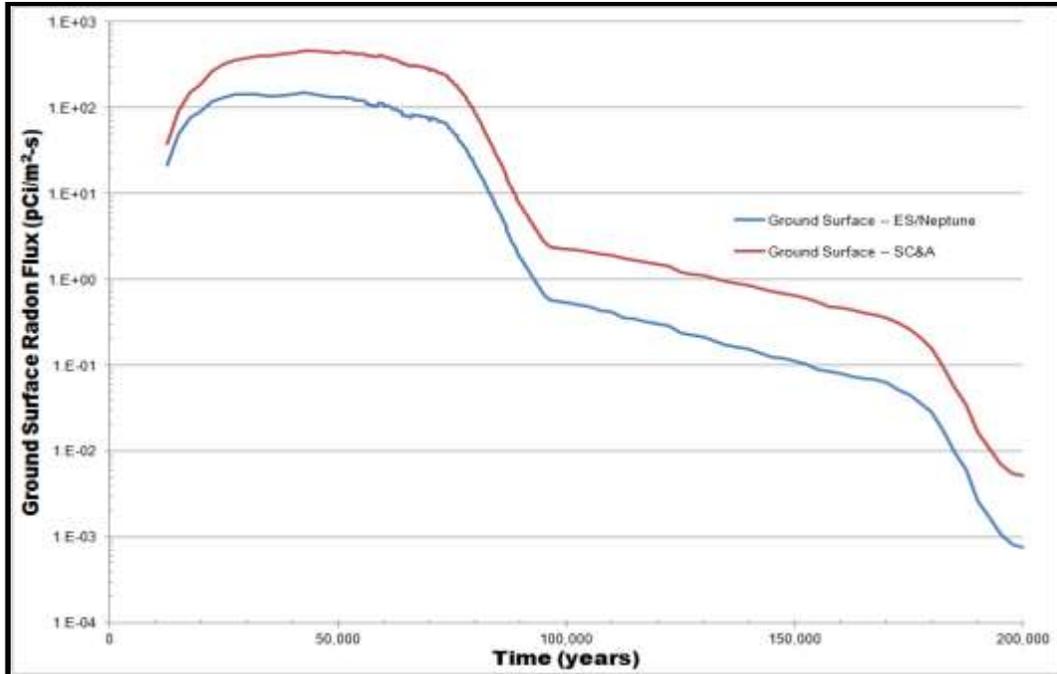


Figure 12: Aeolian Deposition Case Ground Surface Radon Fluxes

The calculated results presented above (i.e., Figure 8, Figure 9, Figure 11, and Figure 12) are all given as mean time-dependent ground surface radon fluxes. In constructing the mean time-dependent flux, GoldSim averages the fluxes calculated from all realizations at each time-step. Because the lakes appear at various times during each realization, this approach tends to reduce the radon flux. For example, in a 1,000 realization simulation, if one realization had a lake return very early and a radon flux of 100 pCi/m²-s was calculated, while for the other 999 realizations, the radon flux at that time step was zero, since the lake had not yet returned, then the mean radon flux for that time-step would be 0.1 pCi/m².

At some time in the simulation, each realization will have a lake return and a corresponding peak radon flux. It may be preferable to select the deep time radon flux from the distribution of peak fluxes, rather than from the time-dependent fluxes. Figure 13 shows the complementary cumulative distribution of the peak radon fluxes. The mean values are shown in Figure 13 as dotted lines; for the SC&A and EnergySolutions/Neptune cases, the means are 1,930 and 870 pCi/m²-s, respectively.

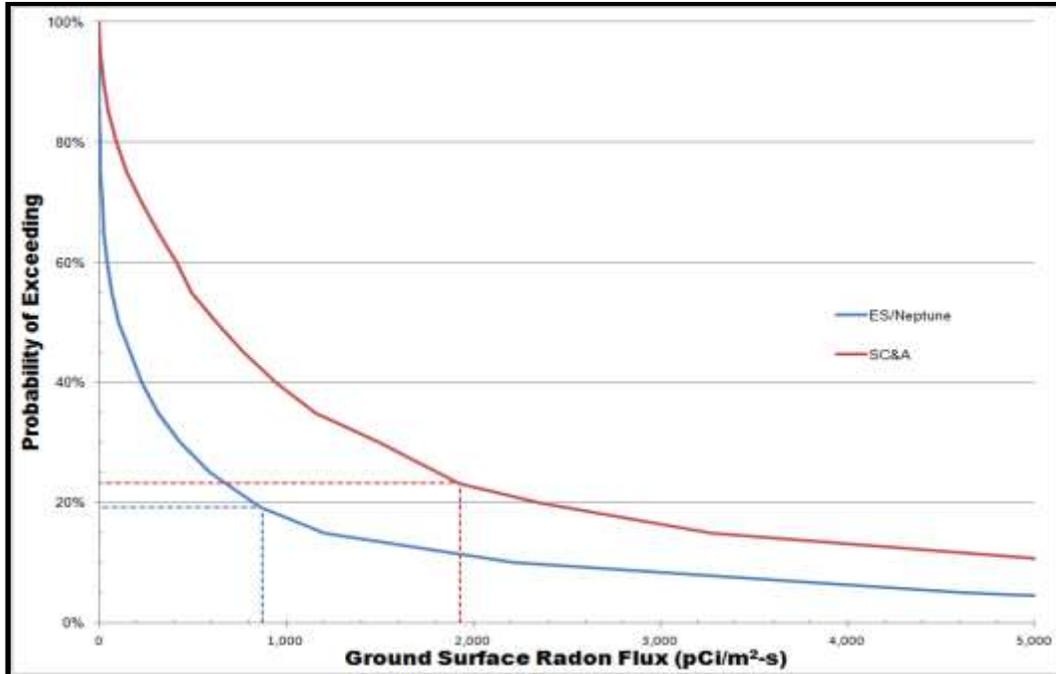


Figure 13: Mean-Peak Ground Surface Radon Fluxes

The results of these analyses are summarized in Table 3.

Table 3: Summary of Calculated Ground Surface Radon Fluxes

Case	Type of Distribution	Radon Flux (pCi/m ² -s)		Increase Over DTSA	
		EnergySolutions/ Neptune	SC&A	EnergySolutions/ Neptune	SC&A
Base Case	Time-Dependent	0.96	8.16	1.0	8.5
Early Lake	Time-Dependent	9.94	20.4	10.4	21.3
Sedimentation	Time-Dependent	106.5	422.6	111.5	442.4
Aeolian Deposition	Time-Dependent	399.7	914.1	418.4	956.9
Aeolian Deposition	Mean-Peak	871.9	1,929	912.7	2,019

For comparison purposes, the 40 CFR § 61.252(a) permissible radon flux from an existing uranium mill tailings pile is 20 pCi/m²-s; alternatively, the national average background radon flux is 0.45 pCi/m²-s (NRC 1988).

Report No. 160 from the National Council on Radiation Protection and Measurements (NCRP 2009) presents an annual effective dose factor for inhaled radon gas, including radon’s short-lived progeny, of 1.4×10^{-3} mSv (Bq m⁻³)⁻¹ [5.2×10^{-3} mrem (pCi m⁻³)⁻¹] (NCRP 2009, Section 3.5.12). Neptune (2014b), Table 3 presents dispersion factors (χ/Q) at the embankment ranging from 2.22×10^{-3} to 2.38×10^{-3} sec/m³. The DEQ checked these dispersion factors using the RESRAD model for estimating the radon concentration above an area contaminated with Ra-226 (ANL 2001, Section C.3.1, equation C.7), and found them to be consistent with the RESRAD model. Thus, with an embankment surface area of about 0.153 km², the Rn-222 concentration on the top of the embankment due to a flux of 1,929 pCi/m²-s is estimated to be

0.72 $\mu\text{Ci}/\text{m}^3$. This radon concentration, when combined with the NCRP (2009) dose factor, results in an effective dose of about 0.4 mrem/hr, or about 0.8 rem/y for a worker spending 2,000 hours per year directly over the DU.

In February 2014, the Nuclear Regulatory Commission (NRC) approved publication of an NRC Staff alternative to modify 10 CFR Part 61 specifically to address the disposal of long-lived radionuclides, such as DU. Unlike the two tier approach of R313-25-9(5)(a), the approved draft Part 61 alternative is based upon a three-tiered approach: (1) Compliance Period, lasting 1,000 years, with a general population dose limit of 25 mrem/y; (2) Protective Assurance Period, from 1,000 to 10,000 years, with a 500 mrem/y general population dose limit; and (3) Performance Period, for time greater than 10,000 years, requiring a qualitative analysis, but no dose limit (NRC 2014a, NRC 2014b, NRC 2014c).

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- NRC 2014b. Commission Voting Record; Decision Item: SECY-13-0075, Title: Proposed Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61) (RIN 3150-A192), U.S. Nuclear Regulatory Commission, Annette L. Vietti-Cook, Secretary of the Commission, February 12, 2014.
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APPENDIX 1: LOREN MORTEN MEMO



State of Utah

GARY R. HERBERT
Governor

SPENCER J. COX
Lieutenant Governor

Department of
Environmental Quality

Amanda Smith
Executive Director

DIVISION OF RADIATION CONTROL
Rusty Lundberg
Director

MEMORANDUM

TO: Helge Gabert

FROM: Loren Morton

DATE: August 13, 2014

SUBJECT: DRC Staff Comments on August 5, 2014 Neptune Deep Time Supplemental Analysis Clive DU PA Model vDTSA (DTSA).

The purpose of this memo is to share my findings after review of the recent ES response, referenced above. That response was an EnergySolutions (ES) reaction to a July 14, 2014 draft SCA white paper regarding radon emanation calculations should a future lake obliterate the ES Federal Cell, recede at about 100,000 yrs, and then leave behind the DU waste at or near native grade. My findings and observations are listed below.

1. Error in ES Reference to Oviatt 2014 – the ES document frequently refers to “Oviatt, 2014”. However, there is only one reference like this in Section 6.0, and it was written by Oviatt and Nash, published by the Utah Geologic Survey (UGS) in 2014 (Miscellaneous Publication 14-1 or MP 14-1). Review of that publication shows it is a study of Lake Bonneville sediments deposited after the Stansbury Episode at approximately 24,000 years ago in the Sevier Desert, in Juab County. Replete in the ES DTSA are discussions of the “Oviatt, 2014” study and its findings on post-Provo-age and Gilbert Episode deposits, i.e., sediments deposited less than 13,500 years B.P. Consequently, the DTSA has referenced the wrong Oviatt paper. Perhaps they intended to refer to another Oviatt 2014 study published by UGS in MP 14-03 (“The Gilbert Episode in the Great Salt Lake Basin, Utah”); herein referred to Oviatt 2014b.
2. ES Interpretation of Unpublished 1985 Oviatt Stratigraphic Section (p.3 and Appendix A) – from the description provided in the DTSA Appendix A, it is clear that Oviatt measured this unpublished stratigraphic section on the West wall of an excavation that was about 6 m deep (~ 29 feet) that later became the former railcar rollover pit (Old Rollover Pit); which was located about 850 feet WSW of the NE corner of Section 32 (now abandoned)¹. Oviatt’s 1985 description of strata included 15 layers to a depth of 6 m (~ 20 feet). Please note that in his 1985 section, Oviatt describes the 4 shallowest sediment layers, Nos. 12 thru 15, as possibly Gilbert-age deposits. He also notes these 4 layers, found as deep as about 1.6 m

¹ See ES engineering drawing 07021-U1, Rev. 0, 1/4/08, as found in the 1/4/08 ES Class A South Cell / 11e.(2) Amendment Request, Attachment 2.

(~5.3 ft) were calcareous muds and silts with sand partings, and included re-worked ostracode fossils and re-worked marl deposits. The latter 2 features are evidence that sediments that had been moved sometime after their original deposition. This certainly could have happened in a regressive lake situation where deeper water sediments were transported as the lake level fell. Other interpretations may also be valid.

The ES DTSA makes a couple of statements that need further examination, as follows:

A. From DTSA page 3, 2nd paragraph:

“The absence of coarse clastic sediments in the described upper layers of the Pit wall of the Clive site (Deep Time Assessment Appendix to version 1.2 of the Modeling Report – reproduced here as Appendix A) is consistent with the absence of significant longshore drift and sedimentary activity associated with larger geomorphic landforms such as spits, barriers, alluvial fans, and river deltas. The most relevant lake features from the geologic record are paleoshorelines.”

DRC Response – we agree that geologic deposits that represent paleoshorelines are critical to determining the physical extent of a former lake. However, the patterns of deposition (depositional facies) are not always easy to discern, as indicated by Oviatt, 2014b (p.2):

“The shoreline for an existing lake is the boundary line between the lake water and the land, and thus is an ephemeral feature that shifts constantly in vertical and horizontal positions with changes in weather, climate, tectonics, and geomorphic processes. For an ancient lake where the water evaporated long ago, the shoreline is defined as a line that connects depositional and erosional landforms that were produced simultaneously at the edge of the ancient lake, and that mark the highest altitude attained by that lake. Ancient shorelines might vary in altitude from place to place by 2 to 3 m (6–9 ft), depending on variations in geomorphic processes.”... Numerous other shorelines were formed before and after Lake Bonneville overflowed and are visible at various places in the basin above and below the Provo shoreline. Some of these (e.g., the Stansbury shoreline of Gilbert, 1890) have been named, although mapping these shorelines has been problematic because they formed while the lake occupied a closed basin and its surface altitude was not stable for an extended period. Sedimentary deposits that were laid down in or near the surf zone or within wave base of ancient lakes, do not define shorelines in the sense the term is used here, but they can be useful in attempts to limit ancient-lake dimensions in basins where landforms are not preserved.”

Likewise, fine-grained calcareous muds and clays are commonly deposited in deep portions of a freshwater lake contemporaneously with coarser shoreline deposits. In fact some of the recent radiocarbon and other geochronometry dating reported in Oviatt, 2014b were done on contemporaneous fine-grained deeper water sediments ².

Unfortunately when Oviatt measured the section in the Old Rollover Pit in 1985, he didn't have the benefit of seeing a rather large and shallow gravel deposit found by ES in 2005 during excavation of a borrow pit in the northeastern part of Section 29 (Section 29 NE Pit), located less than 1 mile north of the Oviatt section ³. A brief description of this deposit and its location is found in Figure 1 of Attachment A, below. It is possible that this gravel deposit is a spit or barrier bar deposited by a Lake Bonneville episode, and that the shallow re-worked calcareous muds, silts, and marls

² See Oviatt's Bailey' Lake sample (Gilbert marl) BL-L13 (Table 1); and Great Salt Lake lake bed sample (carbonate mud) GSL 96-6 (pp. 10-11 & Fig. 7).

³ This same gravel bed later became a point of controversy in the Charles Judd appeal of the Clive LLRW License renewal in 2008.

seen in Oviatt's 1985 Section 32 measurements were laid down simultaneously outside the surf zone in a lower energy location. An alternate explanation may be that the deposits were laid down at different times.

Without additional stratigraphic study and geochronometry data for sediments in either the Old Rollover Pit, or the Section 29 NE Pit, one can only speculate if these sediments were contemporaneous facies deposited in the same environment; or deposited by different stages of Lake Bonneville. Consequently, additional study is warranted to substantiate the DTSA claims regarding Oviatt's 1985 unpublished information.

B. ES DTSA statements on page 4:

"Post-Lake Bonneville rates of aeolian deposition are expected to be relatively high in the Clive area because of the large expanses of exposed lake sediments west of the site. Evidence supporting this conclusion includes: ...

• The upper 70 cm of sediments of the stratigraphic section described at the Clive site is interpreted to be of aeolian origin (see Appendix A of the Deep Time Assessment v1.2 Appendix).

There are significant inferential data for the sediments at the Clive site. The 70-cm aeolian section is inferred to be no greater than the post-Provo shoreline age and is more likely post-Gilbert shoreline age based on recent observations by Oviatt (2014) that Lake Bonneville regressed to the modern Great Salt Lake level by approximately 13,000 ka then transgressed to an elevation of 1295 to 1297 m above mean sea level (amsl)—never reaching the elevation of the Clive site—by approximately 11,600 ka."

DRC Response – the upper 70 cm sediment layer appears to correspond to Oviatt's Layer 15 from the Old Rollover Pit. However, careful review of this 1985 Oviatt stratigraphic section (8/5/14 ES DTSA, Appendix A) shows no description of any aeolian sediments whatsoever. In fact, Oviatt describes all 15 of the layers studied as Lake Bonneville water deposited materials. Please note the uppermost Layers 12 – 15 are designated as possible Gilbert deposits.

Also, close examination of Oviatt's 2014b study also shows no occurrence of "aeolian" anywhere in his text or figures. Further, "wind" is found only 1 time (p. 15), where he describes how "Since the middle Holocene the landscape at Dugway has been lowered as much as 3 to 4 m by wind deflation". Because the Holocene epoch began about 11,700 years ago⁴, this gives pause about potential aeolian erosion at the Clive site in deep time.

3. Application of Oviatt 2014b Study to Shallow Clive Deposits - DRC staff recognizes the important insight that Oviatt's 2014b study and geochronometric data has on previous interpretations of the Gilbert-age deposits in the Great Basin. However, it is important to recognize that he warns the reader that his work on is preliminary, as shown by the following quotes:

"Until more of the uncertainty has been resolved in understanding the Gilbert-episode lake, the Gilbert shoreline, as it has been previously mapped, should not be regarded as a well-defined altitude datum in the lacustrine chronology of the basin." (p. 1)

"One of the purposes of this paper is to point out that there is more uncertainty in our knowledge of lake-surface altitude during the Gilbert episode than a line drawn on a map would suggest. Future geologic work in the basin

⁴ International Commission on Stratigraphy, "International Chronostratigraphic Chart, 2014/2" found at: <http://www.stratigraphy.org/ICSChart/ChronostratChart2014-02.pdf> (accessed 8/12/14)

should not be based on the assumption that the chronology and altitude of the Gilbert lake is known with certainty. Additional detailed work on the Gilbert episode and its shoreline should be pursued to clarify the upper altitudinal limit of the Gilbert lake and to determine its paleoclimatic significance.” (p. 3)

“The shoreline landforms that were produced during the shortlived Gilbert episode are unlikely to have been composed of huge volumes of gravel or sand. The Gilbert-episode shoreline, where it can be identified, is probably a relatively minor feature on the landscape, and may consist of a discontinuous, thin skim of gravel, which in some places may have been added to a pre-existing gravel barrier, and in other places may have been easily eroded away in post-Gilbert time. The Gilbert-episode lake probably did not have time to produce extensive wave-cut platforms and bluffs.” (p. 17)

“This paper should be regarded as a progress report. Further observations of sediments and landforms related to the Gilbert episode, and the paleoclimatic implications of the timing and extent of the Gilbert lake, are needed. Future geologic work in the Bonneville basin below an altitude of about 1300 m (~4260 ft) should be undertaken with a critical approach to the previously mapped Gilbert shoreline. An assumption that the lake reached altitudes higher than about 1297 m (4255 ft) during the Gilbert episode may not be valid. Lacustrine sediments and landforms in the Gilbert altitude range should be carefully described and put into context with other information from the basin before interpretations of lacustrine history are relied on as the chronologic basis for other geologic events such as faulting or mass wasting.” (p. 18)

From these statements, it is apparent that site specific studies are warranted in order to understand timing and depositional relationships of Gilbert-age sediments at Clive or other locations in the Eastern Great Basin. Likewise, this good advice for studies of other locations where Lake Bonneville stage deposits are found. It appears certain that as additional geochronometry data are collected from Lake Bonneville sediments by those in the profession, that our understanding of the shallow deposits at Clive and elsewhere, will be both modified and improved.

4. Possible Aeolian Deposits 10 km WSW of Clive – ES makes the following statements (p. 4):

“Post-Lake Bonneville rates of aeolian deposition are expected to be relatively high in the Clive area because of the large expanses of exposed lake sediments west of the site. Evidence supporting this conclusion includes:

- There are active and vegetated dune fields in the Knolls area west of the Clive site. The Knolls dune field is one of the larger dune fields in the Great Salt Lake Desert dune areas, with gypsum sediments derived from shoreline and lake sediments of Lake Bonneville. The Knoll dune drift directions are variable but are predominantly from the southwest (Jewell and Nicoll, 2011).*
- Examination of satellite imagery for the Clive area shows that active sand dunes are 10 km west-southwest of the Clive site. Sand ramp and aeolian deposits extend eastward to the Clive site.”*

DRC Response – review of the Jewell and Nicoll_2011 paper finds it is a regional study of wind velocity / directions and comparison of many aeolian deposits across the Great Basin. The Jewell-Nicoll dune field (ibid., Fig. 9) mentioned in the ES DTSA (p.4), is located at the following latitude / longitude coordinates: 40° 35’ N & 113° 23” W, and is shown in Figure 1 of this memorandum. As can be seen there, it is approximately 25 km (15 mi) SW of Clive. A close-up aerial photo is found in Figure 1A of this memorandum. Also note how the dunes there are almost un-vegetated, and is therefore an active, modern dune field. Dune patterns also suggest a prevailing southerly wind direction.

However, identification of sediments as dune fields can be difficult with aerial photography alone. Reliable determinations usually require fieldwork and many times coring or trenching to differentiate sand dunes from former Lake Bonneville shoreline features in the Great Basin

⁵. While some surface features may have dune morphology, if they have been stabilized by vegetation, they may not represent modern wind patterns. Instead their forms may be an artifact of former or pre-historic wind conditions, i.e., paleo-dunes (ibid.).

The ES DTSA statement (p.4, 2nd bullet) did not provide survey coordinates for the “10 km dune field” mentioned. However, DRC staff used Google Earth aerial photography to see if it were possible to find sand dune features in that general location. One apparent dune field was located near the terminus of the 10 km WSW vector, see Figure 2 in this memorandum (yellow dashed area). Close review suggests these landforms are vegetated. A northerly striking surficial deposit is also found nearby (blue dashed area). Due to cross-cutting relationships, the apparent dune field may be of older deposition. Additional geologic studies are warranted to determine genesis and timing of these 2 surficial deposits. No “sand ramps” that “...extend eastward to Clive” were apparent in any of the Google Earth images. Perhaps ES can provide additional information to locate these surface features.

5. Aeolian Deposition Rates at Clive – ES makes the following statements (p.4):

*“Second, the lake level associated with the Gilbert shoreline would need to fall well below the elevation of the Clive site (1302 m amsl) before the start of aeolian sedimentation at the site. **Average aeolian sedimentation rates using these age limits are 48 to 70 mm per 1000 years.** These sedimentation rates are consistent with dust deposition rates for the arid southwest United States from Goudie et al. (1997), cited in Interrogatory CR R313-25-8(5)(a)-18/2, which indicates deposition rates of 5 to 141 mm per 1000 years in comparatively short term samples.”* (p. 4, emphasis added)

*“The model addresses long time frames and spatial scales, so input probability distributions for each parameter in the model of the environmental system are developed as distributions of the mean. Given the data in Goudie et al. (1997) **and the pit wall information**, a distribution of the mean aeolian sedimentation rate with a center of 59 mm per 1,000 years and a standard deviation of 5 mm per 1,000 years is considered reasonable.”* (p. 4, emphasis added)

DRC Response – it is interesting to note that Oviatt, 2014b (p. 11) has determined a sedimentation rate for the Gilbert Episode at a location between the Stansbury and Antelope Islands. This rate, 0.014 cm/yr (14 cm per 1,000 yrs), was based on radiocarbon analysis of 3 sediment samples from a lake bed core sample. It seems to reason, that sediments accumulating on the floor of a Lake Bonneville water body would represent both aeolian, water borne sediments, and water column precipitates. If this is true, the 14 cm/1,000 year value Oviatt, 2014b determined is significantly lower than the values claimed by ES in its August 5, 2014 DTSA.

Secondly, the 1985 Oviatt “*pit wall information*” inferred is in error. No aeolian sediments were described in the Oviatt’s stratigraphic section from the Old Rollover Pit, see discussion above.

6. Water Content of the DU Waste Layers (p. 5) – at the end of Section 3.2 of the DTSA, ES makes a statement that the water content for the lowermost 5 layers in the embankment profile, where DU may reside, was determined by version 1.2 of the DU PA model report, submitted July 8, 2014. However, it is important to remember that this infiltration modeling was performed on EnergySolutions’ version of an intact cover system – one that has not addressed and resolved previous interrogatories regarding pedogenesis, biointrusion, fitting parameter relationships for unsaturated soil characteristics, etc. Therefore, the ES reported

⁵ Personal communication, Dr. Paul Jewell, University of Utah Department of Geology and Geophysics.

water contents for the DU waste are subject to change upon resolution of the still open interrogatories.

7. Claims on Timing of the Return of the Next Glacial Cycle (pp. 6-8) – In this part of the DTSA, ES suggests that an intermediate lake that could disrupt the DU Cell is “very unlikely” to form near Clive for the next 50,000 years or longer. I would remind the DEQ review team: 1) that the lake return interval used in the DU PA model should be based on geologic evidence from the Great Basin, and not on global studies; and 2) Estimates of how anthropogenic carbon released today in the atmosphere, and in the near future, will delay or preclude future glacial cycles is speculative. In order to protect the future environment and human health, it is better to assume a lake does return sometime beyond 10,000 years from now - that has the ability to obliterate above-grade waste, and partially or fully expose DU waste at or near the ground surface after the lake recedes.
8. Claims of DU Cell Protection by Future Aeolian Deposition (p. 9) – at the end of Section 4.0 of the DTSA (and elsewhere), a claim is aeolian deposits that accumulate before arrival of a destructive lake arrives at Clive, and effectively protect the DU waste material from being exposed at the ground surface after the lake recedes. Based on DRC observations above, it appears that this claim for Section 32 is over-stated and poorly supported. Performance Assessment modeling assuming layers of aeolian sediment will protect the DU waste from erosion, or otherwise reduce environmental releases in deep time are difficult to support or guarantee, and have likely introduced undue bias into the predictions for Rn-222 exposure.

Conclusion

The gravel bed located in the Section 29 NE Pit, indicates that significant erosion forces have been present within 1-mile of the disposal facility at some time in the past. Additional stratigraphic and geochronometric investigations are needed to determine the age and facies relationship between this deposit and those in Section 32. ES claims that the upper 70 cm of sediment at the Old Rollover Pit appear to be without merit. Further, it is clear that the Oviatt 2014b paper is a preliminary work presenting a hypothesis that deserves additional study; specifically to sediments near Clive in Sections 29, 32, and on the Grayback Hills.

The apparent ES WSW dune field also deserves additional study to determine its origin and age of deposition. If a dune field, its timing of deposition is currently unknown. However, it appears not to be modern in origin based on vegetation on its landforms observed in aerial photography. The cross cutting relationship between it and another N-trending surficial deposit, suggests the ES WSW dunes were deposited beforehand.

ES statements about aeolian deposition rates at Clive appear to be over-stated, based on core samples and geochronometry of Gilbert Stage sediments in the bed of the Great Salt Lake. Consequently, statements that future aeolian deposition on the DU Cell will offset future erosion are speculative and difficult to support. Doubts in depositional age of deposits in Section 32 also make it difficult to speculate the return interval of any future lake in the vicinity of Clive..

In light of all these observations and findings, it appears there are 3 options for moving forward in the DEQ DU PA Review, including:

1. Conduct additional site-specific studies to collect additional stratigraphic and geochronometry data to determine depositional facies and timing of the Lake Bonneville sediments in and near Clive. If the deposits in Sections 32 and 29 are older than Gilbert-

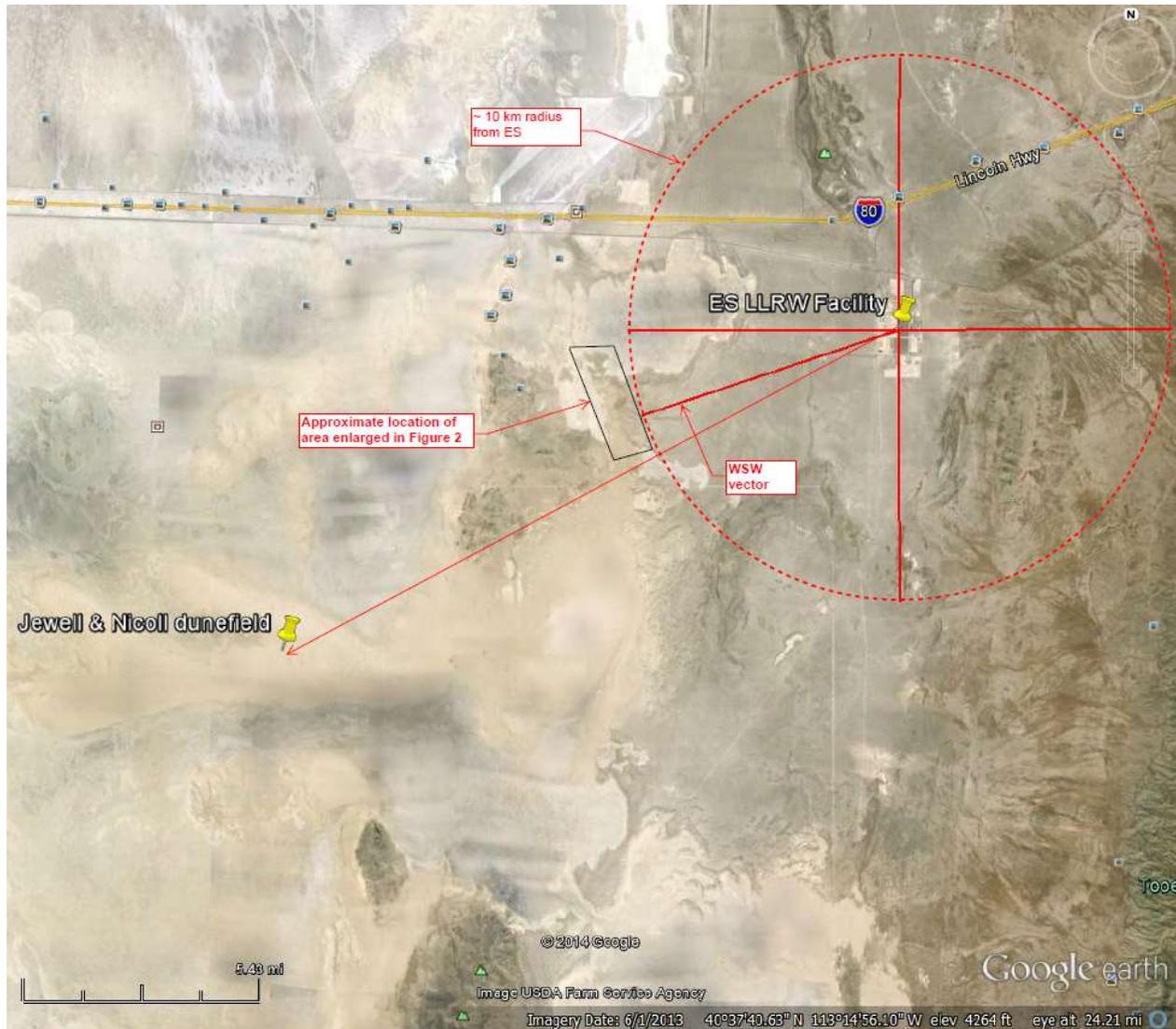
age sediments (pre-Stansbury, Stansbury, Bonneville, or Provo), and are directly correlated with the “Gilbert” shoreline deposits UGS already mapped on the Grayback Hills; this work could possibly reinforce the ES claim that the sediments Oviatt studied in 1985 are older than Gilbert deposits. Under this condition, it would be apparent that the Gilbert Episode shoreline was below Clive site, and reinforce the ES claim that a future disruptive lake stage will not arrive for 50,000 years or more.

2. Accept studies conducted by UGS geologic mapping ⁶ who described Gilbert-level sediments nearby on the Greyback Hills at an elevation higher than Clive. Under this approach, DEQ would continue to require the licensee to evaluate a performance assessment scenario where a future lake, beyond 10,000 years, destroys the embankment and then recedes, leaving behind a Rn-222 exposure problem, as outlined in the July 14, 2014 SCA draft white paper, or
3. Accept the Oviatt 2014b study the final word on Gilbert deposits in the Great Salt Lake Desert, and move forward with the hypothesis that most of the isostatic adjustment of Lake Bonneville sediments was complete before the Gilbert Episode; leaving the Gilbert Shoreline below an elevation of 4,260 ft amsl. This option is similar to Option 1. Under this interpretation, the Clive site was not disturbed by the Gilbert Lake, This approach would allow DEQ to ignore any need for additional site-specific studies and accept the ES claim that Clive was not inundated by the Gilbert Episode. This approach discourages consideration of lake erosion until after 50,000 years or more; which may enough time of PA evaluation for purposes of compliance with R313-25-9(5)(a).

Of the 3 options, and in light of the limited time afforded DEQ to review the ES DU proposal to make a licensing decision, I recommend Option 2, in that is more conservative and more likely to lead to protection of future human health and the environment.

If you have any concerns with these observations, I am open to further discussion and suggestions.

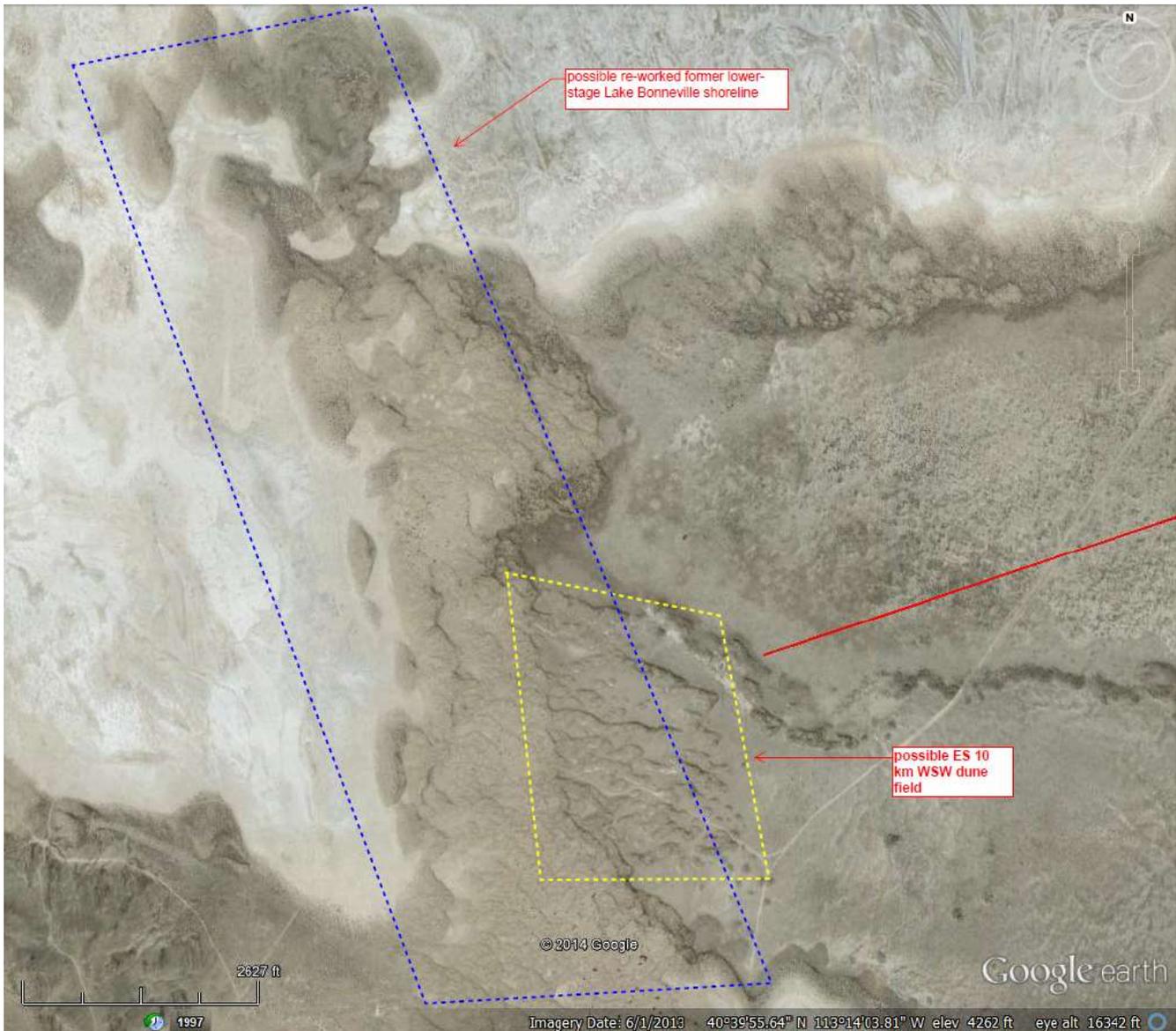
⁶ See UGS Map 166 by Doelling, Solomon, and Davies, Plate 1, where the Stansbury and Gilbert shorelines are denoted. Along the Eastern side of the Grayback Hills the authors place Gilbert shoreline at an elevation between about 4,280 and 4,290 ft amsl. .



Memo Figure 1. Location of modern dune field SW of Knolls, Utah identified in Jewell and Nicoll, 2011. It is approximately 25 km (15 mi) SW of Clive. Also note the 10 km radius around the ES LLRW disposal facility. Area outlined in black-line, is that shown in Memo Figure 2, below. Image from Google Earth, dated 6/1/13 (accessed 8/13/14).



Memo Figure 1A. Modern dune field identified by Jewell and Nicoll, 2011 (Fig. 9). Note sparse vegetation (active, modern dunes) and apparently predominant Southerly wind pattern. Image from Google Earth, dated 6/1/13 (accessed 8/12/14).



Memo Figure 2. Possible ES 10 km WSW (ES WSW) dune field mentioned in the DTSA (p.4), shown in yellow dashed area. Solid red line is terminus of 10 km WSW vector from Clive, see Memo Figure 1. Close review of the ES WSW dune field shows it is vegetated. Cross cutting relationship of other northerly trending sediments in blue dashed area suggests it is younger in age. It is unknown if the northerly trending deposit is aeolian in origin or a re-worked former shoreline of Lake Bonneville. Additional study needed to determine genesis and timing of these deposits. Image from Google Earth, dated 6/1/13 (accessed 8/12/14).

Attachment A

Summary of DRC Field Inspection of Shallow Gravel Deposit in the Section 29 NE Pit, Conducted December 16, 2005

The purpose of this document is to summarize DRC staff photographs and notes taken during a December 16, 2005 field inspection of a relatively shallow gravel deposit found by ES in a borrow pit excavated in the NE portion of Section 29 (Section 29 NE Pit). For location of the borrow pit, see Figure 1, below. Present at the time of the inspection were Messrs. Loren Morton (DRC) and Dan Shrum (ES). Information gathered during the DRC inspection may have relevance to ES interpretations in the August 8, 2014 Deep Time Supplemental Analysis (DTSA), including Appendix A, for the following reasons:

1. During the December 16, 2005 inspection ES staff said they believed the top of the gravel bed in the Section 29 NE Pit was about 8 – 10 feet below the native ground elevation in that area.
2. The area where the Section 29 NE Pit is located may be about 6-8 feet higher ⁷ than the former ES rollover pit (Old Rollover Pit) where Oviatt studied Lake Bonneville sediments in 1985 (ES DTSA, Appendix A), and
3. It is common that “*Ancient shorelines might vary in altitude from place to place by 2 to 3 m (6–9 ft), depending on variations in geomorphic processes.*” (Oviatt 2014b, p. 2).

DRC photos from the 2005 inspection provide context, and are found below. During the inspection we examined a westerly facing borrow pit wall in the Section 29 NE Pit. Photo captions below in italics are notes I made for the photographs on December 20, 2005 a few days after the inspection. Captions in normal type face are additions herein to describe geologic contacts, labels, and other features observed.

Photo 1A, displays the approximate geologic contact between overburden and in-situ materials is denoted in dashed red line. At the far right, the blocky formation represents a fresh-cut pit wall. For a large segment between this location and the area near the truck overburden has fallen to obscure the contact. The red line on the left is more tentative, due to the greater distance and perspective. Note the pickup truck in upper left background.

A better view of the gravel bed is found in Photo 1B, with the same truck on the left. The gravel bed is seen in the upper right where it had rounded weathered look on the pit wall. During the inspection, Dan Shrum reported that he thought the top of the gravel bed was about 8-10 feet below the undisturbed grade, and the gravel bed itself was about 4 – 6 feet thick, although neither of us made any formal measurements during the inspection. The reported gravel bed thickness

⁷ See USGS 7.5 minute topographic map for the Aragonite Quadrangle. The Section 29 NE Pit is located in the NE 1/4 of Section 29, borders on the eastern margin of the section and is a short distance south of the Western Pacific rail line; about 2,500 feet N of the SE corner of Section 29.

appears reasonable, so might the depth to the upper contact. Finer-grained sediments were located below this bed, see Photo 2.

Photo 3A shows larger subrounded to subangular clasts, which suggest short distance transport. A plant root is also hanging from the pit face at the right side of the photo (wall is in shadow, plant root is hanging in sunlight). Based on Photos 1A, 1B, and 2, the root may have been as deep as 10 feet or more below native grade. The largest of the gravel clasts observed appears to be 3 – 4 inches in diameter, see Photo 3B. Again, the hanging plant root is easily seen. Note the axes of many of the gravel clasts are oriented in a sub-horizontal direction.

At a location about 10 yards farther south of Photo 3A, the gravel bed displayed smaller particle sizes that were also sub-angular to sub-rounded, see Photo 4. To the best of my knowledge, the DRC has not received any written records or any other detailed stratigraphic study of this pit wall, nor any gradation analysis for these deposits.

The lack of gravels in Section 32, as shown in Oviatt's unpublished 1985 stratigraphic section ⁸, and described in the ES DTSA (p. 3), may be due to depositional facies changes. Without additional study, it is unknown what the exact relationship might be between these 2 depositional areas. If the calcareous muds and marls of Oviatt's 1985 work at the Old Rollover Pit (Layers 15 – 12) were found to be higher stratigraphically, then the Section 29 NE Pit gravel bed would be older in age. An example of this exact situation is described in Oviatt, 2014b, Figure 4A (p. 9). On the other hand, if the reverse were true, and gravel bed were to be stratigraphically higher than Oviatt Layers 12 – 15, then the gravel bed would be younger (ibid., Fig. 4B). Clearly additional stratigraphic study of the sediments near Clive is warranted.

Currently, it is unknown if the Section 29 NE Pit gravel bed and the location studied by Oviatt in 1985 were deposited at the same time. Additional geochronology data could shed light any relationship these deposits may have. In fact, this is the tool that Oviatt uses in his reinterpretation of the Gilbert Episode sediments in MP 14-3, where he re-examines previous Gilbert deposits identified by Currey; and provides new geochronometry information, based in part on radiocarbon analysis of plant and wood fragments, and gastropod fossils to estimate the depositional age of these deposits ⁹. Perhaps similar study of the shallow deposits near Clive, would yield their depositional ages and provide insight on their stratigraphic relationships.

⁸ August 5, 2014 ES DTSA, Appendix A.

⁹ See Utah Geologic Survey (UGS) Miscellaneous Publication 14-3, "The Gilbert Episode in the Great Salt Lake Basin, Utah", Table 1.



Figure 1. EnergySolutions Section 29 NE Pit (after Google Earth, image dated 7/12/06)



Photo 1A: Dashed redline is approximate contact between disturbed materials, above, and in-situ deposits below. In mid-foreground overburden material has fallen into the pit leaving an apparent soil draping obscuring pit wall. Left far background behind truck is terracing of the borrow pit. Herein, borrow area is referred to as the Section 29 Northeastern (NE) Pit.

“View of new excavation in Sec. 29, located about 2,500 ft North of SE corner of Sec. 29. View to N. Gravel layer is near horizontal, and appears about 1/3 up from toe of slope on right side. Heap of soil in left background (above truck) is spoil from excavation. Dan Shrum reported that: 1) gravel layer ranges from 4-6 feet thick @ N. end of pit, may thicken to the S, and 2) top of gravel bed was about 8-10 ft bgs from the native (undisturbed) ground elevation - before pit excavation.”



Photo 1B: Exposure of gravel bed in westerly wall of the Section 29 NE Pit. Dashed redline indicates approximate overburden contact, while dashed yellow line shows base and top of gravel bed in question. Left of center the pit wall is partially obscured by fallen overburden material.

“Portion of West facing excavation slope, near truck. Gravel layer forms rounded expression about 1/3 up from toe of slope. Horizontally bedded, finer grained sediments found immediately beneath this layer.”



Photo 2. Gravel bed in west facing wall of Section 29 NE Pit. Yellow dashed lines indicate base and top of gravel deposit.

“Closeup of site seen in Envirocare Excavation4.jpg. Basal contact of gravel at about same elevation as Dan Shrum's head. Finer grained sediments below this contact.”



Photo 3A: Closeup of shallow gravel bed in Section 29 NE Pit. Note plant root at upper right.

“Close up of Envirocare gravel deposit, at a location near the middle of the West facing slope. Gravel clasts appear to range from grit sized to 6-8” in diameter. No sieve analysis or mapping yet performed by Envirocare (Dan Shrum).”



Photo 3B: Close up of photo 3A. Key chain for scale. Plant root again at upper right of center. Large clast in upper left may be ~ 3-4 inches in diameter.



Photo 4: Exposure of the gravel bed in Section 29 NE Pit. Here gravel appears to have smaller clasts.

*“Another exposure of gravel in a location about 10 yards S. of previous photo ...”
[Photo 3*