Comm _ 027

Dane Finerfrock - comments on Rule

From:	Steve Nelson <oxygen.isotope@gmail.com>
To:	Dane Finerfrock <DFINERFROCK@utah.gov>, Peter Jenkins <peter.jenkins@hsc.utah.edu>, Pat Cone <pat.cone@browning.com>
Date:	2/1/2010 9:29 AM
Subject:	comments on Rule
Attachments:	Comments on Rule 1.pdf

Peter, Dane, and Pat:

Here are our comments on the draft rule. Attached to our comments is the letter to NRC we submitted as part of their consideration of the issue. This letter is referenced in our comments and is part of the record. Due to limitations of file size, I will be sending, separately, two maps that are referenced in our letter. These are also part of the record.

COMMENTS ON DRAFT RULE R313-25-8

Stephen Nelson[1], Charles Oviatt, Summer Rupper[1]

Introduction:

The proposed revision to rule R313-25-8 is inadequate because it is insufficiently protective of the natural environment. In particular, the quantitative performance period in part (2) (a): ***i)*** is too short, and ***ii)*** a qualitative analysis to the time of peak dose (peak activity), is, by definition, insufficient to demonstrate performance of the system and relies on faulty logic.

We deal with ***ii)*** briefly here and in the remainder of this document the problems with ***i)*** are addressed. However, in addressing ***i)***, we demonstrate that, properly worded, ***ii)*** can and should be met with a quantitative analysis. We do this through two "contentions" that are followed with supporting analysis.

The problem with a "qualitative analysis for the period where peak dose occurs" is that "peak dose," both in its timing and magnitude, cannot be estimated without a quantitative model. Dose refers to human exposure. This may or may not occur when DU has reached maximum activity. If the Board means "peak activity," then the solution is simple. The rule must extend to 1 million years, which is not a new figure in the regulation of radioactive wastes (See Nelson et al., 2009; attached).

Before proceeding with our analysis, we note the language of parts of rule R313-25-8 that have not been modified (except for numbering), but inform what the licensee must "demonstrate." (1) (a) includes exposure pathways in ground and surface water, including natural and engineered features of the site. (1) (d) includes "erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers over disposal areas and adjacent soils, and surface drainage of the disposal site." These criteria must be met within the context of the additional challenges posed by the disposal of large quantities of depleted uranium (DU).

Contention 1: There is a high probability the site will flood, and that probability is so high such that rigorous, quantitative analysis is required.

Flooding of the Clive site would constitute a "disruptive event," defined as follows: *"An off-normal event that, in the case of the potential repository, includes volcanic activity, seismic activity, and nuclear criticality. Disruptive events have two possible effects: (1) direct release of radioactivity to the surface, or (2) alteration of the nominal behavior of the system. For the purposes of screening features, events, and processes for the total system performance assessment, a disruptive event is defined as an event that has a significant effect on the expected annual dose and that has a probability of occurrence during the 10,000-year period of performance less than 1.0, but greater than*

[1] Views expressed are those of these authors and not of their employer.

a cutoff of 0.0001."

NUREG 1804 relates to high-level waste disposal, and volcanic and seismic activity are specifically mentioned because those were examples of plausible disruptive events at Yucca Mountain, NV. The Board should also note that the 10,000 yr performance period has been changed to 1 million years (Nelson et al., 2009; attached). A definition for disruptive event specifically written for Clive would include flooding by changing levels of the Great Salt Lake—Lake Bonneville system.

The Board should recognize that the idea of a disruptive event is relevant to other nuclear waste programs. For example, for transuranic wastes currently disposed at the Waste Isolation Pilot Plant (WIPP) in New Mexico identified 245 relevant features, events, or processes (WIPP 2010). Of these 245, 244 were screened out as improbable or unimportant to the performance of the system. We offer two observations. First, we would invite the Board to review this document. Second, we would hope that the Board would require a semblance of equal rigor to protect the environment from DU releases.

10CFR63 contains similar language and probabilities to NUREG 1804, but generally uses the terms "features, events, and processes" instead of disruptive events. Notable, however, is the straightforward cutoff on how unlikely an event must be before it is ignored. The probability is 1 in 100,000,000 per year. Stated another way, the probability cutoff is 1×10^{-8}.

One of us (Oviatt) examined excavations at the Clive site in 1985. In the walls of a 20' high exposure, were three lacustrine (i.e., lake) sedimentary deposits predating Lake Bonneville. Although the precise ages of these deposits are unknown, they are younger than those of the 150,000 year old Little Valley lake cycle. At Clive, the Little Valley deposits are probably at significant depth. Thus, a complete record at Clive could show many more lake deposits.

The lake system has almost certainly reached the elevation of the Clive site many times in the past 150,000 years. We can demonstrate a minimum of five flooding events: a) the three pre-Bonneville deposits in the excavation, and b) Lake Bonneville itself as it filled and receded, for mean return interval of 30,000 years. This translates to a minimum annual probability of flooding at Clive is 3.33×10^{-5}, or more than three thousand times higher than the cutoff for excluding a disruptive event.

Another way to look at this is that the site has a 33% chance of flooding over the proposed 10,000 year time period in the draft rule! Disruptive events are normally considered "low probability, high consequence events." This demonstrates that flooding is a high probability event. The analysis in a subsequent section shows that it also has serious consequences.

Before leaving this topic, the Board should note that 50,000 years ago the Bear River drainage was diverted from the Snake River into the Bonneville Basin. This increased the mountainous catchment and attendant runoff by 33% (Nelson et al. 2009; attached and references therein). Thus, from that time forward and into the future, the west desert of Utah has an increased sensitivity to climate-driven lake level changes.

We invite the Board to examine aerial images (Figs. 1&2) captured from Google Earth. The first shows the southern end of Pilot Valley north of Wendover, Utah. This valley was in communication with the rest of the Bonneville Basin such that water levels in this valley correlate to lake levels in the rest of the basin, including Clive.

The pin symbol Pilot Valley 1 in Figure 1 is at an elevation of 4280', the approximate elevation of Clive. The pin at Pilot Valley 2 is at the summit of a low pass leading into Pilot Valley at an elevation below the maximum depth of Lake Bonneville. Note that the red line between the pins crosses numerous arcuate features, or fossil shorelines. Many of these shorelines may have been created as Lake Bonneville retreated, but many of them may have formed as the lake advanced, even if that advance were temporary.

Fluctuating lake levels illustrate an important concept for the Board to appreciate. Lake Bonneville and the Great Salt Lake should not be considered as separate entities. The are parts of a single dynamic expanding and contracting system responding to natural variations in climate over time.

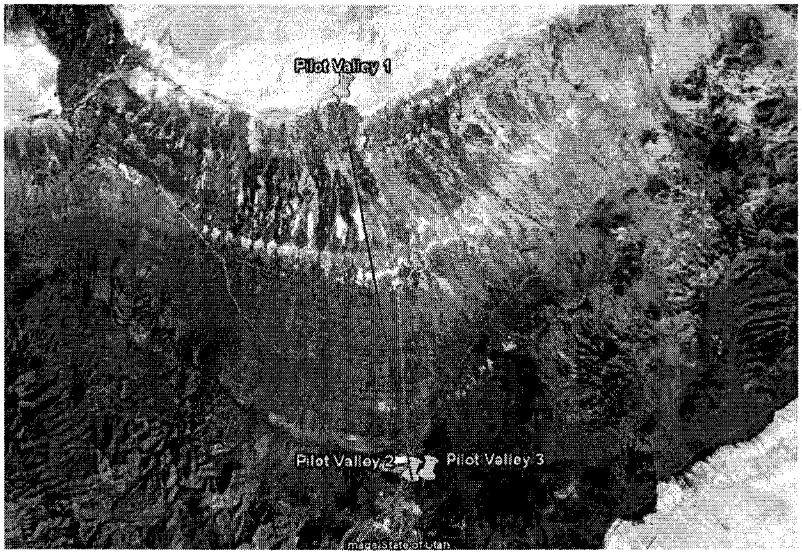


Figure 1. Aerial image of the southern end of Pilot Valley, Utah.

Figure 2 is an image of the Clive site and surrounding areas. Although the surface has been modified by stream erosion and blowing silt and sand, lake processes dominate the overall geology. Within the dark circle are clearly visible shorelines.

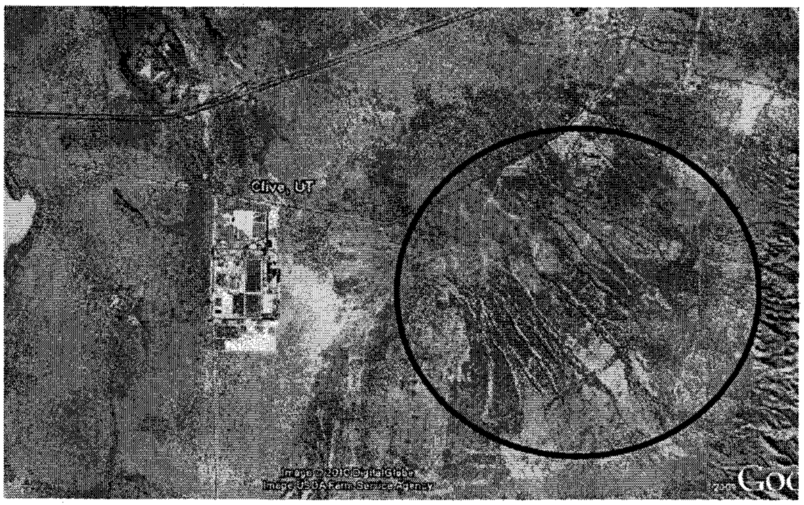


Figure 2. Aerial image of the southern end of the Clive, Utah area.

The Board should also carefully consider the quantitative analysis of the sensitivity of the Lake Bonneville system to climate change. Lake volumes are a function of the balance of all of the ways water can enter or exit the water body. Unless the lake refills to the elevation of the Provo Shoreline (about 4740'; the approximate elevation of the U of U campus), the only way for water to exit the system is by evaporation. Evaporation, in turn, is strongly dependent on average temperature.

The analysis in Nelson et al. (2009; attached) shows that for very small increases in average precipitation (3-6 mm/yr; 0.12-0.24 in/yr) lasting 1000 years, the lake will rise to the elevation of Clive *with no change in average temperature.* In contrast, reduced evaporation rates (cooler temperature) will cause lake levels to rise *with no change in average precipitation.* Predictably, cool intervals are often accompanied by increased precipitation. Millennial scale and century scale climate variations will unquestionably be accompanied by lake level fluctuations.

This is well-illustrated in the attached map of Lake Bonneville and the Great Salt Lake (Curry et al., 1984; attached). There have been enormous decade to century scale changes in the surface area of the Great Salt Lake as lake levels have varied by about 25 feet since 1700 A.D. and 19 feet since 1847. Climatically-driven Lake Bonneville elevations varied by 490 feet between 14,500 and 10,000 years ago.

The Board need not merely rely our word. The USGS (1990a) recognized that Lake Bonneville was likely to return: "*Recurrence of climates that existed in the Pleistocene potentially would refill Lake Bonneville to the level of the Provo shoreline...*" The US Geological Survey recognized the issue of climate change in the analysis of the suitability of the western US for high-level radioactive waste disposal, including the Bonneville basin (USGS, 1989; USGS, 1990a,b). USGS (1989) acknowledges that: "*The longer lived...isotopes, such as uranium-238...and their daughters in the decay chain, such as radium-226, and long-lived isotopes such as technetium-99...persist for millions of years....*"

Twenty years ago, the USGS (1989) understood the implications of climate change on waste disposal. Great strides in climate science have been made since then, but the main point—that climate change will continue to occur on relevant time scales--remains valid:

"*Biological processes and surface- and ground-water systems are greatly affected by climatic change accompanying the expansion and recession of ice sheets. Geomorphic and hydrologic processes that are affected include runoff, erosion, aggradation, and ground-water recharge. Variations of climate during the late Pleistocene Epoch indicate that a significant change in climate may occur within the next 10,000-20,000 yr. Such time spans are well within the period of concern in the evaluation of waste-isolation environments. In this section, the information on the magnitude of climatic change is reviewed and consideration is given to the effect of climatic changes on geomorphic and hydrologic processes.*

Knowledge of climates during the past 2 m.y., the Quaternary Period, comes from a combination of historical, archaeological, geological, and biological records. A broad overview of the roles and methods of Earth science in climate research during the Quaternary Period and longer is given in Smith (1976). Substantial changes in climate have occurred in the past 1,000 yr. Within the past 15,000 yr, the transition from the last major continental glaciation into the current postglacial condition has occurred. The past 150,000 yr includes the last glacial stage and the preceding interglacial stage. Multiple advances and retreats of continental sheet margins occurred during this period. Repeated glacial and interglacial cycles occurred during the past 1 m.y. The astronomical theory of the glacial-interglacial climate procession holds that variations in eccentricity, precession, and obliquity of the Earth's orbital geometry affect climate by changing seasonal and latitudinal distribution of incoming solar radiation. Because these changes can be calculated with great precision for the past several million years, it is possible, in principle, to test the theory by comparing the record of Pleistocene climate with a predicted pattern of climate changes. Imbrie and Imbrie (1980) have prepared a model driven by the Earth's orbital variations that compares favorably with the record of Quaternary northern-latitude, continental glacial record from deep sea cores. The model has been used to predict the climate for the next 100,000 yr in the absence of anthropogenic or other sources of variation (Imbrie and Imbrie, 1980). The model was designed to achieve the closest correspondence with the expansion and contraction of glacial ice using the enrichment of oxygen-18 in deep-sea cores as an index of the volume of continental ice. The model predicts that a long-term cooling trend which began about 6,000 yr ago will continue for the next 23,000 yr."

USGS (1989) notes: "*Because a repository site in the unsaturated zone is designed for effective operation in that zone only, the site* ***must remain above the water table*** *for the effective duration of the repository.*" (emphasis added). Plate 2 in USGS (1990a) is attached. It outlines areas considered potentially suitable for disposal due to thick unsaturated zone. Clive is clearly outside of this area. Does the Board think it proper to allow EnergySolutions to attempt to engineer around a bad site?

Despite DRC staff statements, the site will flood in the future and the consequences cannot be ignored or subjected to "qualitative" analysis. The rule clearly calls for the consideration of natural processes in system performance, including ground and surface water effects on erosion and compaction of the piles. The rule, as previously written, was probably sufficient for short-lived conventional waste streams, but given the quantity of material and long-lived nature of DU, the revised rule is inadequate in terms of reasonable assurance of environmental protection.

Contention 2: The consequences of flooding are unacceptable

Erosion: We are aware from the audio of the Dec. 3, 2009 Board Meeting that EnergySolutions intends to include flooding of the site in its performance evaluation. We do not contend that they will do so, but isn't the very notion of a submerged landfill, or a landfill at the shoreline of a large lake absurd at face value? Isn't the mere fact that this has to be accounted for in their evaluation an implicit admission that this is the wrong place for DU? As noted above: "*the site **must remain above the water table** for the effective duration of the repository (USGS, 1989).*"

That said, we recognize that at least three factors related to flooding that must be accounted for. First, is enhanced seepage and complete saturation of the landfill interior. Second, the lake has the potential to reach the elevation of the Provo shoreline (4740 feet), where it will spill into the Snake River drainage. Thus, the performance evaluation must also consider compaction, and compaction-induced failure of the liner and cap systems due to ~460 feet of overlying water.

The most serious issue is erosion of the piles. We consider their breach very likely. A lake at the elevation of Clive will have a large fetch (i.e., stretch of open water for waves to accumulate by blowing winds). For example, from the northwest there would be on the order of 50 miles of open water.

The past history of the lake provides compelling evidence of the potential erosive power of the lake. Schofield et al. (2004) report that the wave-cut shoreline of the Bonneville level at the base of the mountain between Little Cottonwood and Corner Canyons in the Salt Lake Valley is about 160 feet. The wave-cut platform of the Bonneville level on the north side of Traverse Mountain is well in excess of 1000 feet wide in many places. In fact, this platform is sufficiently wide to permit housing development on it.

Figure 3 shows a south-facing bedrock headland west of West Wendover, Nevada. This platform, as indicated, is 350 feet wide. Note that Nelson et al. (2009; attached) contains model outputs of bedrock erosion by waves where 15-foot wide platforms can be eroded in bedrock in 100 years. These piles are currently covered by loose rock debris, not bedrock. The implication is obvious: The lake will have enormous erosive potential, which causes us to wonder what engineering steps will have to be taken to preserve the piles. Can the output of any computer model that shows the piles surviving flooding be taken seriously?

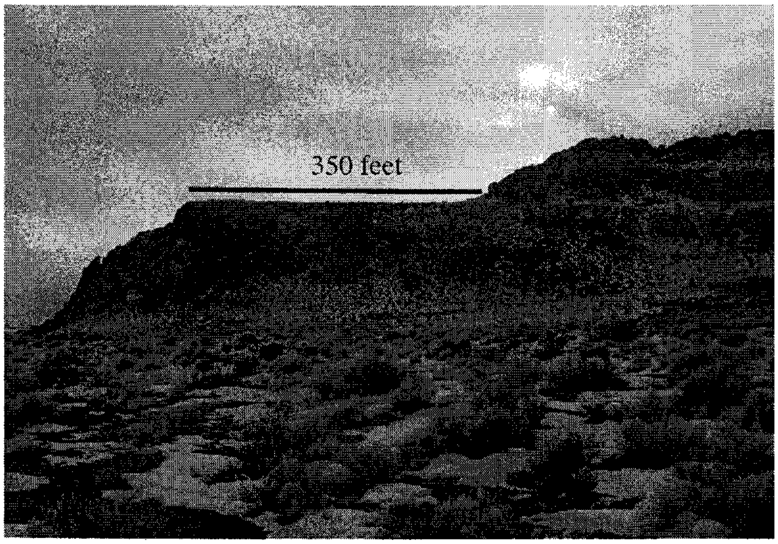


Figure 3. Wave cut-platform into bedrock headland west of West Wendover, Nevada.

The very design of the waste piles is also unfavorable in terms of wave erosion, as illustrated in Figure 4. We understand that the tops of the piles are on the order of 30-40 feet above grade, resulting in two features that will enhance erosion, both of which are well understood. First, as water levels rise around the piles they will act as artificial "headlands" to approaching waves. The waves will refract around the piles, focusing wave energy directly on them. Second, the gaps between piles will act as channels. As waves approach these channels, the velocity of water in them will increase to accommodate the increased flux. This will greatly increase the potential sediment carrying capacity of the water, which scales as the 3rd to 4th power of velocity. In summary, the very presence and design of the landfill system increases its vulnerability.

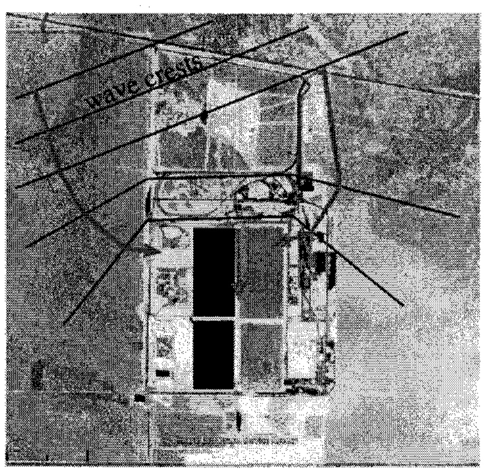


Figure 4. Annotated aerial image of the Clive, Utah site.

Finally, given the long-lived nature of DU, EnergySolutions cannot rely on (nor take credit for) the integrity of steel and concrete containment. We are aware of comments made at the Dec. 2009 Board meeting that some ancient structures like Roman aqueducts are still functional. While that may be true, we have all seen the degradation of iron and steel during the I-15 reconstruction or the collapse of the interstate bridge in Minneapolis a few years ago. Steel and concrete may not last long in the saline environment of the west desert.

DU Releases: Now we consider the effects of the releases of DU into the lake system. For some of this discussion, we rely on a calculation by Prof. Gary Sandquist. Dr. Sandquist is a retired nuclear engineering professor from the U of U. The calculation was forwarded to one of us (Nelson) with his permission and we assume it is correct:

- Assuming 60,000 tons of DU are emplaced at Clive (49,000 tons that may be there already plus 11,000 tons from South Carolina), the concentration of uranium in the lake would be 0.25 ppm
    - This calculation assumes the lake reaches the elevation of Clive and that all uranium is dissolved in the lake.

We believe this is a reasonable calculation, but it raises the question as to the ability of the lake to carry uranium concentrations this high.

UO_3 contains uranium in the 6^+ oxidation state, which is relatively soluble. We understand that the South Carolina material is in powder form, which increases its reactivity due to a high surface area, and also increases its ability to be physically dispersed. We could perform solubility calculations for uranium using thermodynamically-based computer codes, but for simplicity we rely on a report from the Idaho National Engineering and Environmental Laboratory (INEEL, 2000). This report determined that in natural waters, the concentration of uranium in water passing through a 20 micron filter rapidly exceed 70 ppm and reached a steady-state of nearly 100 ppm after 1-2 months. These experiments were conducted with U_3O_8. The conclusion is that an expanded lake would have a large capacity to dissolve uranium.

Sandquist's figure of 0.25 ppm is a lower bound based on may be already at the site, plus what is expected to arrive shortly. However, the Board is aware that the stockpile of DU requiring disposal may be as much as 1,400,000 tons by the middle of this century. Assuming the Clive site eventually contains 1,000,000 tons of DU, lake concentrations could reach 4.2 ppm.

These may not sound like high concentrations. However, we compare them to the EPA limit for uranium in water of 0.03 ppm found at:

(http://www.epa.gov/fedfac/documents/uranium_drinking_water_standards.htm)

At 0.25 ppm, the current inventory of DU at Clive could exceed safe levels in the lake by a factor of 8. At 4.2 ppm, the concentration could exceed safe levels by a factor of 140. Furthermore, the same EPA standard acknowledges that the toxicity of uranium as a heavy metal may exceed its radiological hazard.

We cannot answer the full range of questions surrounding the potential impacts on the ecosystem, such as bioaccumulation up the food chain, etc. But we can identify some processes that need to be considered. For instance, uranium in solution is probably its most bio-available form, and recession of the lake may leave soluble uranium salts in surface sediments.

Although there may be secondary processes that would attenuate uranium concentrations in the lake with time such as adsorption and burial on the lake bottom, or co-precipitation with calcite, our current understanding of these processes is very limited. However, there are a whole host of DU daughter products, some with long half-lives (^{230}Th 75,000 years; ^{234}U 245,000 years; ^{226}Ra 1600) years that may be present. Their mobility and fate must be considered as well and if significant time has passed between burial and release, their activities could approach that of pure ^{238}U.

Finally, Figure 5 is fairly sobering. It illustrates the relative radioactivity of various waste products (y-axis) from the nuclear fuel cycle over time (x-axis). After 100,000 years the activity of DU is not much less than spent fuel and at 1,000,000 years they are nearly the same. There is a very good reason that the NRC is revisiting DU disposal and is taking its time to do so.

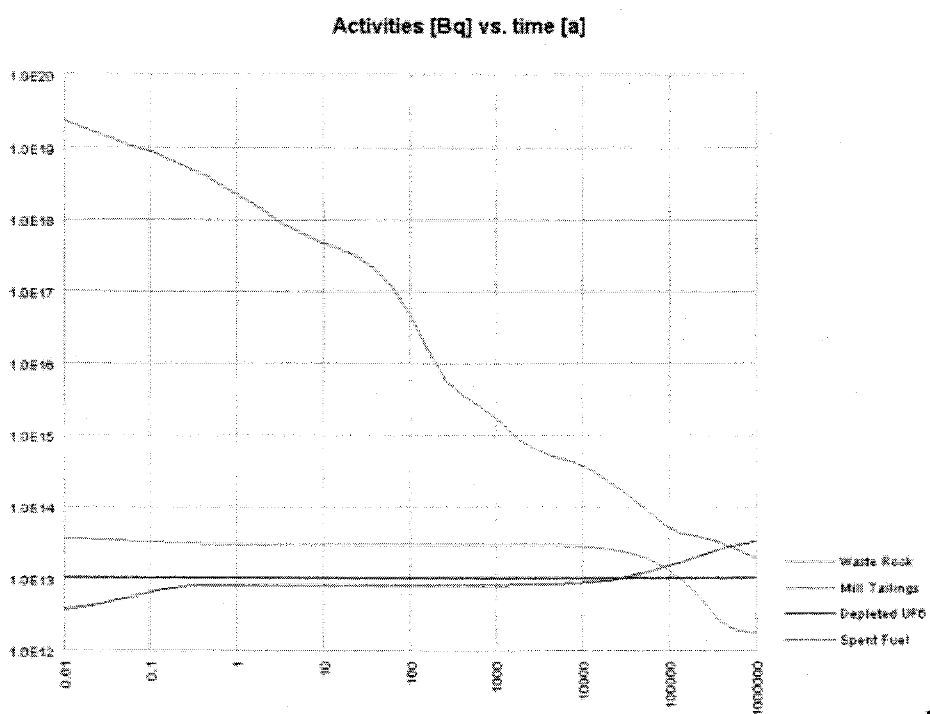


Figure 4. Comparative activities of various byproducts of the nuclear fuel cycle produced from: *http://www.wise-uranium.org/nfca.html*

Other Observations:

One of us (Nelson) took the time to listen to much of the Dec. 2009 Board meeting audio. We offer the following observations on issues raised at that time.

- There was considerable discussion of the difficulty and believability of models run to very long time frames. We agree with this conclusion. Yet, this is a very poor basis for relaxing rigor in the analysis and confidence in the safety of the system. If anything, it is a compelling argument that engineered, compared to geologic disposal, is unsuitable.
- Some of the statements made by DRC staff at that meeting are disconcerting. We have made a compelling case that the past is predictive of what is possible for the future. This is the basis for most long-term geologic hazard analysis. Such logic has been applied by the DRC in other contexts. A large part of the reason the Moab mill tailings must be moved is due to the discovery that the channel of the Colorado River had migrated substantially over the last few hundred years. This discovery was aided by a DRC initiated drilling program. With respect to past behavior indicating what is likely in the future, the DRC cannot have it both ways. This is not a matter of the "alignment of the stars."
- Anthropogenic effects on climate are short term compared to natural climate variations. The continued use of fossil fuels will decline due to scarcity, cost, or alternate technology. The residence time of CO_2 in the atmosphere is a century to two. Thus, although anthropogenic climate change is a serious issue, it cannot be given any weight regarding natural lake cycles .

Conclusion:

The Board has a very high burden to ensure that the rule is adequate--that DU is not released. The rule requires long-term stability of the site without maintenance. Does the Board really believe its draft rule is up to the task? Does the Board really believe that the licensee can meet the requirements? Is the Board confident that DRC, its contractors have sufficient expertise to review the analysis given the high stakes?

Recommendations:

- We recommend that the disposal of DU be prohibited at the EnergySolutions facility in Clive. However, if the Board proceeds to approve a rule, it must be strengthened, carefully considering comments provided.
- If the Board is concerned with the ability of any entity to conduct quantitative models in excess of 10,000 years, there is a way around this problem:
  - Assume that at the time of emplacement the entire inventory of DU is at its maximum activity.
  - Assume that at the time of emplacement concrete and steel containment has corroded.

- Assume that the piles are impacted by waves for an extended period of time (500 yr.) at their midpoints between their tops and the surrounding grade.
- Assume the piles are flooded to a depth of 460 feet (the elevation difference between Clive and the Provo shoreline) to evaluate enhanced seepage and release, as well as differential compaction and containment failure due to the hydrostatic load.

- Since the Board wrote this rule, the Board directly should read and respond to public comment to ensure that the concerns of citizens providing input are heard.
- Empanel an independent group of experts to review the performance evaluation. This panel should include a diverse group of technical expertse and institutional affiliations. The large inventory and long-lived nature of DU make this issue too important to leave solely to DRC staff and contractors.

References:

INEEL, 2000, Actinide solubility experiments in INEEL perched simulant solution final report: INEEL/EXT-01000762, Rev. 0, 11 p.

Schofield, I., Jewell, P., Chan, M., Currey, D., and Gregory, M., 2004, Shoreline development, longshore transport and surface wave dynamics, Pleistocene Lake Bonneville, Utah: Earth Surface Processes and Landforms, v. 29, p. 1675-1690.

USGS (Bedinger, M. S.; Sargent, K. A.; Langer, W. H.; Sherman, F. B.; Reed, J. E.; Brady, B. T.), 1989, Studies of geology and hydrology in the Basin and Range Province, Southwestern United States, for isolation of high-level radioactive waste; basis of characterization and evaluation: US Geological Survey Professional Paper 1370A, 41 p.

USGS (Bedinger, M. S.; Sargent, K. A.; Langer, W. H.) 1990a, Studies of geology and hydrology in the Basin and Range Province, Southwestern United States, for isolation of high-level radioactive waste; characterization of the Bonneville region, Utah and Nevada: US Geological Survey Professional Paper 1370G, 38 p.

USGS (Bedinger, M. S.; Sargent, K. A.; Langer, W. H.) 1990b, Studies of geology and hydrology in the Basin and Range Province, Southwestern United States, for isolation of high-level radioactive waste; evaluation of the regions, US Geological Survey Professional Paper 1370H, 61 p.

WIPP, 2010, Title 40 CFR Part 191Subparts B and C Compliance Recertification Application for the Waste Isolation Pilot Plant Appendix SCR-2009 Feature, Event, and Process Screening for PA, available at: http://www.wipp.energy.gov/library/CRA/2009_CRA/CRA/Appendix_SCR/Appendix_SCR.htm

October 30, 2009

Chief, Rulemaking and Directives Branch
Division of Administrative Services
Office of Administration
U.S. Nuclear Regulatory Commission
Stop TWB 5B01M
Washington D.C. 20555-001
Submitted online via: http://www.regulations.gov

Re: NRC-2009-0257; Notice of Public Workshop on a Potential Rulemaking for Safe Disposal of Unique Waste Streams Including Significant Quantities of Depleted Uranium; Federal Register, Vol. 74, No. 120, June 24, 2009, p. 30,175-30,179.

Dear NRC Staff and Committee:

Introduction

We submit the following comments in order to facilitate consideration of factors that must be taken into account when determining whether depleted uranium (DU) can be disposed of safely in shallow engineered landfills in general, and at the EnergySolutions Utah site in particular. A brief biographical sketch of each signatory is attached to this letter so that you will be familiar with our qualifications.

To begin, contextual commentary regarding the length of the performance period for DU disposal is provided, and we return to this issue in a subsequent section of this letter. In order to maintain environmental protection, the performance period required for a site-specific analysis for DU and its decay products should extend to the time of peak dose or 1,000,000 years, whichever comes first. This is both based upon common sense and consistency with other regulatory programs for nuclear waste. Our view is partially consistent with the paper on depleted uranium prepared by NRC staff last year, which reads in part:

> *"Considering the technical aspects of the problem, the performance assessment staff recommends a performance period of 10,000 years for the analysis of DU disposal. However, analyses should be performed to peak impact, and if those impacts are significantly larger than the impacts realized within 10,000 years, then the longer term impacts should be included in the site environmental evaluation."*

A simpler philosophy, and one that is more consistent with parallel regulatory programs is that the performance period should be long enough to include the time of peak dose.

We take issue, however, with another conclusion from the NRC paper:

> *"Potentially high doses relative to the performance objectives could occur within a timeframe longer than 10,000 years from the disposal of large quantities of DU. However, the majority of sites, waste forms, and disposal configurations that can meet the performance objectives at 10,000 years* ***will continue to meet the performance objectives at longer time periods.*** *A simple approach that should be considered to ensure the eventual risk of radon is managed to* ***select a waste disposal depth and cover thickness based on the projected peak in-growth of the daughter species, rather than the in-growth over the performance period. [emphasis added]"***

Our discomfort with this statement arises from the fact that virtually no shallow engineered disposal system can be envisaged to persist, intact, for periods of up to 1,000,000 years, the timeframe of peak doses. NRC's statement appears to make the implicit assumption that climate and tectonic factors will remain static over these time frames. With respect to climate and attendant consequences to landforms by erosion and deposition, enough is known about natural climate variation that this assumption is false *everywhere at the earth's surface*. NRC's assertion is simply wrong for any shallow, engineered site.

In this letter, we discuss just one aspect of climate change for the EnergySolutions Utah disposal site that makes it inappropriate for DU disposal. As experienced earth scientists with wide-ranging expertise, we believe that rising lake levels associated with glacial and even inter-glacial climate change will likely lead to eventual inundation and wholesale erosion of the EnergySolutions Utah disposal facility.

Any modeling that does not take into account well-understood geological and climatologic patterns displayed in the Lake Bonneville basin will grossly under- and mis-estimate the long-term hazards of exposure from DU and its decay products. Clearly, we believe that any new rule and any associated guidance related to site-specific analysis of DU should require modeling that includes climatic variation, out to the time of peak dose. If that is done for the EnergySolutions site in particular, we are led back to one inevitable conclusion: Over the relevant time frames for DU disposal, the probability that the Clive site will be flooded approaches 100%. Given that near-certainty, we believe that a proper site-specific analysis will also inevitably conclude that the EnergySolutions site is not appropriate or safe for DU disposal.

The remainder of this letter is organized as follows. For context, we review the nature of depleted uranium (DU) in comparison to "conventional" low-level waste (LLW). This is followed by additional discussion of the appropriate regulatory philosophy, and then by more consideration of the suitability (or lack thereof) of engineered landfills to accept and isolate DU, and the EnergySolutions Clive facility in particular. Included in the discussion of the Clive facility are site- and region-specific analyses of the geology and forward models of lake-level perturbations and erosion related to climate change.

Nature of DU

Although you are aware of the nature of DU, there are three properties that we wish to re-emphasize for context. First, DU has an extremely long half-life (4.5×10^9 yr) such that it effectively lasts "forever." Second, as it evolves back toward secular equilibrium with its progeny, it becomes many times more radioactive and at the time of emplacement its activity exceeds that of Class A waste[1]. Such material will emit alpha, beta, and gamma radiation. Third, the daughter products have geochemical properties that are, in many instances, greatly divergent from that of ^{238}U. Since each of the daughters will eventually acquire an activity equal to that of the ^{238}U parent, it is just as important to understand the site-specific geochemical behavior of <u>each daughter radionuclide</u> as it is to understand the behavior of U. In fact, the geochemical behavior of ^{234}Th and ^{234}Pa must be understood at the time of emplacement[1]. And as we are sure you are aware, U itself can be quite mobile in aqueous solutions, especially those with an elevated Eh (U^{6+}) and high carbonate content. As discussed below, future natural climate variation will almost certainly inundate the Clive, Utah site with waters that may very well exhibit these characteristics.

Applicable Regulatory Philosophy

The typical control period for LLW is a few to several hundred years, depending upon its nature. Clearly, the philosophy is to provide reasonable assurance of isolation from the environment by *in situ* decay *<u>until the radiological hazard has largely passed</u>*. The Clive site was developed for these types of materials, not DU.

In the high-level waste (HLW) arena, you are aware that the US EPA sets performance standards. Congress charged the EPA with the adoption of a dose-based standard and further directed the EPA to consider guidance by the National Academy of Sciences (NAS) in developing its rule (40CFR197). EPA had set a compliance period of 10,000 years. We trust that you are aware that a competent Federal Court set aside the EPA rule in 2004 for failure on the part of EPA to adhere to NAS recommendations that the compliance period extend *<u>to 1,000,000 years or until peak doses occurred</u>*. The rule was remanded back to the EPA. A final rule, presumably consistent with NAS recommendations[2], was adopted in Oct. 2008.

---

1 Using long-lived alpha emitting transuranic nuclides as a yardstick, pure <u>metallic</u> DU would exceed limits in Table 1 of 10CFR61.55 <u>at the time of emplacement</u>. "Dilution" with oxygen in oxide forms places DU only modestly below the limit. However, it is easily shown that within a year of processing, the rapid ingrowth of ^{234}Th and ^{234}Pa result in DU having three times the activity it had when processed.

2 We presume the rule is consistent with NAS guidance, not because of the content of the rule, but because as far as we are aware it has not been challenged.

Thus, the overarching regulatory philosophy must be that control of radioactive wastes is maintained _until the radiological hazard has largely passed, regardless of the timescale or the nature of the waste_. The NAS accepted that 1,000,000 years might be an appropriate upper temporal limit for HLW where _geologic_ disposal is required because of the inherent long-lived nature of spent fuel and military wastes.

We cannot overemphasize the difference between engineered disposal (e.g., LLW) and geologic disposal (e.g., HLW). Geologic disposal contains the inherent recognition that the nature of the hazard is sufficiently long-lived that natural barriers are required to mitigate risks. Engineered solutions (i.e., landfills) alone are inadequate. DU is, by its very nature, the longest of the long-lived waste streams and after a few tens of thousands of years (let alone at the time of emplacement) it is hardly benign. Regulatory philosophy and common sense _demand geologic disposal_. DU, at face value, is entirely inconsistent with disposal in any shallow, engineered landfill.

The NRC must resist the environmental narcissism (i.e., "I won't be around when it becomes a problem") evidenced by entertaining the notion of DU disposal in a shallow landfill. All classification issues of DU aside, disposal in engineered landfills is simply wrong.

Suitability of Shallow Engineered Disposal

The nature of DU combined with existing regulatory philosophy should foreclose shallow, engineered disposal on its face. That said, we wish to provide _site-specific_ evidence of the unsuitability of the EnergySolutions Clive, Utah facility for _proposed_ and _existing_ DU disposal.

Effects of Past Climate Variation: Figure 1 shows the approximate location of the Clive facility, well within the Bonneville basin. Clive was under water during the entire existence of Lake Bonneville, a time period extending from approximately 31,000 until 11,500 years ago. Although the Clive site is approximately 25 meters above the current elevation of the Great Salt Lake, it is about 60 meters _below the lowest_ of the 3 major still stands of Lake Bonneville. Figure 2 illustrates some of the shoreline features that developed in response to that lake.

Although the extent, depth and history of Lake Bonneville are well understood, the detailed histories of the lakes that preceded it are not as well documented due to a paucity of well-dated, well-studied, and well-preserved lake cores. Such lakes are known to have existed, however. Oviatt et al. (1999) proposed there were four deep lakes in the Bonneville basin during the last 780,000 years, whereas Eardley et al. (1973) suggested there may have been 17 deep lake cycles over that time interval. Whether there were 4 or 17 deep lakes is not particularly important. Both studies illustrate that based on the past, future repeated flooding of Clive is inevitable.

Link et al. (1999) noted that *"...the permanent addition of Bear River water to Lake Bonneville likely occurred 50 ± 10 ka (Bouchard et al., 1998), increasing the total discharge into the Bonneville basin by ~33%. This addition, coupled with cool, moist conditions during late Wisconsin time, is generally thought to have been responsible for the lake reaching its all-time high during the last (Bonneville) lake cycle (Bright, 1963; McCoy, 1987; Bouchard et al., 1998)."*

It is important to understand the consequences of the piracy of the Bear River into the Bonneville basin. Increasing the catchment area without changing the size of the basin may _amplify_ lake level responses to climate change. Since this event occurred late in the 780,000 year record discussed by Eardley et al. (1973) and Oviatt et al. (1999), past studies of the Bonneville basin may, in fact, under-predict future lake-level fluctuations.

At the Clive locality in particular, inspection of an excavation near the EnergySolutions site by one of us (Oviatt) in the 1980s revealed that Bonneville clays are underlain by oolitic sands approximately 3 m thick. The implication of this observation is clear. Prior to the expansion of Lake Bonneville the Clive site was submerged by shallow water for an extended period of time in order to permit the formation of these deposits.

Owens Lake, CA, is a relevant proxy for climate change in the Great Basin. Owens Lake periodically filled expanded portions of the Owens Valley on the eastern slope of the Sierra Nevada. In fact, due to climate variation, Bischoff et al. (1997) suggested that there were seven distinct episodes over the last 500,000 years (Fig. 3) during which Owens Lake levels rose such that it spilled out of its basin into China Lake, Panamint Valley, and into Death Valley. The timeframe is entirely consistent with 40CFR197 and the period of interest surrounding DU. Bischoff et al. (1997) further suggested that the lake was large and deep enough to spill out of the Owens Valley 34% of the time, or 170,000 of the last 500,000 years. To a first approximation, natural climate variation may have produced similar cyclical inundations of the Clive site.

As mentioned above, the elevation of Clive is significantly below that of the lowest of the three major still stands of Lake Bonneville, so it seems likely that flooding might occur at the Clive site in response to relatively small climate changes. In fact, the low elevation of the Clive site guarantees inundation with a much greater frequency than the complete filling of the Bonneville basin to its spill point into the Snake River drainage.

Effects of Future Climate Variation: The cycles of rising and falling lakes in the enclosed topographic basins of the Great Basin will continue in the future. We can reasonably expect several lake cycles to inundate the Clive site over the next 500,000 years due to natural climate variation, and we can hardly imagine that anyone would consider the return of a pluvial lake to the Clive site to be consistent with waste isolation[3].

We suspect that that there would be nearly complete unanimity that expanded lakes will return in the future in response to climate variation if you polled geologists, geographers, and paleo-climatologists working in or familiar with the Bonneville basin. Even worse, large climate changes may not be requisite to flood the site. For example, the elevation of the Great Salt Lake has varied by six meters just since 1873 (Tarboton, 2006).

Changes in climate required to increase the level of the Great Salt Lake to that of Clive are extremely small when compared to current understanding of natural climate variability over the Holocene Epoch and the last full glacial cycle. We have conducted simple forward models of lake elevation changes. All else being equal, precipitation only has to increase ~3-6 mm/yr for 1000 years to raise the level of the Great Salt Lake to that of Clive.

Mean lake level does not have to reach Clive in order to cause problems. Given reasonable interannual variability in climate, the mean lake level only has to reach 15-20 m above modern day Great Salt Lake. At this level, it is highly probable that the variability about mean lake level will drown Clive for several hundred years out of every 5,000-10,000 years (see amplitude of variability in Fig. 4). The mean shift in precipitation required to achieve this is well within reasonable natural or anthropogenic changes in the climate system. Exposure to shoreline erosion over a few hundred years can conservatively erode several meters of bedrock (Fig. 5). Engineered disposal cells above grade can hardly be expected to resist erosion in a large lake with large fetch.

The implications for the Clive site are clear. Clive has been inundated repeatedly in the past. Clive will be inundated in the future, and the mean changes in climate required to flood and destroy the emplacement piles are small. We estimate that the probability of the EnergySolutions site being flooded in the next 100,000 years is close to 100%. Sandquist (2009) maintains that there are 330 tons of natural uranium currently in the 1700 mi^2 Great Salt Lake. The Clive site, by contrast, could release on the order of 1,000,000 tons of DU from a landfill with a ½ mi^2 footprint.

The consequences in the vicinity of Salt Lake City for lake level rise to the elevation of the Clive site (1305 m) are illustrated in Figure 6. Much of what is now the northwestern part of the valley will be below water, including downtown Salt Lake City. However, what may be more important are the areas that are not flooded. Large areas will remain habitable. No one can predict what the state of society will be when the lake returns to this elevation, but there is every expectation that humans will be inhabiting large portions of the Salt Lake Valley and perhaps relying on lake resources. The almost certain release of hundreds of thousands of tons of DU into their future environment can be foreseen today.

Summary

DU is, at face value, an inappropriate waste stream for any shallow, engineered disposal site. Its very nature requires geologic disposal. Shallow disposal simply does not pass the "laugh test." We suggest that a model exists for proper DU disposal. The operational WIPP site for transuranic waste illustrates that the geological, geochemical, and engineering knowledge needed for safe DU disposal is already mature.

Specifically, the Clive facility could be an appropriate site for the disposal of "conventional" LLW from a purely technical perspective. A control period of a few hundred years for Class A LLW can

---

[3] *There is also considerable irony in the fact that the lacustrine clays [marls, really] from which cells are constructed at the Clive site, combined with underlying oolitic sands, are primary evidence of its unsuitability for DU disposal because they are direct evidence of past inundation.*

probably be met without significant risk given appropriate monitoring and other controls. However, the notion that hundreds of thousands of tons of concentrated DU can be emplaced in this facility (or any other shallow landfill) and releases controlled or prevented over long but relevant time-scales is patently absurd.

Our analysis also reveals a fundamental and we believe fatal flaw in your proposed rulemaking. NRC asks about minimum and maximum quantities, regulatory time frames, inadvertent intrusion, source terms and geochemical modeling, all of which are important issues. However, you have failed to ask two critical questions. First, you do not ask whether shallow disposal is proper to begin with. You seem to assume that it is. Our analysis shows that it is not. Second, you do not ask the types of questions that would raise the issues surrounding the Clive site that we have addressed. If this is true of Clive, then there are probably fatal flaws at most if not all shallow disposal facilities, albeit for different specific reasons, that are related to the inherent nature of surface geological processes over long time scales.

Some of us attended a Radiation Control Board meeting on July 14 in Salt Lake City where many of the objections to DU disposal discussed in this letter were presented. After hearing a presentation by EnergySolutions, the driving force behind this rulemaking has become clear. EnergySolutions suggested that in the coming decades as much as 700,000 tons of DU will require disposal. This is a staggering sum.

If we are not mistaken, current federal statute would permit up to 77,000 tons of HLW to be disposed at Yucca Mountain, or a little more than 10% of the 700,000 tons of DU. Although this is an apples to oranges comparison, it places the scale of the DU problem in perspective. Geologic disposal of DU represents a daunting engineering task. The need to dispose of massive quantities of DU "*somewhere*" is not a justification to dispose of it *"anywhere."* Yet, the need for disposal is clearly driving this action. A programmatic failure on the part of US Government agencies to plan for the ultimate disposition of DU, however, is not a justification for improper (i.e., shallow) disposal. It is not a justification for endangering the future health of the Utah environment, or the environment of any other state even if it is over a long time scale. It is not a justification for the adoption of a regulatory philosophy that is inconsistent with other programs.

We have learned through the media that tens of thousands of tons of DU may have already been emplaced at the Clive facility. It came here under the rubric of "Class A" waste, through a literal but unfortunate reading of the regulations; in fact, an appropriate analysis has never been done. The Utah Board of Radiation Control should have been informed that large amounts of DU were never adequately analyzed under the Federal waste classification scheme at a time when state leaders were still in a position to comment or stop these historical shipments. While there is blame to go around for this state of affairs, including Utah state officials who are responsible for running our Agreement State program, we expect more from the NRC. In this regard, we believe the NRC owes the citizens of Utah an apology for this serious oversight.

Sincerely,

Stephen T. Nelson[4]
Professor of Geochemistry

Summer B. Rupper[4]
Professor of Climate and Paleoclimate

Charles G. Oviatt
Professor of Geology

---

[4] *Because the issues in this letter address both technical and public policy matters, Brigham Young University policy requires that its faculty make clear that their views are their own and not those of the University or its sponsoring institution. No individual or organization has the right to state or imply otherwise.*

Stephen T. Nelson

Professor
Department of Geological Sciences
Brigham Young University
S389 ESC
Provo, Utah 84602

voice: 801-422-8688
e-mail: steve_nelson@byu.edu

Charles G. Oviatt

Professor
Department of Geology
Kansas State University
108 Thompson Hall
Manhattan, KS 66506-3201

voice: 785-532-6724
e-mail: joviatt@ksu.edu

Summer B. Rupper

Assistant Professor
Department of Geological Sciences
Brigham Young University
S318 ESC
Provo, Utah 84602

voice: 801-422-6946
e-mail: summer_rupper@byu.edu

Cc:
Utah Governor Gary M. Herbert
Ms. Amanda Smith, Executive Director, Utah Department of Environmental Quality
Mr. Dane Finerfrock, Director, Utah Division of Radiation Control
Dr. Inés Triay, Assistant Director for Environmental Management, US Department of Energy
Utah Radiation Control Board members
Rep. Rob Bishop
Rep. Jim Matheson
Rep. Jason Chaffetz
Sen. Bob Bennett
Sen. Orrin Hatch
Ms. Judy Fahys, Salt Lake Tribune
Ms. Amy Joi O'Donoghue, Deseret News
Mr. Tim Gillie, Tooele Transcript Bulletin
Mr. Don Porter, Ogden Standard Examiner
Mr. Donald Meyers, Provo Daily Herald
Mr. Todd Siefert, St. George Spectrum

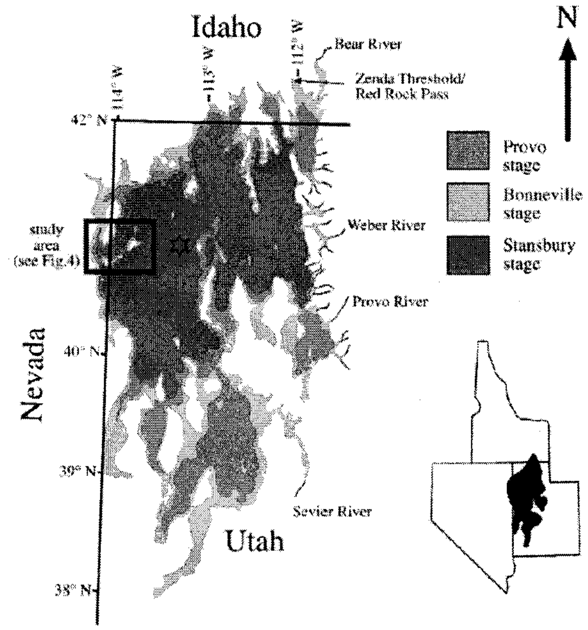
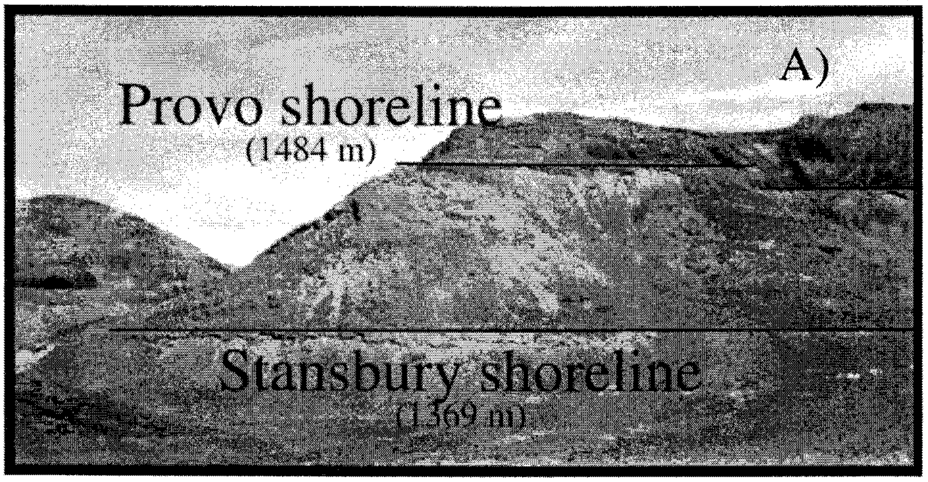


Figure 1. Map indicating the main Lake Bonneville highstands and the approximate location of the EnergySolutions Clive, Utah facility. The Stansbury stage lasted from about 25,000 to 24,000 years ago, whereas the Bonneville and Provo Stages lasted from about 18,300 to 14,500 years ago. Modified from Nelson et al. (2005).



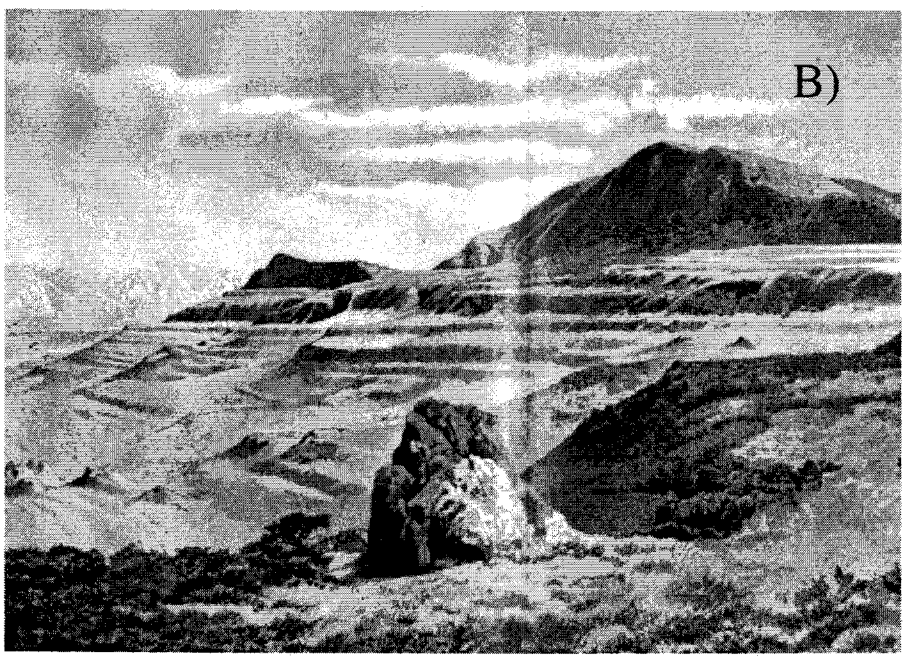


Figure 2. Illustrations of Lake Bonneville shorelines. A) represents shorelines developed in the Pilot Valley area north of Wendover, UT. Modified from Nelson et al. (2005). B) represents an illustration by G.K. Gilbert's illustrator W.H. Holmes in the 1880's of numerous shorelines at the north end of the Oquirrh Mountains prior to being largely obscured by human activity. The familiar Wasatch Mountain skyline can be seen in the distance.

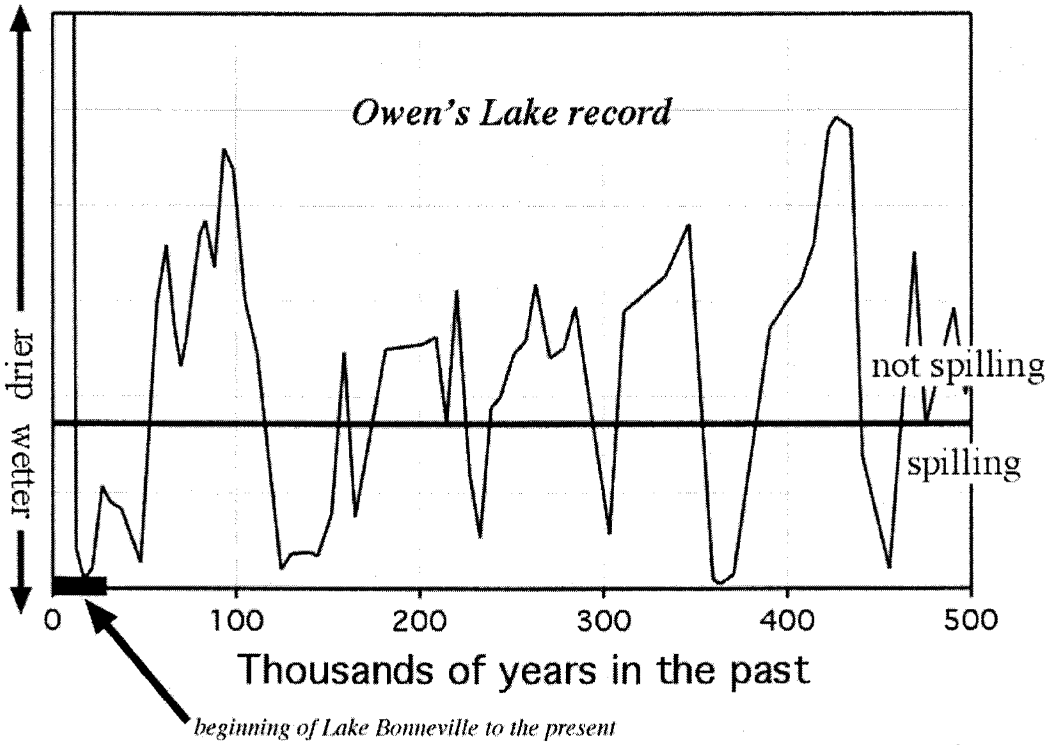


Figure 3. Lake level/climate history for Owens Lake modified from Bischoff et al. (1997). Note that over the last 500,000 years that the lake has expanded and spilled its basin repeatedly. Lake Bonneville has likely experienced similar expansion and contraction in the past and will experience similar episodes in the future.

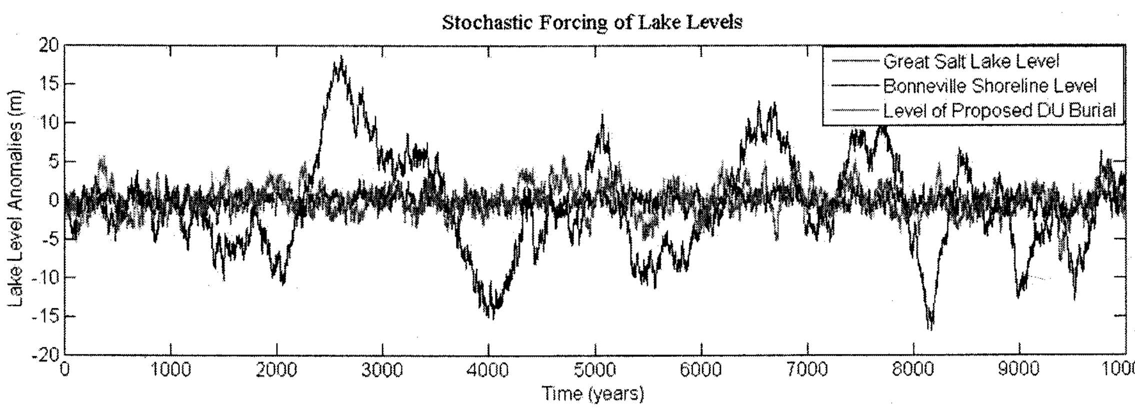


Figure 4: Lake level variability forced by present-day interannual variability in precipitation and temperature, but no change in the mean climate state. The inherent memory of a lake results in integration of the stochastic (white noise) variability in climate variables, resulting in red noise variability in lake levels. This integration of noise depends strongly on lake size. Smaller lakes have rapid and smaller lake level anomalies; conversely, larger lakes have slower and larger lake level anomalies. In summary, lake level can vary even in the absence of a change in climate.

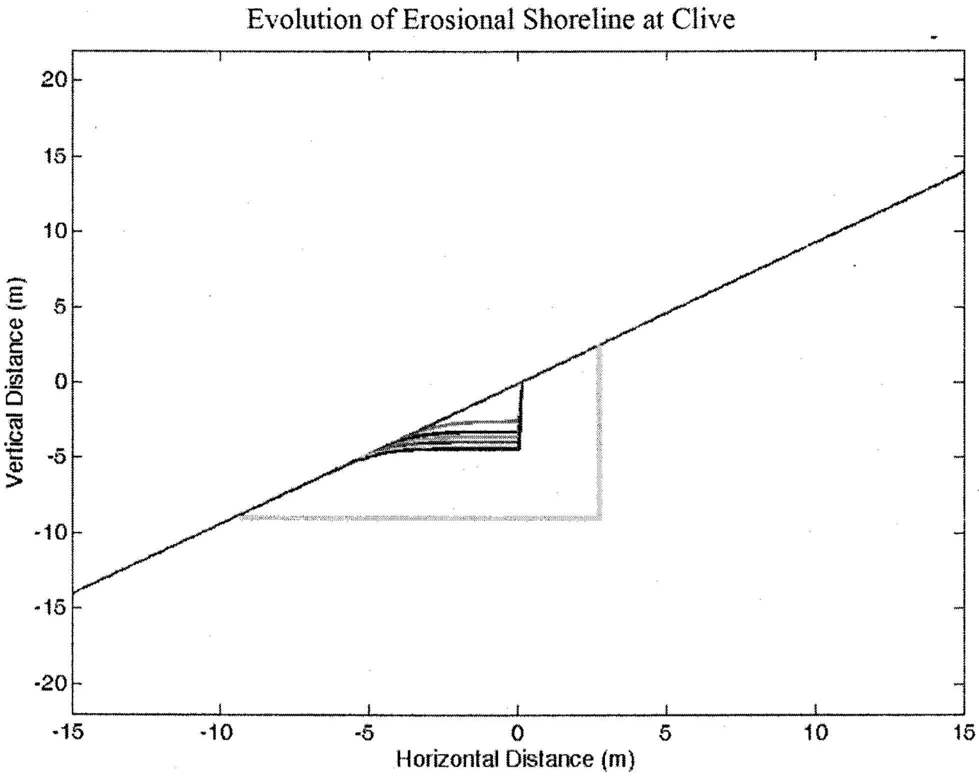


Figure 5: Modeled shoreline erosion over time at Clive for a steady-state lake level. The starting profile for the slope at Clive is in blue. Each successive colored line represents a snapshot in time during the erosion process: magenta=100 years, black=1000 years, green = 2000 years, red = 4000 years, yellow = 7000 years, and blue equals 10000 years. All climate variables and wave generation in the erosion model are based on present day conditions and solid rock. The grey line represents the equilibrium erosion profile after 10000 years when rednoise lake variability is included. Note that in all simulations, the majority of the evolution towards an equilibrium shoreline profile occurs in the first 1000 years.

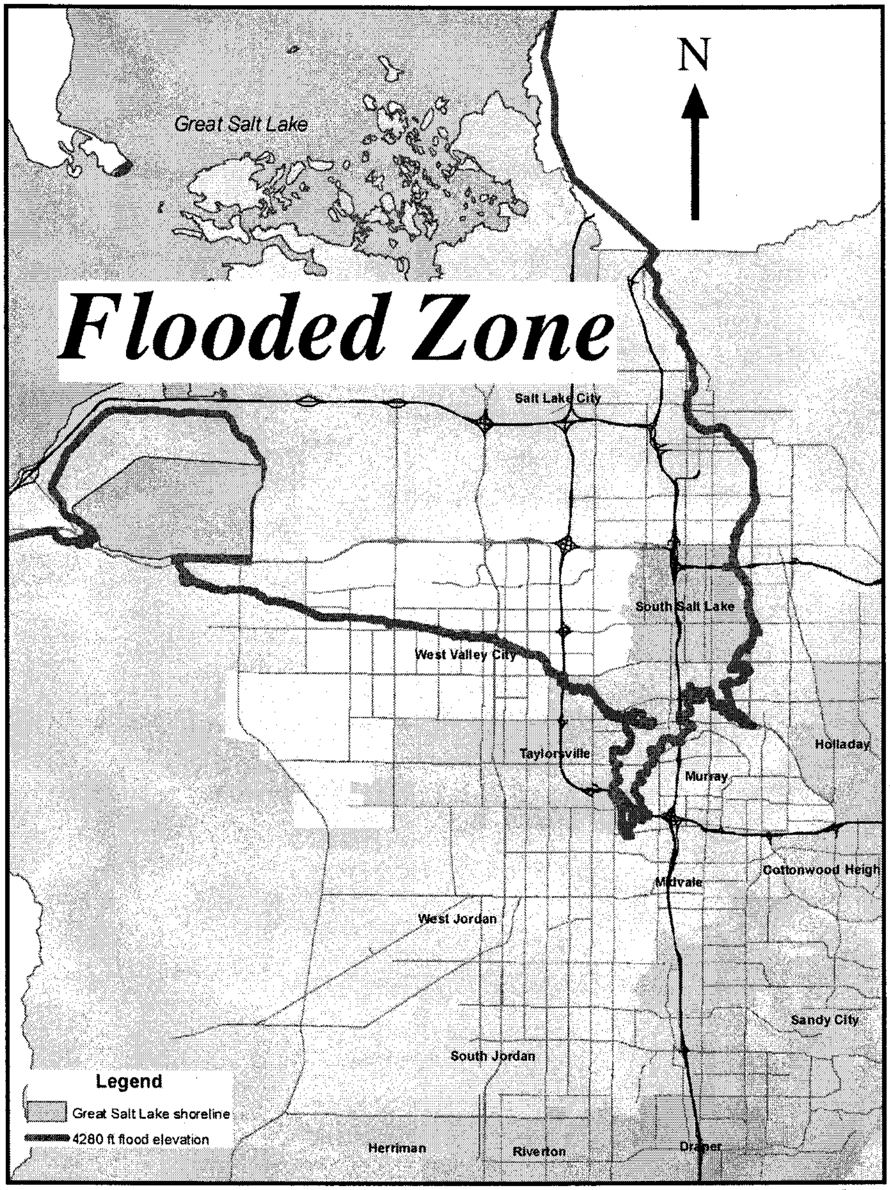


Figure 6. Map showing the extent of flooding relative to the current urban corridor of the Salt Lake Valley should Great Salt Lake levels rise to the elevation of the EnergySolutions Clive site (4280 ft or 1305 m).

References:

Bischoff, J.L, Fitts, J.P., and Fitzpatrick, J.A., 1997, Responses of sediment geochemistry to climate change in Owens Lake sediment: An 800-k.y. record of saline/fresh cycles in core OL-93: Geological Society of America Special Paper 317, p. 37-47

Bright, R.C., 1963, Pleistocene lakes Thatcher and Bonneville, southeastern Idaho. PhD dissertation, University of Minnesota, Minneapolis, 171 p.

Brouchard, D.P., Kaufman, D.S., Hochberg, A., and Quade, J., 1998, Quaternary history of the Thatcher Basin, Idaho, reconstructed from the $^{87}Sr/^{86}Sr$ and amino acid composition of lacustrine fossils: implications for the diversion of the Bear River into the Bonneville Basin: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 141, p. 95-114.

Eardley, A.J., Shuey, R.T., Gvosdetsky, V., Nash, W.P., Picard, M.D., Grey, D.C., and Kukla, G.J., 1973, Lake cycles in the Bonneville Basin, Utah: Geological Society of America Bulletin, v. 84, p. 211-216.

Gilbert, G.K., 1890, Lake Bonneville, U.S. Geological Survey Report M 0001, 438 p.

Link, P.K., Kaufman, D.S., and Thackray, G.D., 1999, Field Guide to Pleistocene Lakes Thatcher and Bonneville and the Bonneville Flood, southeastern Idaho, *in* Hughes, S.S., and Thackray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, p. 251-266.

McCoy, W.D., 1987, Quaternary aminostratigraphy of the Bonneville Basin, western United States: Geological Society of America Bulletin, v. 98, p. 99-112.

Nelson, S.T., Wood, M.J., Mayo, A.L., Tingey, D.G., and Eggett, D.L., 2005, Shoreline Tufa and Tufaglomerate from Pleistocene Lake Bonneville, Utah, USA: stable isotopic and mineralogical records of lake conditions, processes, and climate: Journal of Quaternary Science, v. 20, p. 3-19.

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

Rupper, S., 2009, Stochastic climate forcing of Pleistocene Lake Bonneville: Geological Society of America Abstracts With Programs, v. 41, p. 3.

Sandquist, Gary, 2009, Uranium in GSL, Public Forum, Salt Lake Tribune, Oct. 21, 2009. *(The author of this letter is almost certainly a former Univ. of Utah nuclear engineering professor)*

Tarboton, D.G., 2006, What makes the Great Salt Lake level go up and down: Geological Society of America Abstracts With Programs, v. 37, p. 162.

BIOGRAPHICAL SKETCHES

Stephen T. Nelson, Qualifications:

I am a professor of geochemistry at a major university where I have taught and engaged in research for the last 12 ½ years. My area of teaching and research expertise includes isotope geochemistry. I have established a light stable isotope laboratory, ^{3}H, and ^{14}C liquid scintillation counting facilities, as well as an alpha spectroscopy laboratory for U-series measurements in naturally-occurring matrices. I teach a graduate course in isotope geochemistry and team-teach a graduate course in contaminant hydrogeology. Much of my research includes the response of arid regions to climate change.

From July 1998 to July 2008 I was a member, vice chair, and chair of the Utah Radiation Control Board. From March 1993 to Dec. 1996 I worked under the Management and Operating Contract for the US DOE Yucca Mountain Project. I participated in the management of volcanic hazard, mineralogy and petrology, and geochemistry studies as part of the characterization effort for that site. I also have direct research experience and interests in the Bonneville basin, which includes the EnergySolutions Clive, Utah site. In summary, I have considerable experience and insight relevant to the issue of DU disposal in general and at Clive, Utah in particular.

Charles G. Oviatt, Qualifications:

I am a professor of geology at Kansas State University, in Manhattan, KS. I began studying Lake Bonneville as a graduate student at the University of Utah in 1977, and I am continuing that work today. During the eight years I lived in Salt Lake City, I was employed by the Utah Division of State History, the U.S. Geological Survey, and the Utah Geological Survey, and in each of these positions I continued to work on Lake Bonneville. In 1985 I moved to Kansas State University to teach geology, and have returned to Utah to study Lake Bonneville every year (primarily during summers) since then. I have published numerous scientific articles, maps, reports, and abstracts related to Lake Bonneville. These include: over 20 peer-reviewed scientific journal articles or book chapters, over 40 abstracts of presentations at scientific conferences, and over 30 other reports, maps, and guidebooks.

Summer B. Rupper, Qualifications:

I am a professor of climate and paleoclimate at a major university, and have been studying the Earth's climate system for almost a decade. My specific area of research expertise is in quantifying the interactions between climate and earth's surface, with emphasis on glaciers and lakes. Recently this has included numerical modeling of the lake-level variability of the Great Salt Lake and glacial Lake Bonneville, impacts of that variability on erosion rates and shoreline evolution, and the associated feedbacks and forcings between lakes and regional climate over short and long time-scales. I have published more than 20 scientific articles, proceedings, book chapters, and abstracts related to climate and paleoclimate; served as a reviewer and guest editor for top-tier climate and paleoclimate journals; and served as a reviewer and panelist for climate, glaciology, and geomorphology divisions of major grant funding agencies.