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Update to *Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES* by Arjun Makhijani, PhD. and Brice Smith, Ph.D. based on information obtained since November 2004

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At the time our November 24, 2004 report was written, depleted uranium was considered a "source material" under the Atomic Energy Act and its possible classification, if declared a waste, had not been formally addressed by the Nuclear Regulatory Commission. The NRC staff and analysts at Sandia National Laboratory had argued previously that the depleted uranium from an enrichment facility should be considered Class A low-level waste under 10 CFR 61.55(a)(6), since uranium isotopes were not included among the radionuclides listed for Class B or C wastes, but the Commission had made no such ruling.[1] The analysis we presented in our November 2004 report demonstrated that, with respect to its radiological properties, depleted uranium is most analogous to Transuranic (TRU) or Greater than Class C waste, and that it would require similar care for disposal. In particular, we concluded that near surface disposal even in an arid climate would very likely not be acceptable based upon the dose limits for future intruders and that disposal in a mined repository similar to the Waste Isolation Pilot Plant (WIPP) would likely be necessary. The financial assurances put forward by LES to ensure safe disposal should be based on this assumption for the ultimate cost of disposal for the depleted uranium tails.[2]

This update is based on the latest available information and could be revised as new information becomes available.

Summary of Main Findings in this Update

- A license granted to LES based on the June 2005 Final Environmental Impact State prepared by the NRC staff would have little scientific basis or legal merit. This is due to the fact that (1) the NRC staff misconstrues the Commission's January 18, 2005, ruling regarding the classification of depleted uranium as low-level waste, (2) the NRC staff abandons the long-standing position that additional analysis is required before a disposal option for depleted uranium can be selected and arrives at a preferred option (disposal at Envirocare) without conducting any analysis of the environmental impacts or taking into account Envirocare's latest license amendment, and (3) the apparent preferred disposal option of LES (disposal at the proposed Waste Control Specialists facility) was eliminated from consideration by the NRC staff and thus no analysis is presented for the environmental impacts of the action that is being proposed by the applicant.

[1] See for example [Kozak et al. 1992 p. 1] and [NEF DEIS 2004 p. 2-27].
[2] See [Makhijani and Smith 2004 p. 4-8, 19-29, and 35-51]. For simplicity in this report we will refer interchangeably to TRU and GTCC waste. The important element of their classification with respect to this discussion is the limit of 100 nanocuries per gram of long lived alpha emitting transuranic elements.

- The disposal of bulk depleted uranium oxide at the Envirocare site is not a plausible strategy and would likely be unacceptable due to the fact that (1) the State of Utah has banned the import of Class B and C wastes to the State and Envirocare has announced that it will no longer seek authority to import such waste, (2) Envirocare's License Amendment 22 (adopted June 13, 2005) would likely prohibit the acceptance of bulk DU at the site, and (3) the performance assessments prepared in support of the original license application reveal that the disposal of bulk DU_3O_8 at the Envirocare site could lead to doses in excess of regulatory limits for both workers as well as future intruders.

- The disposal of bulk depleted uranium oxide at the proposed Waste Control Specialists (WCS) site is not a plausible strategy and would likely be unacceptable due to the fact that (1) WCS does not yet have a license to dispose of any type of radioactive waste, (2) the license application filed with the Texas Commission on Environmental Quality in August 2004 does not consider the disposal of bulk depleted uranium oxide and reveals the fact that WCS is unqualified to accept or dispose of any type of uranium-bearing wastes due to WCS's apparent lack of even the most basic knowledge of the radiological properties of uranium, (3) the disposal of depleted uranium at the proposed WCS site would likely lead to intruder doses well in excess of the regulatory limits due to uncovering of the waste by erosion, and (4) the fact that both LES and WCS disclaim any responsibility for the accuracy of the information presented in the January 14, 2005, memorandum of agreement which supposedly supports their selection of this option.

Section 1.1 – The Need to Analyze Disposal Options

In response to the issues raised by our November 2004 report and other supporting information in connection with the intervention by Nuclear Information and Resource Service (NIRS) and Public Citizen in this case, the Commission issued a January 18, 2005 decision addressing, in part, the question of depleted uranium's classification as a waste. In particular, the Commission ruled that

> Depleted uranium clearly is not spent fuel, transuranic waste, or 11e.(2) byproduct material. Nor does it meet the high-level waste definition, which includes specific kinds of wastes such as irradiated fuel and the liquid and solid wastes resulting from the processing of irradiated fuel.[3]

and that therefore

> Although the Commission itself may not have explicitly declared previously, as a matter of law, that depleted uranium is a form of low-level radioactive waste, it has long been understood within the NRC to fall within the low-level radioactive waste umbrella.[4]

Thus, the Commission's decision on depleted uranium's classification as low-level waste did not hinge upon the hazards DU presented, but instead upon a legal argument about its relation to the other existing classes of waste (i.e. high-level waste, transuranic waste, and 11e.(2) byproduct material). In this respect the Commission noted that even

> In the event depleted uranium at some particular radionuclide concentration level and volume were to require disposal by methods more stringent than near-surface disposal, it would still be low-level waste.[5]

The Commission went on to explicitly endorse our position that the legal classification of DU as low-level waste does not settle the question as to the suitability of proposed disposal options. In particular, the Commission concluded that

> A more difficult question – and one we need not answer today -- concerns whether the LES material, in the volumes and concentration proposed, will meet the Part 61 requirements for near-surface disposal. The Commission agrees with the intervenors that a definitive conclusion on this and other disposal method questions cannot be reached at this time, and may require further environmental or safety analysis. Our decision should not be read to intimate any Commission view on this issue, which relates both to the

[3] NRC 2005 p. 25
[4] NRC 2005 p. 26
[5] NRC 2005 p. 25

> plausibility of LES's proposed private disposal options, and to financial assurance -- issues which remain before the Board.[6]

The position taken by the Commission in its January 2005 ruling that the legal classification of depleted uranium as low-level waste is not sufficient to demonstrate the suitability of disposal options is consistent with the position that has been expressed by representatives of the NRC and the DOE going back as many as 14 years. This need for additional case-by-case analysis is due in large part to the fact that uranium, while included in the proposed rule, was explicitly removed from the final version of 10 CFR 61. In 1982, when the final rule and supporting Environmental Impact Statement were issued, it was determined that

> Analysis of the data base for the Part 61 EIS indicates that the types of uranium-bearing wastes typically disposed of by NRC licensees do not present a sufficient hazard to warrant limitation on the concentration of this naturally occurring material.[7]

At that time, only the Department of Energy was in possession of a large quantity of depleted uranium hexafluoride tails in the United States. Since uranium was removed from consideration based on this fact, the results of applying the 10 CFR 61 performance assessment methodology to uranium were not presented by the NRC at that time.

In 1991, as part of its preparation for a review of the expected license application for the construction of a new enrichment facility by LES, the NRC's Executive Director for Operations explicitly took up the issues of waste classification and disposal. At that time it was concluded that "the tails are considered source material" but that they could legally "be disposed of as LLW waste under the requirements of 10 CFR Part 61."[8] However, it was explicitly noted that

> Review of the Environmental Impact Statement supporting 10 CFR Part 61 shows that although NRC considered the disposal of uranium and UF_6 conversion facility source terms in the analysis supporting Part 61, NRC did not consider disposal of large quantities of depleted uranium from an enrichment facility in the waste streams analyzed because there was no commercial source at that time. Therefore, analysis of the disposal of depleted uranium tails from an enrichment facility at a Part 61 LLW disposal facility should be conducted similar to the pathway analyses conducted in support of Part 61.[9]

The Director went on to conclude that, in support of a decision on disposal options, a "detailed pathway analysis of depleted uranium should be conducted following the provisions of 10 CFR 61.58" which states that

> The Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste, on a specific basis, if, after evaluation, of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in Subpart C of this part [Performance Objectives].[10]

As part of the subsequent review of the initial LES license application to build the Claiborne Enrichment Center (CEC) in Louisiana, the Division of Low-Level Waste Management and Decommissioning (LLWM) at Sandia National Laboratories provided technical assistance to the NRC by preparing such a report on the suitability of shallow-land disposal facilities for the disposal of depleted uranium. In the 1992 report *Performance Assessment of the Proposed Disposal of Depleted Uranium as Class A Low-Level Waste*, the authors concluded that

> According to the concentration limits and provisions of 10 CFR 61.55, the depleted uranium [from the proposed enrichment facility] would be considered Class A waste. Thus, these wastes might be acceptable for disposal in a Part 61 facility. Given the large inventory and form of the depleted uranium wastes, and the fact that this type of waste was not included in the Environmental Impact statement (EIS) analyses supporting 10 CFR 61, further analysis is necessary to demonstrate whether the disposal of this material in a 10 CFR 61 disposal facility will be acceptable in terms of public health and safety.[11]

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[6] NRC 2005 p. 26
[7] 10 CFR 61 FEIS 1982 p. 5-38
[8] NRC 1991 p. 5
[9] NRC 1991 p. 4
[10] NRC 1991 p. 5
[11] Kozak et al. 1992 p. 1

This need for additional analysis was also the position taken by the NRC staff in their 1994 review of the environmental impacts of the proposed Claiborne Enrichment Center. The NRC staff described the scope of their analysis presented in the final Environmental Impact Statement as follows:

> The tails disposal impact analysis approach includes selection of representative disposal sites, development of undisturbed performance, exposure scenarios, and selection of consequence estimation models…. Exposure scenarios selected for evaluation of near-surface disposal included drinking of well water and consumption of crops irrigated with water drawn from the well.[12]

In addition to considerations surrounding the CEC facility outlined above, in June 2004 the Department of Energy issued the final Environmental Impact Statements for the management of the approximately 740,000 metric tons of depleted uranium currently stored at the gaseous diffusion plants at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. In the two final EIS's, the DOE listed disposal at the Envirocare site in Utah as the primary option for the proposed disposition of the DUF_6 deconversion product and disposal at the Nevada Test Site as the secondary option. However, in a footnote to this text the DOE explicitly made it clear that the

> DOE plans to decide the specific disposal location(s) for the depleted U_3O_8 conversion product after additional appropriate NEPA review. Accordingly, DOE will continue to evaluate its disposal options and will consider any further information or comments relevant to that decision. DOE will give a minimum 45-day notice before making the specific disposal decision and will provide any supplemental NEPA analysis for public review and comment.[13]

Thus, it is incorrect to claim that the DOE has selected a disposal option as the NRC staff has claimed in the present case.[14] In fact, the DOE has instead reiterated the long-expressed position that disposal in a low-level waste facility would be desired, but that additional analysis would need to be done before the suitability of any particular option could be determined.

Finally, in the present case, the NRC staff initially took a similar, but somewhat more nuanced position. In its 2004 draft EIS for the proposed National Enrichment Facility, the authors noted that

> The environmental impacts at the shallow disposal sites considered for disposition of low-level radioactive wastes would have been assessed at the time of the initial license approvals of these facilities. Final disposal of large quantities of depleted uranium at a licensed facility could require additional environmental impact evaluations depending on the location of the disposal facility and quantity of depleted uranium to be deposited.[15]

While weaker than the previous positions which had concluded that additional analysis will necessarily be required, the NRC staff retained the conclusion that additional analysis could be necessary to ensure that the proposed options for the bulk disposal of tens of thousands of metric tons of depleted uranium would meet all necessary performance objectives and dose limits.

The consistent and repeated conclusion that the classification of depleted uranium as low-level waste is not sufficient to determine a plausible disposal strategy is strengthened by the fact that previous analyses have shown that shallow land disposal of bulk DU_3O_8 is very likely to lead to peak doses well in excess of the 25 millirem (mrem) dose limit imposed by 10 CFR 61 Subpart C (Performance Objectives).[16]

For example, the 1992 analysis conducted at Sandia National Laboratories as part of the CEC license process concluded that

> Intruder radiological doses from the depleted uranium waste stream are large at all times given the assumptions used in the Draft Environmental Impact Statement for 10 CFR Part 61. The doses increase as daughters are produced from the initial uranium waste until about 2 million years. Calculated doses would

[12] CEC FEIS 1994 p. A-7
[13] Paducah FEIS 2004 p. 2-11 and Portsmouth FEIS 2004 p. 2-12
[14] NEF DEIS 2004 p. 2-32 and NEF FEIS 2005 p. 2-33
[15] NEF DEIS 2004 p. 4-58
[16] 10 CFR 61 2005 p. 168

> remain essentially constant for a very long time after 2 million years, until the radiological content begins to decrease from decay of U-238 and U-235.[17]

Using the scenarios, models, and parameters "adopted verbatim from the DEIS" for 10 CFR 61, the authors from Sandia found that the "intruder-construction" scenario would lead to effective doses from all pathways of 18.7 rem to 461 rem, between zero and two million years after placement of the waste. These doses are nearly 750 to more than 18,400 times higher than the 25 millirem dose limit. The authors also found that the long-term doses from the disposal of DU_3O_8 in the "intruder-agriculture" scenario would also likely be several orders of magnitude higher than the 25 mrem per year dose limit.[18]

Following this report, the NRC staff presented its own analysis of the shallow land disposal option in the final EIS for the Claiborne Enrichment Center.

> Using infiltration rate and aquifer flow rate for the humid southeastern site, the doses presented in Table A.3 [not shown] were estimated using the methods of this Environmental Impact Statement (EIS) for release from a near-surface U_3O_8 disposal facility. It should be noted that the estimated doses significantly above the limits specified in 10 CFR Part 61, even though the reported results do not include the potential effects of ingrowth of uranium daughters or of intruder construction scenarios. The analytic model and PRESTO results are consistent, indicating similarity of the pathway models.[19]

In this NRC staff analysis, the estimated drinking water doses alone were more than 20 times the allowed dose limit of 25 mrem per year. In light of this analysis the NRC staff concluded that because "projected doses exceed 10 CFR Part 61 limits, a deep disposal site is most likely to be selected for ultimate disposition of depleted uranium."[20]

In the present case, our November 2004 report addressed the option of shallow land disposal in a more arid environment than that considered in the CEC case. Performing a simple screening analysis using the ResRad dose modeling program we found that, even in an environment with low water infiltration, the long-half lives of uranium isotopes and the potential for erosion would combine to make it very unlikely that the 25 mrem dose limit would be met. In fact, our screening analysis calculated peak annual doses on the order of hundreds of rems occurring between about ten and twenty thousand years after placement of the waste. These results are consistent with the peak doses found in the Sandia analysis cited above.[21]

A final way to examine the likelihood of depleted uranium being able to meet the performance objectives of a shallow land disposal facility is to compare its concentration to the limit included in the proposed 10 CFR 61 rule. This proposed limit was noted by the NRC in its January 18, 2005 ruling on the classification of DU as low-level waste cited above.[22] In the draft 10 CFR 61 rule, the depleted uranium limits for Class A, B, and C waste were all 50 nanocuries per cubic centimeter.[23] Between the proposed and final rules, however, the limit on the long-lived alpha-emitting transuranic radionuclides was increased by a factor of ten from 10 nanocuries per gram to 100 nanocuries per gram. The final EIS noted that this change was due to

> (1) the reduced likelihood of significant intruder exposures with incorporation of passive warning devices at the disposal facility, and (2) the difficulty of contacting waste disposed of at greater depths. Another consideration is that the average concentrations in waste would be expected to be less than the peak concentrations…[24]

Even if we apply this same factor of ten to the uranium limit in the proposed rule, the value of interest for uranium-bearing wastes would be 500 nanocuries per cubic centimeter.

In filings to the NRC dated March 29, 2005 and April 8, 2005 regarding the costs of deconverting and disposing of the depleted uranium, LES discussed a number of possible densities for the DU_3O_8 that they propose to generate. These densities ranged from [redacted] grams U per cubic centimeter of waste for grouted material to [redacted] grams U per

[17] Kozak et al. 1992 p. 48
[18] Kozak et al. 1992 p. 7, 12-14, and 19-20
[19] CEC FEIS 1994 p. A-9
[20] CEC FEIS 1994 p. A-9 to A-10
[21] See [Makhijani and Smith 2004 p. 23-29]
[22] NRC 2005 p. 26
[23] 10 CFR 61 Proposed p. 38097
[24] 10 CFR 61 FEIS 1982 p. 5-33

cubic centimeter of waste for assuming the density of material from [redacted].[25] At these densities, the depleted uranium oxide from the deconversion of the tails from the proposed NEF would have an activity concentration of [redacted] to [redacted] nanocuries per cubic centimeter. This range is [redacted] to [redacted] times the Class C limit in the proposed 10 CFR 61 rule and [redacted] to [redacted] percent higher even if we were to take into account the possible increase of the proposed limit by a factor of ten.

Despite the long history of the position that additional analysis is required before a plausible strategy for the disposal of large quantities of depleted uranium can be selected, as well as the fact that the analyses that have been done thus far have indicated that bulk DU is not likely to be suitable for shallow land disposal, the final EIS for the proposed NEF facility has concluded that no additional analysis is necessary if a licensed low-level waste disposal facility is chosen. This conclusion is presented in two parts in the final EIS. First, the NRC staff now claims that

> In Memorandum and Order CLI-05-05, the Commission concluded that depleted uranium is appropriately categorized as a low-level radioactive waste. Therefore, for the purpose of this EIS, the DUF_6 generated by the proposed NEF will be treated as a Class A low-level waste.[26]

However, the Commission's January 18, 2005 ruling referenced in the above quote from the NEF final EIS explicitly declined to decide the issue of how depleted uranium would be classified under the scheme in 10 CFR 61.55. In particular, while noting that both sides addressed the issue of depleted uranium's proper classification if considered low-level waste (i.e. Class A, B, C or GTCC), the Commission ruled that

> … because our decision rests on the relevant statutes – the USEC Privatization Act and the Low-Level Radioactive Waste Policy Act – we need not reach the issues concerning § 61.55(a)(6) that have been presented in the briefs.[27]

In other words, the Commission has yet to address the issue of classification beyond the fact that depleted uranium falls under the general rubric of low-level waste. Our November 2004 analysis shows that, in fact, depleted uranium is most directly analogous to TRU (GTCC) waste in terms of its radiological properties, and not comparable in this respect to Class A wastes.

Second, after making the claim that DU is Class A waste, the NRC staff goes on to conclude that

> The environmental impacts at the shallow disposal sites considered for disposition of low-level radioactive wastes would have been assessed at the time of the initial license approvals of these disposal facilities or as a part of any subsequent amendments to the license. For example, under its Radioactive Materials License issued by the State of Utah, the Envirocare disposal facility is authorized to accept depleted uranium for disposal with no volume restrictions…. As Utah is an NRC Agreement State and Envirocare has met Utah's low-level radioactive waste licensing requirements, which are compatible with 10 CFR Part 61, the impacts from the disposal of depleted uranium generated by the proposed NEF at the Envirocare facility would be SMALL.[28]

While the first sentence of this statement is the same as in the 2004 draft EIS, the conclusion that additional analysis could be required was replaced by the claim that the Envirocare license already authorizes the acceptance and disposal of any volume of depleted uranium. Thus, in effect, the NRC's environmental impact analysis contains no analysis of environmental impacts for shallow land disposal before declaring them to be "small." The final EIS is seriously deficient for abandoning the previous position of the NRC, DOE, and others on the need for further analysis and for not including any substantive discussion of the impacts from shallow land disposal. We will address some of the specific issues surrounding the ability of Envirocare to accept the depleted uranium waste from the proposed NEF in the following section. Data free analyses should not be acceptable in any venue, but it is especially unacceptable in an environmental impact statement prepared by a government agency charged with protecting public health and safety.

[25] Krich 2005 and Krich 2005b
[26] NEF FEIS 2005 p. 2-27
[27] NRC 2005 p. 27
[28] NEF FEIS 2005 p. 4-63

Section 1.2 – The Envirocare Option

A number of important events have occurred since our November 24, 2004 report was completed in relation to considerations of disposing of depleted uranium at the Envirocare, Utah site. In the final EIS, the NRC staff concluded that

> The disposition of the depleted U_3O_8 generated from the DOE conversion facilities at Paducah and Portsmouth would be either at the Envirocare site (DOE's proposed disposition site) or at the Nevada Test Site (DOE's optional disposal site). Due to the need for separate regulatory actions prior to disposal at WCS, it is assumed that the depleted U_3O_8 generated from the adjacent or offsite private conversion process would be disposed at another disposal site licensed to accept this material. For example, under its Radioactive Materials License issued by the State of Utah, Envirocare is authorized to accept for disposal the quantities of depleted uranium oxides expected to be generated by the conversion of the proposed NEF's DUF_6.[29]

In regard to the impacts from shallow-land disposal at Envirocare they note that

> Several site-specific factors contribute to the acceptability of depleted uranium disposal at the Envirocare site, including highly saline groundwater that makes it unsuitable for use in irrigation and for human or animal consumption, saline soils unsuitable for agriculture, and low annual precipitation.[30]

To support these claims, the NRC staff cite Amendment 20 to the Envirocare license that was adopted on November 23, 2004 and a February 24, 2005 discussion between the NRC staff and staff of the Utah Division of Radiological Control (DRC).[31]

In early February 2005, however, Envirocare officially withdrew its license application seeking approval from the State to allow the acceptance of Class B and C low-level waste. Envirocare's withdrawal of this application came shortly before citizen's efforts were successful at convincing the Utah State House and Senate to pass legislation banning the import of these more dangerous wastes into the state. The measure was strongly supported in the State legislature (26 for, 0 against, and 3 absent in the Senate vote and 57 for to 13 against in the House) and was signed into law by the Governor on February 25, 2005.[32] As noted in the previous section, the classification of depleted uranium under 10 CFR 61.55 has not been officially resolved by the Commission, and our analysis shows that, based on its radiological properties, it should not be included in the Class A definition if the Commission were to take up this consideration under 10 CFR 61.58. The fact that Envirocare is no longer seeking to accept more dangerous classes of low-level waste, and the fact that the legislature has permanently banned such wastes from being imported to the State, makes it more likely that DU from the proposed NEF or from the DOE deconversion facilities would not be acceptable for disposal at this location.

In addition, it is also important to note that, in addition to the decision to abandon the application for a Class B and C license, Envirocare's Amendment 20 upon which the NRC staff based its analysis in the final EIS has been superseded by Amendment 22. This new amendment was formally adopted on June 13, 2005. This change is quite important because Amendment 22 inserted a limit on the "Maximum Radioactivity and/or quantity" of depleted uranium that "the licensee may possess at any one time" given as "250 pounds, 56.8 millicuries or 110,000 picocuries of Depleted Uranium."[33] Assuming a specific activity for pure DU of 396.7 nanocuries per gram, then 250 pounds would be equivalent to 45.1 millicuries, and 56.8 millicuries would be equivalent to 315 pounds. The third limit of 110,000 picocuries is more than five orders of magnitude smaller than either of these values. To be conservative, we will consider only the largest effective limit of 56.8 millicuries in our analysis.

Using the density of uranium in the waste as cited by LES in their March and April 2005 filings with the NRC, we find that a single 55 gallon drum would contain between [redacted] and [redacted] millicuries of uranium.[34] These amounts are nearly [redacted] to [redacted] times the largest possession limit for depleted uranium given in license Amendment 22.[35]

[29] NEF FEIS 2005 p. 2-33
[30] NEF FEIS 2005 p. 4-63
[31] NEF FEIS 2005 p. 2-33, 2-63, 4-63, 4-84, and 4-88 and Blevins 2005
[32] Envirocare 2005b, Bauman 2005, Bauman 2005b, and Henetz 2005
[33] Envirocare 2005 p. 1-2
[34] Krich 2005 and Krich 2005b
[35] Krich 2005, Krich 2005b, and Envirocare 2005 p. 2

For disposal, a number of drums would likely have to be shipped, accepted, and temporarily stored at the same time, further increasing the amount of DU involved. While the license condition in Amendment 22 applies specifically to a "Custom Source – 55 gallon drum containing Depleted Uranium shavings in a homogenous concrete mix,"[36] the similarity of this waste to bulk depleted uranium oxide in a 55 gallon drum makes it very unlikely that the far larger quantities being considered could be possessed by Envirocare if sent from a deconversion facility for the proposed NEF or from the DOE.

The likely unacceptability of the Envirocare site for disposal is further strengthened by considering the results of the original performance assessments from 1990 used to support the initial license for the site. These reports, referenced in the February 2005 conversation between the NRC and Utah DRC staff, placed limits on the concentration of depleted uranium in the waste that would be allowed for disposal. Applying these types of limits today would likely disallow the bulk disposal of DU_3O_8. Under the "intruder-agriculture" scenario they considered, the concentration limits for depleted uranium that would yield an annual dose of 100 millirem were 65.5 nanocuries per gram for doses calculated 30 years after waste placement and 25.1 nanocuries per gram if the doses were calculated 1,000 years after placement. These early performance assessments also considered an "intruder-construction" scenario with a dose limit of 500 mrem per year. If this scenario considered a 100 mrem per year dose limit as was done for the intruder-agriculture scenario, the concentration limit for depleted uranium evaluated at 1,000 years would have been 275.4 nanocuries per gram. The use of a 25 mrem per year dose limit would, of course, further lower all of these disposal limits. Finally, a concentration limit based on limiting worker doses to 5,000 mrem per year was found to be 110 nanocuries per gram by these performance assessments.[37] The activity of the bulk DU_3O_8 from the proposed NEF facility would exceed each of these concentration limits.

The results of our November 2004 screening analysis for shallow land disposal, the results of the early performance assessments for the Envirocare site, the February 2005 decision by the site operators to no longer seek acceptance for disposal of Class B and C wastes, the permanent ban on the import of the wastes by the State Legislature, and the June 2005 adoption of license Amendment 22 which sharply limits the possession of some types of depleted uranium bearing wastes all point to the likely unacceptability of the Envirocare site for the disposal of depleted uranium. The analysis in the NRC Staff's final EIS is erroneous and deficient on a number counts which lead to the conclusion that Envirocare is not a plausible strategy for the disposal of DU from the proposed NEF facility.

Section 1.3 – The Waste Control Specialist Option

In the final EIS for the NEF, the NRC staff notes the following considering the actions that would be necessary before it would be possible to dispose of the depleted uranium from the NEF facility at the proposed Waste Control Specialists (WCS) site in Andrews County, Texas:

> Before the depleted uranium generated by the proposed NEF could be disposed at the proposed WCS Compact Facility, a series of legal procedures and approval processes would have to be successfully addressed. These procedures and processes include:
>
> 1. Approval by the State of Texas of WCS's application, including authorization by the State for the WCS Compact Facility to accept for disposal depleted uranium oxides of the type and quantities expected to be generated as a result of the proposed NEF's operations;
> 2. Approval by the Rocky Mountain Compact (in which the proposed NEF would be located) for the export of the depleted uranium oxides from the Compact; and
> 3. Approval by the Texas Compact for the import and disposal of the depleted uranium oxides generated as a result of the proposed NEF's operations.[38]

They go on to specifically recognize that "[a] separate licensing process could be required to obtain approval from the State of Texas" for the disposal of DU even if the general low-level waste application is eventually granted.[39] In light of these considerations, the NRC staff concluded that

[36] Envirocare 2005 p. 2
[37] Blevins 2005 p. 2, Baird et al. 1990 p. 5-12, and Baird et al. 1990b p. 25
[38] NEF FEIS 2005 p. 2-32 to 2-33
[39] NEF FEIS 2005 p. I-83 (in the electronic version of the FEIS this quote appears on page I-82)

> Due to the need for separate regulatory actions prior to disposal at WCS, it is assumed that the depleted U_3O_8 generated from the adjacent or offsite private conversion process would be disposed at another disposal site licensed to accept this material.[40]

Surprisingly, the NRC staff's preferred option in the final EIS (disposal at Envirocare) is not the same as the apparent preferred option of LES (disposal at WCS). In fact, the apparent choice of LES to pursue disposal at WCS which was explicitly removed from consideration by the NRC staff in the final EIS as noted above. In a memorandum of agreement signed on January 14, 2005, the presidents of LES and WCS expressed their

> … [redacted][41]

In particular, the discussions would be to consider a contract for WCS accepting [redacted] years worth of depleted uranium from a private deconversion facility amounting to a total of [redacted] metric tons of DU_3O_8 or [redacted] tons of DU. This quantity is less than [redacted] percent of the 133,000 metric tons of DU that the proposed NEF facility would be expected to generate over its operational lifetime.[42] The failure to include an analysis of the environmental impacts from disposal at the WCS in light of this agreement is a serious deficiency of the final EIS. Specifically, we do not believe that the FEIS has provided any environmental or technical basis for granting a license to LES in which the disposal of the depleted uranium would be done at the proposed WCS facility.

In addition to the lack of analysis in the FEIS, a particular concern regarding the information contained within the memorandum of agreement between LES and WCS is the claim that

> [redacted][43]

An examination of the license application filed by WCS on August 4, 2004, which was finally ruled administratively complete and accepted for technical review by the State of Texas on February 18, 2005, calls this representation into question.

The WCS license application is for two facilities, a Federal Waste Facility (FWF) that proposes to accept low-level waste from DOE facilities and a Compact Waste Facility (CWF) which would accept waste from the Texas Compact states of Texas, Vermont, and Maine. The depleted uranium from the proposed NEF would be disposed of in the CWF if accepted by the Texas Compact Commission. However, the WCS license application does not include a single consistent number for the volume of the Compact Waste Facility. In different parts of the application the effective volume of the CWF is discussed as being equal to

250,000 cubic yards,[44]
345,700 cubic yards,[45] and
926,000 cubic yards.[46]

In addition, there is the question of the effective density with which the waste will be placed into the disposal cell. All waste that will placed in the CWF is planned to be placed within large concrete canisters to help remove void spaces and to stabilize the site over time. The effective density of waste in the disposal cell is thus lowered by the inclusion of the canisters and the other amounts of concrete used as fill. This packing density is claimed to be approximately 30 percent at one point in the license application, however, an examination of the geometry of the

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[40] NEF FEIS 2005 p. 2-33
[41] MOA 2005 p. [redacted]
[42] MOA 2005 p. [redacted] to [redacted]
[43] MOA 2005 p. [redacted]
[44] WCS 2004 p. 3.0-1-1
[45] WCS 2004 p. 5-4
[46] WCS 2004 p. 8.0-6-29

canisters used to contain waste in 55 gallon drums would give a maximum packing density of just 18.2 percent.[47] We will use the larger volume and the lower packing density in our examination of the WCS application since the DU would most likely be sent for disposal in 55 gallon drums.

If the full 133,000 metric tons of DU were sent to WCS, this would amount to [redacted] to [redacted] cubic yards of bulk DU_3O_8 assuming a density of [redacted] grams U per cubic centimeter for grouted waste and [redacted] grams U per cubic centimeter for un-grouted waste as was done by LES in their March and April 2005 filings with the NRC.[48] If this full volume was disposed of along with the entire inventory of Texas Compact waste assumed by WCS, the depleted uranium from this one enrichment facility would amount to [redacted] to [redacted] percent of the total volume of all waste disposed of in the CWF. The remaining [redacted] to [redacted] percent of the volume would consist of the waste from more than 35 different generators in the Texas Compact, including the decommissioning wastes from six nuclear power reactors. In other words, the depleted uranium from the proposed NEF would amount to a significant increase in the total volume of waste disposed of in the CWF.[49] In fact, if the smaller excavation volume of the disposal cell of 250,000 cubic yards is considered, the volume needed to dispose of the DU in the canisters for 55 gallon drums would amount to [redacted] to [redacted] percent more than the entire volume of the Compact Waste Facility.

More important than the shear volume of waste, depleted uranium oxide is not radiologically similar to the waste inventory that is currently considered for disposal in the CWF in the license application's performance assessment. Specifically, the assumed inventory of the waste in the CWF includes very little uranium. The amounts considered for the three uranium isotopes of interest were just

U-234 2.17×10^{-2} curies
U-235 4.29×10^{-5} curies
U-238 2.02×10^{-1} curies.[50]

On the other hand, the total amount of depleted uranium from the proposed NEF would include

U-234 8,250 curies
U-235 730 curies
U-238 43,775 curies.[51]

This is more than 235,700 times the amount of uranium activity considered in the current WCS license application. Even if the smaller amount of [redacted] tons of DU mentioned in the January 2005 memorandum of agreement is considered (two years worth of product from a private deconversion facility for the DUF_6), the waste would still contain

U-234 [redacted] curies
U-235 [redacted] curies
U-238 [redacted] curies.

This would still be more than [redacted] times the uranium activity included in the CWF performance assessment.

In addition, if disposed of, the depleted uranium would dominate the long-lived radioactivity in the CWF. If the full inventory of DU from the proposed NEF was disposed of, after 2,000 years only three radionuclides in the other compact waste considered would have a total activity greater than 1 percent of the DU activity. These radionuclides would be

Radium-226	7.8 percent of the DU activity
Nickel-59	5.0 percent of the DU activity
Carbon-14	2.5 percent of the DU activity

[47] WCS 2004 p. 5-4, 3.0-1-23, 3.0-1-24, 3.0-1-26 and 3.0-1-29

[48] The March 29, 2005 memorandum from LES states that its proposed cost estimates for disposal are based on the average of using a density of [redacted] to [redacted] grams per cubic centimeter for the DU_3O_8. [Krich 2005] For the grouted waste, we have retained the LES assumption for the uranium density as stated in their April 8, 2005 memorandum. However, we note that the LES density is more than [redacted] percent higher than the uranium density assumed in the 1997 Lawrence Livermore National Laboratory engineering analysis. The use of the LLNL density would significantly increase the volume of waste that would require disposal from the proposed NEF facility. [LLNL 1997 p. 6.13-1-17 and Krich 2005b]

[49] WCS 2004 p. 5-4 and 8.0-1-3 to 8.0-1-5

[50] WCS 2004 8.0-1-26

[51] This calculation assumes 133,000 metric tons of depleted uranium with the following isotopic composition: 99.749 percent U-238, 0.25 percent U-235, and 0.001 percent U-234. [LLNL 1997 p. 2-8]

The combined activity from all others radionuclides disposed of in all other compact wastes would amount to less than 5 percent of the DU activity. After 10,000 years, only the nickel-59 activity would be above 1 percent of the DU activity. By this time, the DU from the proposed NEF would account for more than 90 percent of the total activity of all wastes remaining in the CWF.[52] Even if just the smaller amount of DU was disposed of as discussed in the January 2005 memorandum of agreement, the depleted uranium would still be the majority of the total activity at 10,000 years, with nickel-59 being the only other single isotope with an activity above 10 percent of the total activity.[53]

The differences between the volume, specific activity, and half-life of bulk DU compared to the other types of low-level waste considered in the WCS assessment of the Compact Waste Facility was implicitly noted by the NRC when it acknowledged that additional licensing could be required for WCS to accept depleted uranium even if the original application was granted by the State. While it is true that WCS's performance assessment of the Federal Waste Facility considered large amounts of uranium bearing wastes, Section 1.5 will discuss the very serious concerns over this part of the performance assessment. In fact, as shown in Section 1.5, WCS is not competent to make any claims regarding the "[redacted]" *[characteristics]* of any uranium bearing wastes and should be disqualified from being licensed to accept or dispose of any uranium bearing wastes. In light of this conclusion it is interesting to note that the January 2005 memorandum of agreement explicitly states that

[redacted][54]

This type of agreement should not form the basis for a plausible disposal strategy, and should not be accepted by the NRC. Indeed, as we show below, some of the information in the WCS license application is scientifically wrong making this memorandum of agreement that has been arrived at before WCS has been granted a license more wishful thinking than a plausible strategy.

Section 1.4 – Considerations of the Potential Acceptability of the WCS Site for Disposal

Given that the WCS application contains no credible performance assessment for the disposal of bulk depleted uranium oxide powder in the Compact Waste Facility, and the fact that the NRC staff's final EIS also contains no analysis of shallow land disposal at the WCS or any other site, we have performed our own investigation as to the likelihood of disposal at WCS being acceptable based on the dose limit requirements in 10 CFR 61.

In the final EIS for the proposed NEF facility, the NRC staff note in relation to Envirocare that

> Several site-specific factors contribute to the acceptability of depleted uranium disposal at the Envirocare site, including a lack of potable groundwater, extremely low annual precipitation, and land use controls by Tooele County.[55]

However, poor water quality and an arid climate cannot be relied upon to prevent all types of inadvertent intrusion upon the site. The areas surrounding the Envirocare site have been used in the past for "grazing of sheep, jackrabbit hunting, and occasional recreation vehicle driving" prior to the placement of the disposal facility.[56] At the WCS site it was noted that "[t]he majority of the land within five miles of the Site is used for grazing and ranching activities."[57] In addition, future climate changes could lead to more favorable conditions for agricultural activities at the site and thus to an increased likelihood of such human intrusion.

For many types of intruder scenarios, the external radiation, inhalation, and soil ingestion pathways are relevant even if a resident or agricultural scenario was not considered. In this respect we note that the 1992 Sandia analysis

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[52] WCS 2004 8.0-1-26
[53] The nickel-59 activity at 10,000 years would be approximately [redacted] percent of the DU activity assuming that [redacted] metric tons of DU was disposed of in the CWF.
[54] MOA p. [redacted] (emphasis added)
[55] NEF FEIS 2005 p. I-86 (in the electronic version of the FEIS this quote appears on page I-85)
[56] Baird et al. 1990 p. 4-4 to 4-5
[57] WCS 2004 p. 2-9A

found, due to the ingrowth of radium-226 over time, that if the waste was not very mobile in the environment, than high intruder doses would be expected due to these types of pathways.[58] This same conclusions would also apply to arid or semi-arid sites with low levels of precipitation and water infiltration. In light of these considerations, we chose to focus our investigation of the potential suitability of the WCS site on the question of erosion since this process could lead to the waste becoming uncovered over time. This focus is consistent with the methodology set forth in the draft EIS supporting 10 CFR 61 which noted that

> Still, it is difficult to predict the effectiveness of measures intended to minimize erosion over the long term, and it is instructive to obtain an upper-bound estimate of the level of potential exposures that could occur if through some reason the waste did become exposed through erosion.[59]

While IEER continues to support the use of the resident farmer scenario as a means of accounting for possible future climate and land-use changes, we will not present such an analysis here since it is not necessary to show that the WCS site is unlikely to be acceptable for disposal of depleted uranium. Our November 2004 report includes both the agricultural and groundwater pathways as part of our screening analysis of a shallow land disposal site in an arid to semi-arid climate.[60]

The WCS site is located in a region that currently has a semi-arid climate.[61] The area across the proposed disposal site has a slope that varies from about 1 percent to a maximum of 3.3 percent.[62] With respect to the potential for erosion at the site, the WCS license application claims that

> As is typical of these arid climates, it is generally interpreted that active erosion processes have a minimal impact in the area. Lehman (2000) suggests that the present landscape of the Southern High Plains is in dynamic equilibrium; erosion by overland flow is balanced by deposition through runoff, and wind erosion is balanced by sediment deposition from upwind source areas. Lehman (2000) concludes that, not only is the area not subject to significant long-term erosion, the area is more likely subject to slow depositional buildup due to addition of wind-blown sand and sediments.[63]

The paper cited is entitled *An Assessment of Long-term Erosion Potential at the WCS Facility, Andrews County, Texas* which was prepared by Thomas M. Lehman at the Department of Geosciences, Texas Tech University. This paper was included as part of the WCS license application.

In direct contradiction to this conclusion, however, we found that an April 1996 draft memo from Stephen D. Etter, a staff geologist with the Texas Natural Resource Conservation Commission (TNRCC), expressing the preliminary conclusion that

> The WCS site [in Andrews County] is clearly an erosional area and nothing short of a wholesale change in geologic and climatic conditions is likely to alter the situation in the foreseeable future. Even stopgap engineering measures to slow erosion must be considered only temporary fixes in the long-term. Eventually the radioactive wastes will be exposed by erosion and available for migration into the environment.[64]

We have been able to find no documents from the State contradicting this initial opinion. In fact, an April 26, 2005 review of the merits of the current WCS application (although not its technical accuracy) by the Texas Commission on Environmental Quality noted that "[a]dditional information may be required on soil erodability indices and data quality regarding the soil formations."[65]

In addition to the above, the preliminary position from Stephen Etter also noted that

> Detailed geomorphological studies have not been done for the Andrews County site and long-term erosion rates are not known. The site is located directly on the caprock "escarpment," which, although at the site appears relatively flat to the eye, is a gently sloping erosional feature. Rough calculations by the staff

[58] Kozak et al. 1992 p. 49
[59] 10 CFR 61 DEIS 1981b p. M-14
[60] [Makhijani and Smith 2004 p. 23-25]. For a further discussion of the use of the resident farmer scenario in the context of setting cleanup standards at former DOE facilities see [Makhijani and Gopal 2001].
[61] WCS 2004 p. 2-30, 2-33, and 2-49 and Schenk and Jackson 2002 p. 482
[62] WCS 2004 in Appendix 2.6.1 p. 4-29 to 4-30 and WCS 2004 in Attachment 3.0-3.18
[63] WCS 2004 p. 2-43
[64] Etter 1996 p. 7
[65] Wheatley 2005 p. 5 of Attachment A

> indicate that if the escarpment in the vicinity of the WCS site continues to retreat due to erosion at the same average rate that it has retreated since the integration of the Pecos River system 600,000 to 2 million years ago, then wastes disposed of at the WCS site could be exposed and removed within 5,000 years.[66]

In the paper from Thomas Lehman, the author notes that

> The position of the Caprock Escarpment in the vicinity of the WCS facility is very difficult to determine because, unlike along the eastern and northern border of the High Plains, there is no prominent topographic expression.[67]

and that

> A number of authors have produced similar estimates for the rate of retreat of the eastern escarpment of the High Plains based on geomorphic history (see Table 1) [not included]. These estimates range from 4 cm/yr to a maximum of 19 cm/yr, and were summarized by Gustavson and Simpson [Simpkins] (1989) who regarded a range of 6 to 18 cm/yr as realistic.[68]

If we take the "long-term estimates based on geomorphic history" for the rate of retreat of the eastern edge of the caprock escarpment (6 to 18 cm per year) and the location of its nearest boundary (which is perhaps as little as 5 km away from the WCS site), we find that Professor Lehman's own work would support the conclusion that it might take as little as 28,000 to 83,000 years for erosion to breach the site.[69] Given the uncertainties surrounding these estimates, the results from Professor Lehman's analysis are reasonably consistent with the lower bound time cited by Etter. This consistency lends further support to the applicability of Etter's preliminary conclusions regarding erosion at the WCS site.

In order to address this stark conflict in overall conclusions between the work of Etter and Lehman, IEER sought the review of Dr. James Carr, a Professor of Geological Engineering at the University of Nevada-Reno.[70] His opinion (dated May 16, 2005) is included in full below:

> I have completed my review of the article, "An Assessment of Long-term Erosion Potential at the WCS Facility, Andrews County, Texas," by Thomas M. Lehman, Department of Geological Sciences, Texas Tech University. I have also reviewed the TNRCC Preliminary Staff Memo that discusses erosion at the WCS Site.
>
> With respect to the Lehman paper, I have the following concerns:
>
> 1. Rates of erosion (denudation) are highest for semi-arid environments; the climate at the WCS site is semi-arid, consequently this geographic location should be expected to have a net loss of sediment with time, not a net accumulation; I agree with the TNRCC Preliminary Staff Memo on this issue that the WCS site is an erosional area.
>
> 2. The Lehman paper seems to dismiss climate change as important to the WCS site, although indicating at the bottom of page 3 that the last episode of incision by streams near the WCS site was 20,000 years ago to 12,000 years ago, a period of time that was associated with the most recent ice age; this paper later (page 15) dismisses climate change as a potential problem by noting that increased aridity is predicted to result in the formation of sand dunes consistent with nearby geomorphological features and further stating that increased humidity will result in denser vegetative cover with associated decrease in erosion. In fact, increased aridity may result in increased erosion because vegetation cover is decreased, moreover erosion by water is the most potent erosive agent in deserts; maximum rates of denudation in arid regions are sometimes unknown and may exceed rates observed in semi-arid regions, rates in excess of 100 cm in 1000 years. If precipitation

[66] Etter 1996 p. 7
[67] WCS 2004 in Appendix 2.5.3 p. 9
[68] WCS 2004 in Appendix 2.5.3 p. 11
[69] WCS 2004 in Appendix 2.5.3 p. 11-12
[70] From 1983 to 1986 James Carr was an Assistant Professor of Geological Engineering at the University of Missouri-Rolla and has been a professor of Geological Engineering at the University of Nevada-Reno since then (Assistant Professor – 1986 to 1989, Associate Professor – 1989 to 1994, and Professor – 1994 to present). He has authored numerous peer reviewed technical papers and is the author of two textbooks entitled *Numerical Analysis for the Geological Sciences* (1995) and *Data Visualization in the Geosciences* (2002). The complete curriculum vita of Professor Carr accompanies this report. Dr. Carr provided his opinion to IEER pro bono for which we thank him.

increases at the site, it is uncertain how rapidly vegetation density will increase with increased moisture levels. Erosion rates may be very high initially until vegetation density increases.

3. The most uncertain aspect of long-term erosion rates at the WCS site is the affect that changes in climate will have. Construction of the WCS facility should include a design for erosion mitigation. The maximum rate of erosion observed anywhere is that which occurs in Badlands-type topography, up to 1 meter of erosion per year (100,000 cm over 1000 years; Saunders and Young, 1983, "Rates of surface processes on slopes, slope retreat and denudation," Earth Surface Processes and Landforms, v. 8, pp. 473-501). Rates or denudation in semi-arid regions are 10 to 100 cm over 1000 years (0.01 to 0.1 cm per year) and rates of denudation in arid regions range from as little as 1 cm per 1000 years to a maximum amount that is not known. Given this highly variable rate of erosion, the design of the WCS facility should include erosion control.

4. Rates of erosion for different climates are listed below and are from the Saunders and Young, 1983, article that is referenced in item 3 above:

Climate	Relief	Range of Erosion Rates
Glacial	Normal (ice sheets)	5 – 20 cm / 1000 years
	Valley Glaciers	100 – 500 cm / 1000 years
Polar		1 – 100 cm / 1000 years
Temperate maritime	Normal	1 – 10 cm / 1000 years
Temperate continental	Normal	1 – 10 cm / 1000 years
	Steep	10 – 20+ / 1000 years
Mediterranean	Normal	1 – ? cm / 1000 years
Semi-arid		10 – 100 cm / 1000 years
Arid		1 - ? cm / 1000 years
Subtropical		1? – 100? cm/1000 years
Savanna		10 – 50 cm / 1000 years
Rainforest	Normal	1 – 10 cm / 1000 years
	Steep	10 – 100 cm / 1000 years
Any Climate	Badlands	100 – 100,000 cm / 1000 yrs

Please let me know if you have any questions about this letter, or need clarifications of any statements herein.[71]

The rate of erosion cited by Professor Carr in relation to the general climate of the WCS site (0.01 to 0.1 centimeters per year) is consistent with other ranges that have been used in evaluating shallow land disposal sites as discussed below.[72] For example, the draft EIS supporting 10 CFR 61 cited previous NRC and DOE analyses of waste disposal sites that considered erosion rates equivalent to 0.015 to 0.1 centimeters per year. The draft EIS chose to consider the highest rate of erosion which they noted was "associated with typical farming activities" in order to calculate the upper bound impact of erosion.[73] The WCS license application itself includes an analysis of water erosion using the Universal Soil Loss Equation and today's climate parameters to estimate an erosion rate of 0.0023 cm per year and "empirical methods" based on the Natural Resource Conservation Service maps for agrarian applications to estimate an upper bound wind erosion rate of 0.074 to 0.098 cm per year.[74] In addition the WCS application notes that "[t]he hazard of soil blowing is noted as moderate," but retains the conclusion of Professor Lehman that the site will slowly accrue material rather than erode.[75] Finally, the erosion rate considered in our screening analysis from November 2004 was 0.05 to 0.1 cm per year.[76] These values are summarized in the following table.

[71] Carr 2005
[72] The recommendations from Professor Carr cite the results of [Saunders and Young 1983 p. 493-497] which considers primarily data from the U.S. west for its analysis of erosion in semi-arid climates.
[73] 10 CFR 61 DEIS 1981 p. 5-86 and 10 CFR 61 DEIS 1981b M-16 to M-18
[74] WCS 2004 in Appendix 3.0-3.18
[75] WCS 2004 in Appendix 2.6.1 p. 4-30 to 4-31
[76] Makhijani and Smith 2004 p. 23-25

Source	Description of Site Considered	Erosion Rate (centimeters per year)
Draft EIS for 10 CFR 61[(a)]	generic analysis of a shallow land disposal site	0.015 to 0.1
IEER November 2004 Analysis[(b)]	arid to semi-arid environment, screening analysis	0.050 to 0.1
WCS License Application[(c)]	upper bound rate at proposed site of the WCS disposal facility	0.076 to 0.1
Comments of Dr. James Carr[(d)]	long-term rate in semi-arid climates, normal slope	0.010 to 0.1

(a) [10 CFR 61 DEIS 1981b p. M-16 to M-18]
(b) [Makhijani and Smith 2004 p. 24-25]
(c) [WCS 2004 in Attachment 3.0-3.18]
(d) citing [Saunders and Young 1983 p. 493-497]

The thickness of the cover used in the Compact Waste Facility performance assessment is 12.3 meters, and therefore any erosion rate greater than 0.0123 centimeters per year will lead to the waste becoming uncovered within the first 100,000 years.[77] An examination of the ranges for erosion rates cited in the above table reveals that only the lowest rate cited by Professor Carr lies below this value, and that therefore it is likely that the waste will become uncovered at the WCS site at some point within the next 100,000 years. To examine the impact that erosion will have on the performance of the site we reproduced the ResRad calculations used in the WCS performance assessment of the CWF, but included the full inventory of depleted uranium from the proposed NEF facility and a non-zero rate of erosion. We used the same methodology to determine the average waste concentration in the disposal cell as was applied in the WCS application, and averaged the total depleted uranium activity over the total volume of the cell including the concrete canisters and fill material. The only conceptual difference between our model runs and those of WCS is that we considered a 100 percent outdoor occupancy and restricted the pathway analysis to only the external, inhalation, and radon pathways to enable a consideration of exposures to intruders such as ranchers who may not build a house or grow food on the site. Occupancy and the conduct of agricultural activities on the site would decrease the importance of the external and inhalation pathways somewhat due to shielding in the home, but would significantly increase the doses from radon and from consumption of contaminated food as the cover was eroded and direct uptake through the roots became possible.

In our ResRad analysis, we considered two disposal options for the waste, one grouted at a density of [redacted] grams U per cubic centimeter and one un-grouted at a density of [redacted] grams U per cubic centimeter. The details of the site parameters that differ from the CWF assessment in the WCS license application are given in the following table.[78]

	Grouted Waste	Un-grouted Waste
Depth of Contaminated Zone	13.1 meters	13.1 meters
Area of Contaminated Zone	[redacted] square meters	[redacted] square meters
Length Parallel to Aquifer	[redacted] meters	[redacted] meters
Effective Activity of U-238	[redacted] nCi/gm	[redacted] nCi/gm
Effective Activity of U-235	[redacted] nCi/gm	[redacted] nCi/gm
Effective Activity of U-234	[redacted] nCi/gm	[redacted] nCi/gm

For the erosion rates we considered the upper and lower bounds cited by Professor Carr as well as their geometric and arithmetic means. At these rates it would take the following amount of time to first uncover the waste

123,000 years (0.01 centimeters per year)
38,438 years (0.032 centimeters per year – geometric mean)

[77] WCS 2004 p. 8.0-6-32
[78] For a description of the other non-default ResRad parameters used in our assessment see [WCS 2004 p. 8.0-6-28 and 8.0-6-32].

22,364 years (0.055 centimeters per year – arithmetic mean)
12,300 years (0.1 centimeters per year).

The peak doses from the external and inhalation pathways will occur at a slightly later time due to the continued buildup of radium-226 in the DU as the waste continues to erode. The following table summarizes the results of our ResRad runs for these input parameters.

	Grouted Waste		Un-grouted Waste		
Erosion Rate (cm per year)	Peak External Dose (rem per year)	Peak Inhalation Dose (rem per year)	Peak External Dose (rem per year)	Peak Inhalation Dose (rem per year)	Year of Peak Dose
0.01	7.31×10^{-12}	0	8.97×10^{-12}	0	100,000
0.032	121.2	3.12	148.4	3.75	78,286
0.055	73.7	2.61	90.2	3.13	45,540
0.1	44.1	2.17	53.9	2.61	25,060

As is clear, all of the doses (external plus inhalation) for the higher erosion rates are above the 25 mrem per year dose limit by more than three orders of magnitude. The peak dose at the lowest erosion rate would be even higher, but it would not occur until sometime after 123,000 years which is beyond the timescale the ResRad is capable of considering. Significantly, if we consider just the two mean erosion rates and sum the doses from the external and inhalation pathways, than we find that it would take just 1.44 to 2.87 hours on the site to violate the 25 mrem per year dose limit.

These doses are generally consistent with the external dose calculation from the 1992 Sandia study for the intruder scenario under the 10 CFR 61 methodology. At 10,000 years, Kozak *et al.* found that the external dose would be 13.5 rem per year with Ra-226 contributing more than three-fourths of that dose. At secular equilibrium (about 2 million years after placement) the external dose would rise to 407 rem per year with radium-226 accounting for more than 99 percent of the dose. These values are nearly 550 to more than 16,200 times greater than the 25 mrem limit. Given that the Sandia analysis considered a different volume of waste and used a different type of dose calculation and different assumptions regarding such things as the dilution of the uranium in the disposal site, and that the results are calculated at different times with different amounts of radium-226 ingrowth, these sets of results are in satisfactory agreement.[79]

In addition to the external and inhalation doses discussed above, we note that at all levels of erosion, including the lower limit, the radon emanations at the time of peak dose are more than an order of magnitude higher than the EPA limit for any source at DOE facilities of 20 picocuries per square meter per second. For the geometric mean erosion rate of 0.032 centimeters per year, the radon emanations are more than two orders of magnitude larger than the EPA guideline at the time of peak external dose.[80] While this EPA regulation would not directly apply to a commercial disposal facility disposing of depleted uranium produced at the proposed NEF facility, the fact that the radon emanations would likely exceed this limit by one or two orders of magnitude needs to be considered in relation to the acceptability of such a strategy. This conclusion would be strengthened if the intruder scenario is considered to include a residence onsite. In such a case (75 percent indoors onsite and 25 outdoors onsite) the radon doses could exceed even the external pathway and amount to annual peak doses in excess of 100 rems even in the lowest erosion rate scenario.

Thus, once the likelihood of erosion is included in the WCS performance assessment, it becomes very unlikely that it would be able to meet the performance objectives of 10 CFR 61 in relation to the peak dose from the disposal of depleted uranium. The overall conclusions from our November 2004 report continue to stand in relation to the WCS site which has become the apparent preferred option of LES since January 2005. Given these results, the final EIS is seriously deficient for not considering the likely performance of the WCS site and for actually excluding it as an option to consider.

[79] Kozak et al. 1992 p. 13-14
[80] 40 CFR 61 2004 p. 143

Section 1.5 – Other Weaknesses of the WCS Performance Assessment

While the treatment of erosion is likely to be one of the most important weaknesses of the WCS license application as far as the quantitative assessment of site performance is concerned, there are a number of other weakness to the WCS application that should be addressed. The first such set of weaknesses relate to their treatment of water infiltration. In their calculations of the infiltration of water through the engineered cover system they use a value of 10^{-9} centimeters per second for the conductivity of the compacted clay performance layer, while their sensitivity analysis considers a higher value of 10^{-8} centimeters per second. These values are used despite the fact that the design criteria in the license application states only that "[t]he performance cover shall have a minimum effective saturated hydraulic conductivity of 1 x 10^{-7} cm/sec."[81] The consideration of higher conductivities should be included in the performance assessment.

In addition, WCS did not perform a proper uncertainty analysis for infiltration and leaching in that WCS did not consider the impact of changing multiple parameters simultaneously on the rate of water moving through the cover system. They changed the assumed level of precipitation and the assumed conductivity of the performance layer independently, but not together. Had they done so (i.e. used a precipitation of 28 inches per year and a conductivity of 10^{-8} centimeters per second), they would have found a long-term infiltration rate that was nearly 11 times higher than their baseline value (0.305 centimeters per year versus 0.0285 centimeters per year) and more than four times higher than their upper-bound (0.305 centimeters per year versus 0.0719 centimeters per year).[82] A more realistic upper bound for the infiltration rate should be used in the ResRad uncertainty analysis. Given the current design criteria, this upper bound should be derived from the consideration of a 10^{-7} centimeter per second conductivity and a doubling of the annual baseline rainfall to 28 inches per year.

Finally, other issues affecting the long-term performance of the cover in relation to the impact of erosion should be considered. These would include the overall loss of cover thickness with time, the potential for puddleing and pooling in erosional low-spots, and the potential for intrusion of vegetation roots as the top layers of the cover are eroded away. In particular, the WCS application notes that "there is a substantial likelihood that shrubs, especially mesquite (Prosopis spp.), will invade and ultimately dominate the cover after management is suspended."[83] The average thickness of the undisturbed cover over the CWF facility used in determining the rate of water infiltration is 8.84 meters while the cover thickness used in the ResRad calculation was 12.3 meters. Compared to these thicknesses we note that the maximum root depth of shrubs can range from an average of two to three meters to a 90 percent limit of as much as seven meters.[84] As the cover erodes there will likely be a long time during which roots could penetrate the performance cover layer and affect its hydraulic properties.

The second area of weakness in the WCS application relates to their treatment of the transport of radionuclides through the environment. The partition coefficients (K_d) used in the performance assessment for uranium were simply equal to the geometric mean values reported in the ResRad data collection manual and no site specific information was used beyond general soil type.[85] WCS also claimed that, due to the presence of grout, "[w]henever pH-dependent K_d values were available, the values for high pH were used."[86] Their uncertainty analysis considered a range of K_d values that were log-uniformly distributed from 10 times above to 10 times below their baseline.[87]

These baseline K_d values are also cited in the 1999 Environmental Protection Agency report entitled *Understanding Variation in Partition Coefficient, K_d, Values*. This EPA report shows that, even within a given class of soil, the K_d values can vary widely and be outside the generic range used by WCS. Specifically, the ranges cited for sandy and clay soils are

[81] WCS 2004 p. 3-29, 8.0-6-23, 8.0-6-25, and 8.0-7-4
[82] [WCS 2004 p. 8.0-7-4 to 8.0-7-5]. The results for the alternative water infiltration rates were derived from runs of the Hydraulic Evaluation of Landfill Performance (HELP) model conducted by George Rice. [personal communication]
[83] WCS 2004 p. 3.0-1-40
[84] WCS 2004 p. 8.0-6-24 and 8.0-6-32 and Schenk and Jackson 2002 p. 484
[85] WCS 2004 p. 8.0-6-28 and Yu et al. 1993 p. 110-111
[86] WCS 2004 p. 8.0-6-26
[87] WCS 2004 p. 8.0-7-7

	Observed Range	Range Used by WCS
Sand	0.03 to 2,200	3.5 to 350
Clay	46 to 395,100	160 to 16,000

The observed range from measurement data is nearly four to five orders of magnitude while the WCS range is just two orders of magnitude.[88] In addition, the EPA guidance document also includes a lookup table for uranium K_d's as a function of pH. The table shows that uranium K_d's are highest at neutral pH and decrease at both high and low pH. Thus the high pH conditions at the WCS site would also argue for considering a range with lower K_d's than was done by WCS.[89] These considerations echo the conclusions of the 1992 Sandia analysis which noted that

> Uranium solubilities can vary widely, even under fairly well established ground-water chemical conditions. As an example, a recent performance assessment was performed of an arid site for which substantial site-specific ground-water characterization was available; in this performance assessment the uranium solubility ranged over five orders of magnitude.[90]

The issue of radionuclide transport would become more important with an improved treatment of the rate of water infiltration as discussed above. Sufficient field measurements for the partition coefficient should be made at the site to ensure that the transport properties are reasonably understood before any performance assessment is accepted.

The third weakness of the license application is that despite the fact that WCS acknowledges that

> The area was heavily exploited for oil and gas reserves over the last 30 years. Two producing oil wells are located approximately 1.5 miles north of the proposed disposal site on WCS property. One non-producing well is located about one-half mile southwest of the proposed Site.[91]

Despite this history, the authors of the WCS license application go on to conclude that

> Subsurface petroleum product exploration, development, and production have been conducted in the area for over 75 years. Most of the oil wells in the vicinity of the Site have been abandoned or are in the process of secondary or tertiary recovery. The absence of oil wells on or near the proposed disposal Site supports the absence of favorable conditions for oil production. A single, non-operational oil well exists several hundred yards southwest of the proposed disposal site and is the nearest well to the Site that has produced oil. The status of this well, combined with the exploration and production history in the immediate area, make any future secondary recovery or other well activity unlikely. Several oil wells that did not produce were drilled within several miles of the proposed disposal site. These "dry wells" provide evidence that significant oil and gas reserves are unlikely in the area.[92]

Given the long history and large amount of resource exploration that has occurred in the area as well as the fact that presently producing wells are located within 1.5 miles of the site, it would be proper to consider the area around the proposed WCS facility to be a resource area and to therefore evaluate the impact of potential future oil and gas exploration. This conclusion is supported by the very long timescales over which the depleted uranium will remain dangerous if disposed of at the WCS site and the fact that abandoned areas could begin active production again as future prices for oil and gas rise and future technologies improve the ability to recover these resources.

The fourth weakness of the license application relates to the competence of WCS with respect to knowledge of even the most basic radiological and radiochemical properties of uranium. As noted in Section 1.3, the expected inventory for the Compact Waste Facility includes very small quantities of uranium. The Federal Waste Facility, on the other hand, is claimed to potentially dispose of large quantities of uranium bearing wastes. The inventory cited in the WCS license application for the FWF includes a total inventory of

[88] EPA 1999 p. J.18 and WCS 2004 p. 8.0-7-7
[89] EPA 1999 p. J.22
[90] Kozak et al. 1992 p. 49
[91] WCS 2004 p. 2-9A
[92] WCS 2004 p. 2-54 to 2-55

Isotope	Total Activity (Curies)	Percent of Total Uranium Activity	Implied Mass (Metric Tons)	Percent of Total Mass
U-238	21,700	28.5%	65,758	82.3%
U-235	31,200	40.9%	14,182	17.7%
U-234	23,300	30.6%	3.76	0.0047%
Total	76,200		79,943	

The FWF inventory cited by WCS in its performance assessment also includes 112 curies of thorium-230 and 387 curies of radium-226.[93]

On examination, the isotopic ratios of U-238, U-235 and U-234 in the above table are clearly incorrect and could not have been produced by any combination of enriched, natural, or depleted uranium. First, uranium-235 never contributes more than about 5 percent to the total specific activity of uranium at any level of enrichment. Thus, these total radioactivity numbers are unmistakably wrong. Second, the implied mass ratios are also clearly wrong. The implied average enrichment of the uranium in this waste is 17.7 percent, which is about 25 times the uranium-235 percentage in natural uranium. Therefore, the mass of U-234 in the waste would also have to be enriched. However, the numbers in the table do not show this to the be the case for the cited waste numbers. The claimed U-234 mass percentage is wrong by just above a factor of 25.[94] To have included these grossly erroneous numbers in a license application indicates that WCS has no understanding of uranium and its radiochemical properties. Moreover, a performance assessment based upon these erroneous inventory numbers physically cannot describe any real-world facility.

These fundamental errors are seen in more accentuated form in the following table showing the waste expected from two specific DOE facilities as they are reported in the WCS license application.[95]

	Paducah(1)	Oak Ridge(2)
U-238 (Curies)	3.13E+03	5.34E+01
U-235 (Curies)	2.97E+03	2.74E+04
U-234 (Curies)	3.22E+03	6.99E+02
U-238 (Metric Tons)	9,478.86	161.85
U-235 (Metric Tons)	1,348.60	12,448.23
U-234 (Metric Tons)	0.52	0.11
Implied Enrichment	12.45%	98.72%

(1) sum of Paducah LLRW Debris, MLLRW Debris Commercial, and MLLRW TBD
(2) sum of Oak Ridge Site Wide Commercial and Site Wide TBD

It is difficult to overemphasize the significance of the errors in these inventory tables. These errors show a lack of basic familiarity with the properties of uranium, of the history of production of U.S. enriched uranium, or of what might be reasonably expected in any realistic waste streams. For instance, the stated Oak Ridge waste stream contains a vast amount of highly enriched uranium ("HEU"). The stated quantity is more than 12 times the entire amount of HEU ever produced in the United States![96] Further, the mass percentage of U-234 in typical HEU is about 1 percent. This means that there should be about 120 to 130 metric tons of U-234 in a total mass of HEU amounting to about 12,500 metric tons. However, the U-234 amount cited is more than 1,000 times less than what

[93] WCS 2004 8.0-2-24 to 8.0-2-25
[94] This factor was incorrectly reported as "250" in the *Motion on Behalf of Intervenors Nuclear Information and Resource Service and Public Citizen for Admission of Late-Filed Contentions Concerning LES Disposal Strategy* filed with the Atomic Safety and Licensing Board on May 16, 2005. (Docket No. 70-3103, ASLBP No. 04-826-01-ML)
[95] [WCS 2004 p. 8.0-2-16 to 8.0-2-21]. Representative numbers from the WCS application for the Oak Ridge waste streams were checked against the cited source document [U.S. Department of Energy, *The Current and Planned Low-Level Waste Disposal Capacity Report, Revision 1*, September 18, ,1998].
[96] The total HEU produced in the United States was 994 metric tons. (see chapter two of *Closing the Circle on the Splitting of the Atom* online at http://legacystory.apps.em.doe.gov/text/close/close2.htm)

would be expected. Third, the total amount of natural uranium needed to produce the amount of HEU listed as Oak Ridge waste would be greater than the total amount that has ever been mined.

The Paducah waste streams reported in the WCS Application also have ratios that are impossible. The 12.45 percent enrichment implied in the Paducah waste should have a much higher weight percent of U-234 than the indicated 0.005 percent, which is characteristic of natural uranium. Moreover, the Paducah plant did not produce uranium that was enriched to such a high percentages of U-235.[97] It is a facility designed and operated to produce LEU. These statements in the WCS Application cast great doubt upon WCS as a prospective manager of large quantities of DU waste. It is clear that WCS lacks scientific capabilities in these most elementary matters relating to uranium. This situation indicates that WCS is completely unqualified to address issues relating to the impact of DU or its disposal. Given its complete lack of qualifications in the most elementary matters (literally and figuratively), WCS could not even reliably ensure that the uranium waste that could be shipped to it met the waste acceptance criteria and did not contain non-permitted materials. WCS should therefore be disqualified from consideration as a company that is qualified to accept or manage or dispose of DU from the proposed NEF.

The direct use of DOE waste numbers without even the most rudimentary reasonableness checks as was done by WCS is made worse by the long history of problems that have been identified with other DOE waste data. For example, in 1997 IEER issued a report pointing out that

> Volumes of wastes listed as buried TRU wastes in the DOE's Integrated Data Base Reports vary inexplicably from year to year. Moreover, these data are inconsistent with data reported in other documents. For instance at Los Alamos, there are two quite different estimates of the amount of plutonium in the waste -- one of 610 kilograms published by the DOE headquarters and the other 1375 published by the site. The enormous difference of 765 kilograms [of plutonium] is unexplained as far as we are aware.[98]

In a letter from the DOE's Assistant Secretary for Environmental Management to IEER regarding this report, Carolyn L. Huntoon noted that

> Your 1997 report indicated that DOE's "Official date on the volume, mass, and radioactivity of buried transuranic waste and transuranic soil are inconsistent and contradictory. There does not appear to be any scientific basis on which data are entered and changed from one year to the next, and one document to the next." ***The DOE agreed with this criticism*** and, in response, committed to "undertake a review and update of its information on its inventory of buried TYU wastes as well as the status of remedial decisions proposed or made to date." The DOE further committed to update the information using consistent and documented assumptions.[99]

In addition to these concerns over TRU waste, IEER has identified similar issues with the DOE's high-level waste inventory numbers as well. The data on the high-level waste inventories reported in the DOE's Integrated Data Base Reports from three past years is shown below.

Facility	FY 1994[(a)] (millions of curies)	FY 1996[(b)] (millions of curies)	FY 1999[(c)] (millions of curies)
West Valley	24.7	23.6	23.3
INEEL	51.6	48.4	300.1
Hanford	347.9	332.1	383.5
Savannah River Site	533.7	498.0	1,727.2
Total	957.9	902.1	2,434.1

(a) [DOE 1995 p. 66]
(b) [DOE 1997 p. 2-23]
(c) [DOE 2001 p. 4-23]

The FY94 and FY96 data are reasonably consistent with each other after taking into account a decay correction that assumes most of the activity remaining in the tanks is due to strontium-90 and cesium-137. The FY99 data for the

[97] The Paducah plant was originally built to enrich uranium to no more than 2 percent U-235. In 1995, certain parts of the Paducah plant were modified to allow enrichment to 2.75 percent. [NAS/NRC 1996 p. 17]
[98] Fioravanti and Makhijani 1997 p. 9
[99] [Huntoon 2000] emphasis added

three DOE facilities, however, is clearly not correct. While the value for Hanford is only about 24 percent too high based on the previous numbers, the value for the Savannah River Site is 3.7 times too high and the value for INEEL is more than 6.6 time too high. The SRS and INEEL numbers are literally incredible, and more than the total inventory of longer-lived radionuclides ever discharged to the tanks even without taking into account a decay correction.

Finally, the 2004 General Accounting Office has also noted that DOE waste data are unreliable in a report that the NRC is aware of because it is cited in both its draft and final EIS. In its report the GAO chose not to rely on the information from DOE's Manifest Information Management System (MIMS) "because of shortcomings in its usefulness and reliability."[100] The GAO went on to note that

> DOE takes no responsibility for verifying the accuracy of the data supplied by the disposal facility operators. Furthermore, while DOE takes some steps to ensure that it accurately uploads operator-supplied data into MIMS, it does not perform other systematic quality checks on the data on the data, such as "reasonableness" checks, cross tabulations, or exceptions reports. As a result, we determined that the lack of consistent and comprehensive internal controls, such as controls over information processing, undermine our confidence in the data output in MIMS for several types of information, including sources of waste coming from states, compacts, and generators.[101]

As a specific example of shortcomings in the DOE's data, the GAO noted that the volumes of low-level waste disposed of at Envirocare between 1999 and 2003 were reported at 10.4 million cubic feet by the site operator and 15.7 million cubic feet by MIMS. This difference of 5.3 million cubic feet of waste is more than 50 percent of the total volume disposed of according to the site operator.[102] The causes of the discrepancy were not investigated by the GAO, but it in view of the lack of checks even for reasonableness of the data, the earlier statement of the DOE made to IEER, cited above, regarding the lack of scientific basis for certain DOE waste data is worth keeping in mind in this current context.

The Department of Energy has thus demonstrated that its buried TRU, high-level waste, and low-level waste disposal numbers are not to be trusted at face value. Therefore, it is highly improper for WCS to have accepted the DOE's low-level waste estimates without comment. This is particularly so when the low-level waste estimates from the DOE are so obviously incorrect with respect to uranium as discussed above.

To manage and safely dispose of nuclear waste at a facility such as that proposed by WCS, the operator must obviously understand the nature and quantity of the various radionuclides that it plans to dispose of. Such data are necessary to evaluate the critical model factors, such as:

> a. the characteristics of the radionuclides, including the expected specific and total activity of the various constituents of the waste,
> b. the period of containment for which the disposal system must comply with release limits,
> c. the ingrowth and decay of radionuclides occurring during containment and potential release events,
> d. the behavior of components of the nuclear waste within the repository and, in event of release, within the surrounding soil and rocks, such as solubility and retardation characteristics of waste that reaches groundwater.

These factors cannot be properly calculated and understood, if one begins from erroneous inventory data, as WCS has evidently done.

The performance assessments presented by WCS, which are designed to establish that WCS can safely manage and dispose of nuclear waste at the Andrews County site, are predicated upon inventory data concerning the nature of the radioactive waste to be disposed of, as a fundamental underlying assumption. Since the WCS application is grossly in error as to the facility's waste inventory, the WCS performance assessments must be considered invalid. While Texas is an Agreement State, and it is the Texas Commission on Environmental Quality that will initially review the WCS application, the NRC retains an oversight role for all licensed activities regarding the handling of radioactivity. In fact, in late April 2005, the NRC already placed the Texas Department of State Health on "heightened oversight,"

[100] NEF DEIS 2004 p. 4-52, 4-58, and 4-78, NEF FEIS 2005 p. 4-57, 4-63, and 4-85, and GAO 2004 p. 14
[101] GAO 2004 p. 15 to 16
[102] GAO 2004 p. 15

which is just one step above probation.[103] If the State of Texas were to eventually grant a license to WCS, the NRC has the authority under its agreement with the State and Section 274 of the Atomic Energy Act to step in and determine that WCS is not competent to receive or dispose of uranium bearing wastes and to prevent them from accepting such wastes.[104] Specifically, the Texas Agreement with the NRC includes the condition that

> The Commission, upon its own initiative after reasonable notice and opportunity for hearing to the State, or upon request of the Governor of the State, may terminate or suspend this Agreement and reassert the licensing and regulatory authority vested in it under the Act if the Commission finds that such termination or suspension is required to protect the public health and safety.[105]

Given the use of such grossly wrong and unphysical data for uranium-bearing wastes in their license application combined with our demonstrations that erosion at the site is likely to uncover the waste and lead to very high doses for future intruders, the Commission should exercise its duty "to protect the public health and safety" and inform the State of Texas that WCS should be disqualified from consideration as a company that is suited to manage or disposal of uranium bearing wastes, including the depleted uranium from the proposed NEF. The failure of the final EIS to address this issue is a serious deficiency.

Section 1.6 – The Likely Need for Geologic Disposal of Depleted Uranium

The previous sections have shown that WCS should be disqualified from accepting or disposing of uranium bearing wastes and that the Envirocare site is unlikely to be able to accept the very large amounts of depleted uranium that would be produced by the proposed NEF facility. In addition, we have shown that at the WCS site the erosion of the cover would likely lead to the waste becoming uncovered over time with very large intruder doses as a result. While low-level waste is typically regulated for a limited time and not to the time of peak dose, the very long half-lives of the uranium isotopes make it a special concern. Both the draft and final EIS in the current case include a dose estimate for disposal in a mine that was calculated "[i]n the year of maximum exposure" as we have done for the case of shallow land disposal.[106] The issues raised by the very long half-lives of the uranium isotopes in relation to the analysis of shallow land disposal were summarized by the authors of the Sandia analysis as follows:

> The acceptability of near-surface disposal for large quantities of depleted uranium depends upon the regulatory time frame applied to the analysis. Risks associated with the disposal grow for about 2 million years. Truncation of the analysis prior to that time will not capture the potential peak doses, but extrapolation of current conditions to 2 million years is of dubious merit for a near-surface facility. The potential exists for more adverse conditions than present to exist at the site over that long time frame.[107]

These considerations further strengthen the conclusion that depleted uranium will likely require disposal in a mined repository. The radiological similarity between depleted uranium and TRU waste or the likely need for the disposal of depleted uranium in a mined repository of some kind has been recognized by the International Atomic Energy Agency, the OECD's Nuclear Energy Agency, the National Research Council of the U.S. National Academy of Sciences, and the staff of the Nuclear Regulatory Commission (in the Claiborne Enrichment Center case).[108]

The remaining question is what type of mined repository would be acceptable. As pointed out in our November 2004 report, the similarity of DU to TRU waste has been noted by the National Research Council, both in regard to their radiological characteristics as well in regard to the likely difficulties that will be associated with their disposal:

> If disposal [of depleted uranium oxide] is necessary, it is not likely to be simple. The alpha activity of DU is 200 to 300 nanocuries per gram. Geological disposal is required for transuranic waste with alpha activity above 100 nanocuries per gram. If uranium were a transuranic element, it would require disposal in the Waste Isolation Pilot Plant (WIPP) based on its radioactivity. The chemical toxicity of this very large amount of material would certainly become a problem as well. One option suggested by the U.S. Nuclear Regulatory Commission (USNRC) is disposal in a mined cavity or former uranium mine. Challenges for this option

[103] Dallas Morning News 2005
[104] NRC 2002 p. 1-149 and Texas Agreement 1963 p. 5
[105] Texas Agreement 1963 p. 5
[106] NEF DEIS 2004 p. 4-59 and NEF FEIS 2005 p. 4-63
[107] Kozak et al. 1992 p. 49
[108] CEC FEIS 1994 p. A-9, IAEA/NEA 2001 p. 23, NAS/NRC 2003 p. 64, IAEA 2003 p. 29

> would include understanding the fundamental differences between uranium ore (see Sidebar 6.1) and the bulk uranium oxide powder.[109]

In addition, Dr. John Bredehoeft, one of the most eminent hydrogeologists in the United States and a member of the National Academy of Engineering[110], concluded that

> The type of site required for disposal of depleted uranium from NEF is roughly comparable to the WIPP site in terms of the level of isolation required. All three isotopes contained in depleted uranium have very long half-lives, with the half-life of the principal one, U-238 extending to the billions of years. The specific activity of depleted uranium exceeds 300 nanocuries per gram of alpha-emitting radionuclides, and radium 226 and thorium 230 would build up over time to exceed 100 nanocuries per gram. The transuranic waste disposed of at WIPP has a concentration of at least 100 nanocuries per gram of alpha-emitters. The WIPP project involves deep disposal in a sealed mine in bedded salt more than 2000 feet below the surface. The plan for WIPP was examined in a detailed performance assessment, which was reiterated several times. It required well over 20 years of analysis by a large team of scientists and engineers to achieve a level of understanding such that a consensus was reached that the WIPP facility is safe and could receive waste.
>
> Only after a specific site and design are proposed can one assess its safety. It would be prudent to assume that, before a site could be qualified to receive depleted uranium waste, a similar amount of time, effort, expense, and scrutiny to that which went to qualify WIPP would be required.[111]

Despite these considerations, the final EIS from the NRC staff includes the same fundamentally flawed generic mine scenario that we discussed at length in our November 2004 report.[112] The following tables show the dose estimates for the mine scenario as presented by the NRC staff over time.

Granite Site (Sieverts per year)

Scenario	Pathway	CEC FEIS	NEF DEIS	NEF FEIS
Well	Drinking Water	1.59×10^{-7}	3×10^{-7}	3×10^{-7}
	Agriculture	2.30×10^{-6}	4×10^{-6}	4×10^{-6}
River	Drinking Water	5.31×10^{-16}	9×10^{-16}	9×10^{-16}
	Fish Ingestion	1.01×10^{-15}	2×10^{-15}	2×10^{-15}

Sandstone/Basalt Site (Sieverts per year)

Scenario	Pathway	CEC FEIS	NEF DEIS	NEF FEIS
Well	Drinking Water	1.28×10^{-10}	2×10^{-10}	2×10^{-10}
	Agriculture	1.80×10^{-9}	3×10^{-9}	3×10^{-9}
River	Drinking Water	1.62×10^{-14}	3×10^{-19}	3×10^{-14}
	Fish Ingestion	2.98×10^{-14}	5×10^{-14}	5×10^{-14}

(CEC FEIS 1994 p. A-14 to A-15, NEF DEIS 2004 p. 4-59, and NEF FEIS 2005 p. 4-64)

While the NRC staff did fix the estimated river drinking water dose from the NEF DEIS that we pointed out was 54,000 times less than the CEC FEIS estimate, they have yet to present the detailed technical bases for these calculations and the result remain quite literally incredibly low and scientifically unbelievable.[113] The final NEF EIS is seriously deficient in not presenting the detailed bases and assumptions used in these calculations and for failing to address the fact that they are quite likely to underestimate the drinking water doses by many orders of magnitude.

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[109] NAS/NRC 2003 p. 64

[110] Dr. Bredehoeft worked for the U.S. Geological Survey for 32 years before starting The HydroDynamics Group, a consulting firm, in 1995. He was a member of the National Academy of Sciences/National Research Council Committee on the Department of Energy's Waste Isolation Pilot Plant (WIPP) as well as a member of the NAS/NRC Panel responsible for reviewing groundwater issues at the Yucca Mountain nuclear repository. The complete curriculum vita of Dr. Bredehoeft accompanies this report.

[111] as quoted in [Makhijani and Smith 2004 p. 27-28]

[112] See [Makhijani and Smith 2004 p. 20-23 and 25-29]

[113] Makhijani and Smith 2004 p. 21

Finally, the final EIS for the proposed NEF facility also remains seriously deficient for including no discussion of the chemical toxicity of uranium beyond citing the current 10 milligram per week intake limit for occupational exposures and for not including a discussion of the emerging evidence regarding uranium's health risks from research that has been conducted primarily in the wake of the 1991 Gulf War as detailed in our November 2004 report.[114] These omissions are all the more stark given that a National Research Council committee as well as analysts at the Idaho National Engineering Laboratory, the Lawrence Livermore National Laboratory, and the Sandia National Laboratories have all noted that the chemical toxicity of large quantities of depleted uranium should be addressed in evaluating the impacts of disposal.[115]

[114] [NEF FEIS 2005 p. C-1]. See [Makhijani and Smith 2004 p. 8-19] for a detailed discussion of the emerging picture of uranium's health risks.
[115] Kozak et al. 1992 p. 49, Hertzler et al. 1994 p. 10 to 12, LLNL 1997 p. 6.13-1-6 and 6.13-1-16, and NAS/NRC 2003 p. 64

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