Attachment A

November 18, 2005

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
LOUISIANA ENERGY SERVICES, L.P.	)	Docket No. 70-3103
	)	
(National Enrichment Facility)	)	ASLBP No. 04-826-01-ML
	)	

AFFIDAVIT OF DONALD E. PALMROSE

I, Donald E. Palmrose, Ph.D., being duly sworn, state as follows:

1. I am employed by Advanced Systems Technology and Management, Incorporated. I am providing this affidavit under a technical assistance contract with the NRC. I assisted the Staff in the development of the Draft and Final Environmental Impact Statements (EIS) for the proposed construction and operation of the National Enrichment Facility (NEF) in Hobbs, New Mexico (NUREG-1790).

As part of my official responsibilities, I developed or contributed to the sections and appendices of the proposed NEF DEIS and FEIS which pertain to public and occupational health impacts under normal operations and waste management impacts, including depleted uranium disposition. I also supervised the overall development of Chapter 4, "Environmental Impacts," and associated appendices of the DEIS and, later, the overall development of the FEIS. I was the principal author of Section 4.2.14.4, entitled "Impacts from Disposal of the Converted Waste".

I reviewed the Applicant's Environmental Report (ER) and Safety Analysis Report (SAR) pertaining to public and occupational health, waste management, and the other impact areas analyzed in Chapter 4 of the DEIS, as well as the Applicant's responses to the NRC Staff's

requests for additional information. In addition to documents I found through independent research, I reviewed various documents referenced by the Applicant's ER, and previously published or available NRC documents. These documents are referenced in the proposed NEF DEIS and FEIS.

2. In the environmental review of the proposed NEF, the environmental impacts of disposal of depleted uranium in an abandoned mine, or deep disposal, was presented in Section 4.2.14.4, notwithstanding the fact that no existing mine was licensed to receive or dispose of low-level radioactive waste nor was any license application pending for such an application. The radiological impacts for this type of disposal were drawn directly, as modified for the proposed NEF quantity of depleted U_3O_8, from the analysis in the Final Environmental Impact Statement (FEIS) for the Claiborne Enrichment Center (CEC), NUREG-1484.

3. Before incorporating the results of the CEC FEIS analysis, a member of the proposed NEF EIS team with expertise in hydrology reviewed the information in the CEC FEIS regarding the parameters and the models that were used and determined that they were appropriate. He also concluded that the results of the analysis appeared reasonable. I also discussed the CEC deep disposal analysis with Dr. Abe Zeitoun, the Project Manager and my supervisor during the development of the proposed NEF DEIS. He was also the Project Manager for the development of the CEC FEIS and was very familiar with the process and determination that went into the CEC FEIS deep disposal analysis. Dr. Zeitoun also concluded that this analysis was still reasonable and appropriate for the proposed NEF. The EIS team also had direction from the NRC staff to apply appropriate environmental analysis and impacts presented in prior NRC-approved EISs and specifically from the CEC FEIS. Therefore, based on all of the above, I determined that it was appropriate to proceed with applying the CEC FEIS deep disposal analysis for the potential disposal of depleted U_3O_8 that would result from the deconversion of the depleted UF_6 produced by the proposed NEF.

4. Since there was not then a licensed deep disposal facility for depleted uranium, the CEC FEIS examined and presented in Appendix A the potential environmental impacts of deep disposal for two generic sites under certain exposure scenarios. The two generic sites were a granite formation overlain by a thin layer of glacial till and a sequence of interbedded sandstone and basalt layers (pg. A-10 of CEC FEIS). The exposure scenarios considered were (1) consumption of drinking water or fish from a river and (2) consumption of drinking water or food grown using irrigation from well water (pg. A-7 and A-8 of CEC FEIS). The release rate of uranium and daughter radionuclides from the disposal facility would be limited by either their solubility in water or by the total inventory of radionuclides present at the time of release. In order to provide a conservative assessment of potential impacts, the more conservative release rate - that of solubility - was used for the analysis.

5. The potential disposal impacts from the proposed NEF geologic disposal sites would be proportional to the quantity of waste material from the Claiborne Enrichment Center. The CEC was expected to generate approximately 91,000 metric tons of depleted U_3O_8 over the life of the facility. If the proposed NEF would have produced the same amount of depleted U_3O_8, the dose results from deep disposal as presented in the CEC FEIS would be directly appropriate for the proposed NEF without any adjustments. However, the proposed NEF is expected to generate approximately 157,000 metric tons of U_3O_8 over its lifespan. Thus, the proposed NEF will generate roughly 1.72 times as much waste for disposal. Because the disposed waste associated with the proposed NEF will be greater than that from the previously planned CEC, the estimated doses from the CEC analysis must be revised upward to account for the larger amount of U_3O_8 from the proposed NEF. Therefore, I multiplied the doses associated with the CEC FEIS by 1.72 to obtain the potential deep disposal doses for the proposed NEF. This resulted in the doses for deep disposal of the proposed NEF waste still being below

0.5 millirem/year for all scenarios, which is roughly 50 times below the dose limit of 10 C.F.R. § 61.41.

6. In reviewing the CEC FEIS, I found a discrepancy that affected the proposed NEF DEIS. Table A.7 and Table A.8 on pages A-14 and A-15 of the CEC FEIS list the estimated peak doses for the well and river scenarios. These tables list the estimated dose for each radionucliude separately but not the total. The total estimated doses for each pathway were only directly given in the CEC FEIS text on page 4-67. The total dose estimate for the drinking water pathway from the sandstone/basalt site in Table A.8 (River) was listed in the text on page 4-67 as $1.6x10^{-9}$ Sievert ($1.6x10^{-14}$ millirem). This value was incorrect and should have been $1.6x10^{-14}$ Sievert ($1.6x10^{-9}$ millirem). There was not a mistake in the CEC analysis or in Table A.8. Instead, there was a mistake in describing the result of that analysis in the text of the CEC FEIS.

7. When the CEC FEIS values were incorporated into the computations for radiological dose for the proposed NEF DEIS, the incorrect millirem value for the drinking water river scenario for the basalt site from page 4-67 of the CEC FEIS was used, resulting in the unusual value described by NIRS/PC in the February motion as being 54,000 times lower in the proposed NEF DEIS than in the CEC FEIS. This mistake has been corrected in the proposed NEF FEIS. Specifically the listed dose for the drinking water pathway under the river scenario for a sandstone/basalt disposal site, which read $3x10^{-16}$ millisieverts and $3x10^{-14}$ millirem in the proposed NEF DEIS, has been corrected to read $3x10^{-11}$ millisievert and $3x10^{-9}$ millirem in Table 4-19 of the FEIS.

8. A second discrepancy was the result of a typographical error. The proposed NEF DEIS incorrectly listed the dose for the drinking water pathway under the river scenario for the granite disposal site as $3x10^{-11}$ millirem. That value is incorrect. In the FEIS, it has been corrected to read $9x10^{-11}$ millirem.

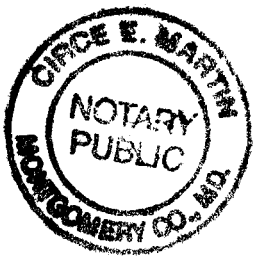
9. Neither discrepancies in the proposed NEF DEIS change the environmental impacts of deep disposal of the U_3O_8 since the doses are still significantly below the dose limit of 10 C.F.R. Part 61.

10. I hereby certify that the foregoing is true and correct to the best of my knowledge, information and belief.

Donald E. Palmrose

Subscribed and sworn to before me
this 18 day of November, 2005

Notary Public



My commission expires: March 1, 2007

CIRCE E. MARTIN
NOTARY PUBLIC STATE OF MARYLAND
My Commission Expires March 1, 2007

Attachment B

ATTACHMENT B

November 17, 2005

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
LOUISIANA ENERGY SERVICES, L.P.	)	Docket No. 70-3103
(National Enrichment Facility)	)	

AFFIDAVIT OF DR. RATEB ABU-EID

I, Rateb Abu-Eid, being duly sworn, state as follows:

1. I am a Senior Level Advisor on Waste Management and Environmental Protection in the Office of Nuclear Material Safety and Safeguards (NMSS) at the NRC. I provide authoritative technical advice and consultation to NMSS management on issues related to decommissioning and waste management. I also lead and direct interdisciplinary teams to analyze and evaluate technical, regulatory, or policy development and review projects related to decommissioning and waste management. I earned a Ph.D. from the Massachusetts Institute of Technology (MIT) in Geochemistry and Nuclear Chemistry. In addition, I have completed numerous formal training and credit courses in the areas of Health Physics, Contaminant Transport, and Risk/Dose Analysis. I have taught and/or conducted research at MIT, University of Bonn, Kuwait Institute for Scientific Research, Johns Hopkins University, and the Geophysical Laboratory/Carnegie Institute of Washington. I have published over 50 articles in professional journals.

2. I reviewed the dose impact analysis regarding the deep disposal of U_3O_8 presented in Appendix A of the Claiborne Enrichment Center (CEC) FEIS. NIRS/PC Ex. 58. The dose impact analysis in Appendix A was based on generic assumptions regarding two potential deep mine disposal sites. It provided a generic deep disposal site description and certain sensitive flow path parameters such as: hydraulic conductivity, flow area, and gradient. Appendix A also provided certain chemical constituents of the deep groundwater with concentration ranges of these constituents. The solubilities of U, Th, and Ra were calculated. For example, the solubility of U was calculated as 10 E-04 mg/L assuming that the dominant solid phase was UO_2. NIRS/PC Ex. 58 at A-13. It should be noted that the CRC Handbook of Chemistry and Physics (*75th Edition, David R. Lide, and F.R. Frederiksie, 1994-1995*) classifies the main uranium oxides U_3O_8 and UO_2 as insoluble in both cold and hot water. This CEC analysis considered radionuclide transport through groundwater (GW) seeping vertically through the disposal facility to a more permeable unit (aquifer). NIRS/PC Ex. 58 at A-13. It then assumed the radionuclides would be dispersed horizontally through the aquifer by the predominately horizontal flow. Two potential radiological exposure pathways were analyzed, discharge in a river, and under conditions that are not expected to occur, an individual obtaining water by drilling a deep well down-gradient from the disposal facility. The assumptions for the deep disposal analysis in Appendix A of the CEC EIS appear to be reasonable considering the generic nature of the analysis.

3. The CEC EIS analysis used the PHREEQE code (*Parkhurst, D.L., D.C. Thorstenson, and L.N. Plummer, PHREEQE-A Computer Program for Geochemical Calculations, Water Resources Investigation 80-96, U.S. Geological Survey, Reston, VA, November 1980*) to calculate radionuclide solubilities and IAEA thermodynamic data. NIRS/PC Ex. 58 at A-12. Longitudinal and transverse dispersion coefficients were taken from literature studies. NIRS/PC Ex. 58 at A-13. The concentration of radionuclides in GW were estimated

based on an analytical solution to the one-dimensional flow, three-dimensional dispersion equation developed by the USGS (*Wexler, E.J. Analytical Solutions for One-, Two-, and Three-Dimensional Solute Transport in Groundwater Systems with Uniform Flow, U.S. Geological Survey, Reston, VA, 1992*). Dose conversion factors based on unit soil concentration were developed using the RESRAD code (*Gilbert, T. et. al.; A Manual for Implementation Residual Radioactive Material Guidelines, DOE/CH/8901, Argonne National Laboratory, Argonne, IL, June 1989*). The pathways included: direct exposure, soil ingestion, and ingestion of crops, meat, and milk. For the drinking water pathway, the dose was estimated using an analytical solution predicting the radionuclide water concentration, water intake rate (0.73 m^3/y), and the RESRAD code radionuclide ingestion dose factor. Dose from fish was estimated from the product of radionuclide water concentration, bioaccumulation factor, fish consumption rate, and ingestion dose factor. Bioaccumulation factors were taken from NUREG/CR-5512. The dose conversion factors were consistent with EPA's Federal Guidance Report No. 11 (*Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion; EPA-520/1-88-020, 1988*).

4. Appendix A of the CEC FEIS presented a summary of approaches and methodology of the dose analysis and estimates of the most sensitive parameters. While Appendix A did not provide detailed input and output of data and parameters, the analysis appears to be reasonable and conservative considering the assumptions used for the exposure and transport scenarios. However, duplication of the analysis cannot be made because of the lack of detailed input data and because some of the codes used in the assessment has been modified or updated.

5. I hereby certify that the foregoing is true and correct to the best of my knowledge, information and belief.

RATEB ABU-EID

Subscribed and sworn to before me
this 1 day of November, 2005

Circe E Martin
Notary Public

My commission expires: March 1, 2007

CIRCE E. MARTIN
NOTARY PUBLIC STATE OF MARYLAND
My Commission Expires March 1, 2007

Attachment C

ATTACHMENT C

UNITED STATES OF AMERICA

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
Louisiana Energy Services	)	Docket No. 70-3070
	)	February 27, 1995
(Claiborne Enrichment Center)	)	

TESTIMONY OF DR. ARJUN MAKHIJANI REGARDING CITIZENS AGAINST NUCLEAR TRASH'S CONTENTIONS B, J.3, AND W

Q. 1: Please state your name, affiliation, and qualifications.

A: My name is Arjun Makhijani. I am President of the Institute for Energy and Environmental Research. I am an expert in the field of nuclear engineering. I have extensive experience in the area of nuclear waste classification and disposal, and have published numerous books and reports on these topics. A copy of my resume is attached as Exhibit 1 to my testimony.

Q. 2: What is the purpose of your testimony?

A: I have been asked by Citizens Against Nuclear Trash to evaluate two issues with respect to the application by Louisiana Energy Services, L.P. ("LES") for a combined construction permit and operating license for a proposed uranium enrichment plant called the "Claiborne Enrichment Center" ("CEC") in Claiborne Parish, Louisiana. Those two issues are: whether the Nuclear Regulatory Commission ("NRC") staff conducted a complete and adequate analysis of the potential adverse environmental impacts and costs of disposing of the 91,000 metric tons of depleted uranium oxide (U3O8) to be disposed from the proposed CEC, and whether the NRC required the license applicant to set aside sufficient funds for the disposal of the tails.

Q. 3: What materials did you review in preparation for your testimony?

A: I reviewed those aspects of the License Application, Safety Analysis Report ("SAR") and Environmental Report ("ER"), submitted by LES to the NRC in support of LES' combined construction permit/operating license application for the CEC, which relate to LES' cost estimates for disposal of the depleted uranium tails. In addition I reviewed various reports and correspondence prepared by LES and its consultants regarding the costs and environmental impacts of tails disposal.

I also reviewed the discussion of decommissioning cost estimates in NUREG-1491, Safety Evaluation for the Claiborne Enrichment Center, Homer, Louisiana (January 1994); the discussion of costs and impacts of tails disposal in NUREG-1484, the Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center, Homer, Louisiana (August 1994) ("FEIS" or "EIS"), and various reports and correspondence prepared by NRC and its consultants regarding the costs and environmental impacts of depleted uranium tails disposal.

Finally, I reviewed relevant NRC regulations in 10 C.F.R. Part 51, 61, and 70, as well as Environmental Protection Agency regulations in 10 C.F.R. Part 191.

Q. 4: Please describe LES' proposal for uranium tails disposal and decommissioning funding.

As required by 10 C.F.R. § 70.25(e), LES' license application includes a decommissioning funding plan, containing "a cost estimate for decommissioning and a description of the method of

specific geologic environments could be different, depending on the specific conditions. This could lead to different environmental and dosimetric characteristics of the two. For example, a Sandia Report on depleted uranium disposal states:

> U3O8 is thermodynamically unstable in ground water. U3O8 is therefore expected to convert to other oxide forms; the favored form under oxidizing conditions is schoepite, but other complexes may be favored depending on site-specific conditions.[20]

The NRC should have considered UO2 in addition to U3O8, and presented a comparative analysis showing the legitimacy of its choice of U3O8.

I would also note that after selecting U3O8 for analysis, the NRC appears actually to have used UO2 as the dominant solid phase for its solubility analysis.[21] It is unacceptable to mix up chemical forms in a single analysis in this way, because it distorts the analysis.

Q. 8: Please explain the basis for your statement that the NRC staff's analysis of the environmental impacts of deeper than near-surface burial is deeply flawed and fails to address significant uncertainties and variables.

The NRC's analysis of the environmental impacts of tails disposal is fundamentally deficient in a number of ways which could have a significant effect on the estimates of doses to the public from deeper-than-surface disposal of depleted uranium. I will detail

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[20] FIN A1764, Final Letter Report, Performance Assessment of the Proposed Disposal of Depleted Uranium as Class A Low-Level Waste at 30-31 (December 16, 1992) (hereinafter "1992 Sandia Report"). Exhibit I-AM-70.

[21] See FEIS at A-13, Table A.6.

five areas of deficiencies, which illustrate the NRC's egregious failure to follow sound scientific practice.

1) The NRC has not considered a wide enough range of geologic settings. It has arbitrarily selected only two types of geologic settings. A much wider range of potential geologic settings, besides granite and basalt, should have been considered initially, including salt, complex geologies such as granitoid rocks overlain by sedimentary formations, and tuff. As discussed in a 1983 study of geologic disposal of radioactive waste by the National Academy of Sciences, "Each rock type has certain generic advantages and disadvantages, but the reader is reminded that no repository can be evaluated without site specific hydrogeologic, hydrochemical, and structural data."[22] A preliminary screening would therefore have considered these generic advantages and disadvantages, and then selected rock types for study. There is no indication in the EIS that the NRC staff performed any serious analysis to identify the most appropriate rock types.

2) The NRC has mixed up data from various geologic settings. In conducting its evaluation, the NRC did not use a consistent set of data corresponding to a coherent set of geologic conditions. For example, instead of using chemical data for groundwater in a deep basalt formation or deep granite formation, the NRC used near-surface water data from a location in New York state.[23] In contrast to the pH value of 7.8 that the NRC used,

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22 National Academy of Sciences, A Study of the Isolatuion System for Geologic Disposal of Radioactive Waste at 150 (National Academy Press: 1983) (hereinafter "NAS Report").

23 FEIS at A-10, citing West Valley Nuclear Services (WVNS) Company, Incorporated, and Dames and Moore, West Valley Demonstration Project Site Environmental Report for Calendar Year 1992, West Valley Nuclear Services Company, Incorporated, West Valley, New York, May, 1983.

which presumably was based on the values from New York state, the pH of groundwater in the basalt at Hanford for repository locations has been found to be greater than 9.[24] As discussed below, such variations could have a significant effect on the solubility and transport of uranium, and therefore the calculated dose to the public.

3) The NRC has ignored available data from basalt and granite locations in the U.S., and chosen to rely on a 1978 Swedish study instead.[25] Based on the Swedish study, the NRC used a retardation factor of more than 1,200.[26] However, the National Academy of Sciences reports retardation factors for granite of between 10 and 500, and for basalt of between 20 and 1,000, with 50 being a recommended estimate if one number is to be used for both geologic settings.[27] The lowest NAS estimate of retardation factor is more than 100 times lower than the value assumed by the NRC in its calculations. The higher retardation factor used by NRC would produce lower dose estimates than the values given by the NAS; thus, the NRC's choice of retardation factor underestimates potential doses. This is only one example of the NRC's selective use of data, which results in biased estimates.

4) The NRC has tended to choose values for parameters that do not systematically correspond to uranium mines and that tend

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24 NAS Report at 171, 173.

25 FEIS at A-13, citing Karn-Bransle-Sakerhet (KBS), Handling and Final Storage of Unreprocessed Spent Nuclear Fuel, Vol. 1, Karn Bransele Sakeerhet, Stockholm, Sweden, 1978.

26 FEIS at A-13.

27 NAS at 147.

to seriously underestimate the possible doses. It has assumed a value that falls outside the range of values for uranium mines, and misrepresented the value it used as representative of that range.

One measure of the potential of groundwater to oxide or reduce, that is, to chemically change materials disposed of in it, is the "redox potential." It is measured in volts or millivolts (mV). If the potential is negative, the groundwater is a "reducing" environment; if it is positive, the groundwater is an "oxidizing" environment. The solubility of uranium in a reducing environment is far lower than in an oxidizing environment.

The EIS assumes that the depleted uranium tails will be disposed of in a reducing environment, for which the NRC has used an eH value of -100 mV in its environmental impact analysis.[28] This value falls entirely outside the range of eH values cited by the NRC itself as typical of uranium mine water.[29] All of the eH values cited by the NRC as typical of uranium mine water (-89 to +60 mV) would result in a higher solubility of uranium in groundwater. Moreover, the NRC cites no comparable eH values for other deep groundwater ranges, leaving data for uranium mines as the only basis for comparison of its choice of eH value for this parameter.

The solubility of uranium is critical to the determination of the amount of uranium in groundwater, and clearly the NRC has made arbitrary assumptions that tend to minimize the amount of uranium in solution. For instance, as conceded in to the affidavit of

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28 FEIS at A-12.

29 Id.

the NRC's expert, Yawar Faraz, uranium is 3,500 times more soluble at an eH of 50 mV than at an eH of -100 mV.[30] In contrast to the eH value used by the NRC, an eH of 50 mV is within the range of eH values cited by the NRC for uranium mines.

Further, the NRC has not properly represented the Swedish KBS study on which it claims to rely as the source of its data for uranium mine water characteristics. The Swedish study cites a much larger range of values for the critical parameter, eH, in a uranium mine: -212 to 220.[31] The NRC cites a range of -89 to 60, as noted above. This misrepresentation is significant because it could have a great effect on the calculated amount of uranium dissolved in the water.

One can understand the significance of solubility issues by simply accepting for the sake of argument the NRC's expert testimony in the affidavit of Yawar Faraz. He has argued that depleted uranium is far less dangerous than the transuranic waste ("TRU") to be disposed of in a geologic repository by the Department of Energy ("DOE"). This assertion is largely based on the claim that for an intake having the same amount of radioactivity, the cancer risk from radionuclides in DOE TRU would be two to 200 times greater than for depleted uranium.[32] However, the same affidavit shows that under oxidizing conditions, of eH = 50 mV,

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30 Affidavit of Yawar H. Faraz at 7 (February 6, 1995). This affidavit was submitted in support of the NRC's opposition to CANT's January 17, 1995, waiver petition.

31 Karn-Bransle-Sakerhet (KBS), Handling and Final Storage of Unreprocessed Spent Nuclear Fuel, Vol. 1 at 114, Karn Bransele Sakerhet, Stockholm, Sweden, 1978.

32 Faraz Affidavit at 4-5.

uranium would be about 1,000 times more soluble than DOE TRU.[33] Thus, the intake of uranium under comparable oxidizing disposal conditions could be 1,000 times greater than the intake of DOE TRU. The overall doses under such conditions would be several times to several hundred times greater for depleted uranium than for DOE TRU.

The EPA considers DOE TRU to be dangerous enough that it requires disposal of TRU in a geologic repository under rules that apply to high level radioactive waste disposal. The NRC's own data show that under some circumstances, prevalent in some uranium mines, doses from depleted uranium could be greater than from DOE TRU. Therefore, the level of regulatory concern and technical investigation required for depleted uranium disposal should not be less than that required for DOE TRU. In particular, the NRC's assumption that reducing conditions will prevail in uranium mines is unwarranted, and clearly shows the NRC's failure to take into account data it has itself presented in the EIS.[34]

5) Contrary to good scientific practice, and clear exhortation by the Science Advisory Board of the Environmental Protection Agency that uncertainty analyses should be standard practice in radiation dose calculations, the NRC has failed to perform an uncertainty analysis as part of its environmental impact analysis. This is an egregious omission.

A central element of any uncertainty analysis is the use of reasonable range of values for all important parameters. This procedure is used to calculate upper and lower bounds for the

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33 Faraz Affidavit at 7.

34 FEIS at A-12.

estimate of doses. If only a single value is used, as the NRC has done for its dose calculations, this gives no indication of the range of uncertainty. Another essential practice in uncertainty analysis is that the central value within the uncertainty range should be representative of expected conditions. As I have discussed, the central values of important parameters -- notably eH -- do not correspond to the central values for uranium mines as cited by the NRC itself.

As can be clearly seen from the above discussion, the range of conditions that might prevail in uranium mines or other similar deep disposal locations is very great. The NRC simply assumes all of the possible variations away, by limiting its calculations to a single set of parameters that appears generally designed to yield low dose estimates. For example, the NRC's choice of a pH of 7.8 is within the narrow range of values of pH for which some chemical forms of uranium have their very lowest solubilities. Specifically, the lowest solubility for schoepite is within the range of pH of approximately 7 to 8. In other words, the solubility of schoepite rises when the pH falls below 7 or increases above 8. Schoepite is one possible chemical form into which U3O8 might be transformed in some geologic environments. One study showed that a change of pH from 8 to 9 would increase the solubility of schoepite by a factor of about 10.[35]

Similarly, the NRC's failure to consider an appropriate range of eH values has resulted in an overly optimistic dose assessment. The NRC's expert, Yawar Faraz, has stated that depleted uranium would be disposed of in a reducing environment because ground-

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35 Jordi Bruno and Amai Sandino, The Solubility of Amorphous Crylstalline Schoepite in Nuetral to Alkaline Aqueous Solutions, Mat. Res. Soc. Symp. Proc. Viol. 127 (1989).

water conditions at a "greater-depth disposal facility are expected to be reducing." This is not even validated by the NRC's own data for uranium mines, where some eH values for water and uranium mines are shown as oxidizing.[36] The Sandia Report gives an example of a site with well-characterized groundwater, at which uranium solubility ranged over five orders of magnitude (100,000 times).[37]

The NRC has also failed to consider the full range of chemical species that might result from disposal of U3O8 in various geologic environments. This is an essential part of environmental and uncertainty analyses. According to the 1992 Sandia Report,

> U3O8 does not exist in solution, but rather speciates to other oxide, hydroxide, and complex forms, all of which are soluble to some extent. In addition, U3O8 is thermodynamically unstable in ground water. U3O8 is therefore expected to convert to other oxide forms; the favored form under oxidizing conditions is schoepite, but other complexes may be favored depending on site-specific conditions. As an example, Chu and Bernard (1991) showed that uranium complexes with silicates are important to the solubility of uranium at the Nevada Test Site. Uraninite is the favored form under reducing conditions, but we expect oxidizing conditions to dominate in a disposal unit in the unsaturated zone . . . .[38]

The authors also found that the "solubility limits of radionuclides in ground water are affected by the ability of the

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36 FEIS at A-12, Table A.5, column 4.

37 1992 Sandia Report at 49.

38 Id.at 30-31.

compound to form complexes with other species in and near the disposal unit."[39] In this regard, the authors concluded that:

> Site-specific conditions can produce a wide range of solubility behavior for uranium oxides, and the potential exists for U3O8 to react to form other oxides, hydroxides, or complexes with soil minerals under some conditions. Therefore, on a generic basis, we cannot specify a solubility limit for U3O8 with much confidence.

Id. (emphasis added).

The NRC seems to have entirely ignored these important considerations discussed in the Sandia Report, so far as its evaluation of deep geologic disposal is concerned. FIN A1764, Final Letter Report, Performance Assessment of the Proposed Disposal of Depleted Uranium as Class A Low-Level Waste (December 16, 1992).

In sum, the NRC's analysis fails both to meet the minimal tests of sound science in general, and the requirements of an adequate environmental analysis for this particular case.

Q. 11: Please explain the basis for your statement that the NRC staff failed to evaluate burial of the CEC tails in a deep geologic repository, which is a prudent and reasonably foreseeable disposal measure.

A: The EIS has analyzed the environmental impacts of near surface disposal and deeper-than-surface disposal of depleted uranium tails. The analysis of near-surface disposal found that doses would exceed acceptable limits, and thus the NRC effectively rejected that method. As discussed above, the NRC's analysis of deeper-than-surface disposal is seriously deficient.

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[39] Id. at 31.