RULEMAKING ISSUE
(NOTATION VOTE)

October 7, 2008 SECY-08-0147

FOR: The Commissioners

FROM: R. W. Borchardt
Executive Director for Operations

SUBJECT: RESPONSE TO COMMISSION ORDER CLI-05-20 REGARDING DEPLETED URANIUM

PURPOSE:

The purpose of this paper is to respond to the Commission direction provided in Order CLI-05-20 (In the Matter of Louisiana Energy Services [LES], October 19, 2005). In this Order, the Commission directed staff, "outside of the LES adjudication, to consider whether the quantities of depleted uranium (DU) at issue in the waste stream from uranium enrichment facilities warrant amending section 61.55(a)(6) or the section 61.55(a) waste classification tables." This paper presents four possible regulatory approaches in response to this direction and requests approval of the recommended approach selected in this paper. This paper does not address any new commitments.

SUMMARY:

Staff completed a technical analysis (see Enclosure 1) to understand the impacts of near-surface disposal of large quantities of DU, such as those expected to be generated at uranium enrichment facilities. The technical analysis addressed whether amendments to § 61.55(a) are necessary to assure large quantities of DU are disposed of in a manner that meets the performance objectives in Subpart C of 10 CFR Part 61. The analysis concluded that

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near-surface disposal of large quantities of DU may be appropriate, but not under all site conditions. Shallow disposal of large quantities of DU or disposal at humid sites with a potable groundwater pathway would likely result in the performance objectives not being met. Because of the unique characteristics of the waste and the additional considerations required for its disposal, staff concluded that existing regulations need to be amended to ensure that large quantities of DU are disposed of safely.

Staff recommends conducting a limited rulemaking to revise Part 61 to specify the need for a disposal facility licensee or applicant to conduct a site-specific analysis that addresses the unique characteristics of the waste and the additional considerations required for its disposal prior to disposal of large quantities of DU and other unique waste streams such as reprocessing waste. The technical requirements associated with disposal of large quantities of DU would be developed through the rulemaking process. Specific parameters and assumptions staff recommends for conducting the site-specific analysis would be incorporated into a guidance document that would be issued for public comment prior to being finalized.

BACKGROUND:

The licensing of new uranium enrichment facilities in the United States has brought DU to the forefront of low-level waste (LLW) disposal issues. The DU waste stream is unique; the relatively high concentrations and large quantities of DU that are generated by enrichment facilities were not considered in the Final Environmental Impact Statement (FEIS) supporting the development of 10 CFR Part 61.[1] When the FEIS was issued in 1982, there were no commercial facilities generating large amounts of DU waste, therefore, the FEIS considered only the types of uranium-bearing waste streams being typically disposed of by U.S. Nuclear Regulatory Commission (NRC) licensees at the time.[2] The NRC concluded that those waste streams posed an insufficient hazard to warrant establishing a concentration limit for uranium in the waste classification tables in 10 CFR 61.

With the existing U.S. Department of Energy (DOE) stockpile of DU at the Paducah and Portsmouth Gaseous Diffusion Plants, and the recent licensing of LES National Enrichment Facility (NEF) and the United States Enrichment Corporation (USEC) American Centrifuge Plant, more than 1 million metric tons of depleted uranium hexafluoride (DUF_6) will need a disposition path.[3] Existing disposal facilities such as the Energy*Solutions* facility in Clive, Utah and the proposed Waste Control Specialists (WCS) LLW facility in Andrews County, Texas have expressed interest to their Agreement State regulators in disposal of large quantities of DU at their sites.

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[1] Part 61 FEIS, NUREG-0945, Vol. 1, (November 1982) at 5-38. The FEIS relies on extensive analysis and calculations found in the Draft Environmental Impact Statement (DEIS) that are incorporated by reference. The references in this paper to the FEIS include the supporting information found in the DEIS.

[2] The Part 61 FEIS (NUREG-0945, November 1982) considered 17 Curies of U^{238} compared to approximately 100,000 - 200,000 Curies of U^{238} that will be generated from LES during its 25-year lifespan (FEIS for the Proposed National Enrichment Facility in Lea County, New Mexico, NUREG-1790, June 2005).

[3] Draft Supplement Analysis for Locations to Dispose of DU Conversion Product Generated from DOE's Inventory of DUF_6, (DOE/EIS-0359-SA1 and DOE/EIS-0360-SA1), March 2007 at p. 43; FEIS for the Proposed National Enrichment Facility in Lea County, New Mexico, NUREG-1790, June 2005 at p. 2-27; FEIS for the Proposed American Centrifuge Plant in Piketon, Ohio, NUREG-1834, April 2006) at p. 4-51.

As the Commission indicated in Order CLI-05-20, the current waste classification for DU is "based upon § 61.55(a)(6), which specifies that if radioactive waste does not contain any of the radionuclides listed in either of two listed waste classification tables, it is Class A waste. Depleted uranium does not contain the radionuclides listed in the specified tables, and therefore under a plain reading of the regulation, depleted uranium is a Class A waste." As such, any existing disposal facility currently licensed to accept Class A waste represents a potential disposal path for the DU waste stream.

To fully understand how DU is currently being disposed of, staff communicated with Agreement State regulators that oversee existing or proposed LLW disposal facilities in their States (i.e., South Carolina, Texas, Utah, and Washington). Most of these disposal facilities have accepted small quantities of DU in the past. In general, these State regulators agreed with the need to handle large quantities of DU as a unique waste stream, regardless of its current waste classification, and agreed that additional analysis should be conducted prior to its disposal. The Utah Division of Radiation Control indicated that Energy*Solutions* has completed site-specific performance modeling for disposal of natural uranium at their Clive, Utah site, and Energy*Solutions* concluded that even when the disposal cells were assumed to contain 100 percent natural uranium, risks were found to be within Utah Administrative Code regulatory limits, which are comparable to those in Part 61. Energy*Solutions* compared the risk from natural uranium to the risk associated with DU and found that DU can be safely placed in their facility.[4] This conclusion is based on numerous assumptions that can be found in Energy*Solutions'* performance assessment.

Similarly, the Texas Commission on Environmental Quality (TCEQ) requires its licensees and applicants to perform additional analysis prior to disposal of large quantities of DU. For example, the draft license for WCS' LLW disposal facility issued August 12, 2008, states that in order to dispose of DU, "information on complete waste profiles, radionuclide information, total radioactivity, radionuclide concentrations, chemical constituents, and analysis of any impacts to members of the public and the environment must be submitted as an application for amendment to this license." Currently, the TCEQ has not received information from WCS to satisfy this requirement. Finally, the Washington Department of Health has completed a performance assessment for the U.S. Ecology LLW disposal facility related to site closure that does not currently include large quantities of DU; however, the analysis could be modified to include the impacts from DU disposal. Staff did not contact enrichment facility licensees or other potential licensees when conducting its analysis.

In order to develop an informed response to the Commission direction, the staff performed a technical analysis to evaluate the impacts of near-surface disposal of large quantities of DU and to determine if amendments to § 61.55(a) are necessary to assure that large quantities of DU are disposed of in a manner that meets the performance objectives of Part 61.[5] The results of

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[4] "Review of the Institute of Energy and Environmental Research Report Related to Shallow Land Disposal of Depleted Uranium," Enchemica, LLC, (November 21, 2007).

[5] The staff also considered whether requirements for uranium mill tailings impoundments in 10 CFR Part 40, Appendix A, could be applied to disposal of large quantities of DU in a Part 61 LLW disposal facility. For example, Part 40 requires that the disposal design control radiological hazard from radon for 1,000 years. However, uranium mill tailings are a significantly different source term than the large quantities of DU from enrichment facilities, because the concentration of radium and radon in mill tailings is generally at its maximum concentration when disposed of and slowly decreases over time, in comparison to DU, where these daughter products increase over time and exceed the

this technical analysis are summarized in the discussion below; Enclosure 1 provides additional detail. Following the summary of the technical analysis, this paper presents four possible regulatory approaches to respond to the Commission direction.

In addition to these four approaches, the staff also evaluated the use of § 61.58 during development of this paper. This section of Part 61 may have been designed to allow licensees to perform and submit evaluations to address the performance requirements in Subpart C to Part 61 without a rule change. But the use of an exception provision like § 61.58 to *require* an additional site-specific study on certain Class A waste streams, without any associated rule change, is inconsistent with the basic premise of an exception. Specifically, the purpose of building an exception into a generally applicable rule is to allow an activity that would not otherwise be permitted, rather than to impose an additional requirement (e.g., performance of a site-specific study) on an activity that is already permitted (e.g., near-surface disposal of Class A waste). Thus, if § 61.58 were utilized to approve an alternate classification or characteristic, such action would provide additional options for a licensee, but would not require use of a particular option. Compliance with the approved alternative would not be the *only* method of compliance. Therefore, if the staff intended to use § 61.58 in order to develop an alternate waste classification or alternate characteristics for a Class A waste stream such as DU, *and to require licensees to conform to the alternate classification or characteristics as the sole method of compliance in place of (as opposed to as an alternative to) the existing regulations*, a rule change would be necessary.[6]

DISCUSSION:

Summary of Results of Technical Analysis

Staff developed a screening model to evaluate the radiological risk and uncertainties associated with near-surface disposal of large quantities of DU at a generic LLW disposal site. The generic disposal site had a broad range of climatic (e.g., humid or arid), hydrological, and geochemical conditions. The model was used to understand the impacts of key variables such as: disposal configurations, performance periods, institutional control periods, waste forms, site conditions, exposure pathways, and receptor scenarios. Calculations were performed probabilistically to

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mill tailings concentration about the 1,000 year time frame. For similar disposal conditions, the peak risk (at 2 million years) from radon from DU is orders of magnitude larger than from uranium mill tailings. However, even after 1,000 years, if the radon barrier is lost (meaning that the institutional controls had failed), radon hazards at uranium mill tailings impoundments would likely produce doses to intruders that exceed 500 millirem/yr, the intruder dose objective used in the development of the Part 61 waste classification system (NUREG-0706, Final Generic EIS on Uranium Milling, September 1980). Therefore, the staff concluded that specific and unique guidance was needed for disposal of large quantities of DU in LLW facilities to mitigate the potential impacts to the intruder.

[6] This is consistent with the discussion of § 61.58 in NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations: Draft Final Report for Interim Use." Specifically, NUREG-1854 states:

> 10 CFR 61.58 was intended to allow the NRC the flexibility of establishing alternate waste classification schemes when justified by site-specific conditions *and does not affect the generic waste classifications established in 10 CFR 61.55.* Thus, if the results of concentration calculations performed in a manner consistent with the principles and examples described previously in this document indicate that radionuclide concentrations in the waste exceed Class C limits, then the waste is greater than Class C waste for waste classification purposes. If it can be demonstrated that the performance objectives of 10 CFR Part 61 can be satisfied, then the waste would be suitable for near-surface disposal. " *Id.* at 3-36 (emphasis added).

represent the impact of variability and uncertainty on the results. The analysis methodology used in the model is consistent with the technical analysis methodology found in the FEIS supporting Part 61. The model framework is based on several key assumptions, which are detailed in Enclosure 1.

The technical analysis concluded that near-surface disposal (i.e., at a depth of less than 30 meters [m], as defined in Part 61) may be appropriate for large quantities of DU under certain conditions. However, unfavorable site conditions, such as shallow disposal (i.e., at a depth of less than 3 m) or disposal at humid sites with a potable groundwater pathway, could exceed the performance objectives of Part 61, Subpart C. Although shallow disposal for large quantities of DU is not likely to be appropriate regardless of site conditions, small quantities (approximately 1 – 10 metric tons) of DU could be disposed of at shallow depths.

Regulatory Options for Waste Classification

Based on the results of the technical analysis, staff believes that a change to existing regulations or a generic communication is necessary to ensure large quantities of DU are disposed of safely. Staff identified four options that it believes would facilitate safe disposal. Each option would likely draw significant stakeholder input from LLW disposal facilities interested in disposing of DU; commercial enrichment facilities generating DU; as well as DOE, who has responsibility for disposal of DU from NRC licensed enrichment facilities, if requested,[7] and responsibility for disposal of Greater than Class C (GTCC) waste.

The options and a summary of the pros and cons for each option are discussed below. The resources required for each option are presented in Enclosure 2. A complete discussion of the staff's evaluation of the use of § 61.58 is presented in Enclosure 3.

Option 1 – Generic Communication to Clarify Need to Demonstrate Compliance with Performance Objectives

In Order CLI-05-05 (In the Matter of LES, January 18, 2005), the Commission stated "In the end, the 'bottom line for disposal' of low-level radioactive wastes are the performance objectives of 10 C.F.R. Subpart C, which set forth the ultimate standards and radiation limits for (1) protection of the general population from releases of radioactivity; (2) protection of individuals from inadvertent intrusion; (3) protection of individuals during operations; (4) and stability of the disposal site after closure." Under Option 1, staff would issue a generic communication (e.g., a regulatory issue summary) that would reiterate the Commission's statement expressed in Order CLI-05-05 and would clarify acceptable methods for dealing with unique waste streams like large quantities of DU. The generic communication would emphasize that compliance with the existing performance objectives needs to be demonstrated through analysis and that classification under § 61.55(a)(6) should not be relied upon for this purpose. After developing the generic communication, staff would revise the associated guidance documents to describe an acceptable method for conducting a site-specific analysis for nuclides or concentrations not specifically covered in the waste classification tables. The specific parameters and assumptions

[7] Section 3113 of 1996 USEC Privatization Act.

> If the radioactive waste does not contain any nuclides listed in either Table 1 or 2, it is Class A.
>
> Proposed Change: Modify paragraph 61.55(a)(6) to include a statement that, for unique waste streams including, but not limited to, large quantities of depleted uranium, the requirements of § 61.55(a)(9) of this part must be met. Section 61.55(a) would then be modified to include a paragraph (a)(9), which would include a requirement that *the disposal facility licensee must perform, and the Commission must approve, a site-specific analysis demonstrating that the unique waste stream, including large quantities of depleted uranium, can be disposed of at the site in conformance with the performance objectives in subpart C to Part 61.*

Staff proposes that the rule language be broad enough to include other unique waste streams that may arise in the future, so that additional rulemakings may not be necessary. The term "unique waste streams" would be defined in the rule language. As currently envisioned, unique waste streams could include those that may result from spent fuel reprocessing, or other types of waste streams that could emerge in the future from new kinds of facilities that generate significantly different concentrations and quantities of waste not previously considered in the Part 61 FEIS. Similarly, staff intends to define "large quantities" of DU in the rule language as quantities similar to those being generated at uranium enrichment facilities. Staff does not intend to submit a rulemaking plan to the Commission for the rulemaking under this option.

In order to ensure that the site-specific analyses that would be conducted by licensees and applicants are consistent with the analysis performed in the Part 61 FEIS, and to be protective of public health and safety, staff believes certain technical requirements will also need to be specified in the rule language in paragraph (a)(9). For example, the type of receptors used to assess protection of the general population from releases of radioactivity, the exposure scenarios evaluated to protect individuals from inadvertent intrusion, and the period of performance evaluated are key parameters that affect the determination of suitability of disposal of large quantities of DU. Therefore, under Option 2, the specific technical requirements associated with disposal of large quantities of DU (as well as other unique waste streams) would be developed in the notice and comment rulemaking process. Option 2 also involves developing and issuing a guidance document that would provide the Agreement State regulators, and their licensees and applicants, technical guidance to conduct these site-specific analyses.

The primary advantage of Option 2 is that it creates a legally binding requirement, which ensures a site-specific analysis is performed by licensees and applicants and reviewed and approved by the Commission or Agreement State regulators. The staff believes that this outcome is consistent with the Commission's expectations set forth in its June 2, 2006, Order CLI-06-15 (In the Matter of LES). Specifically, the Commission stated "*We would expect the appropriate regulatory authority to conduct any site-specific evaluations necessary to confirm that radiological dose limits and standards can be met at the disposal facility, in light of the quantities of depleted uranium envisioned.*" (emphasis added). Because the Commission expects such an analysis to be conducted, staff believes it is appropriate to codify this expectation in the rulemaking under this option. Furthermore, several Agreement State regulators indicated that they preferred this option because it could be easily enforced. In addition, this option ensures the protection of health and safety by imposing an additional

requirement for large quantities of DU in a risk-informed manner that will be consistent with the analysis performed to develop the waste classification tables in § 61.55. The primary disadvantage of Option 2 is that, unlike other radionuclides in the waste classification tables, large quantities of DU would require a site-specific analysis instead of the use of a convenient table with a specific concentration limit. This option would also be more resource intensive than Option 1.

Option 3 – Determine classification for DU within existing classification framework

Staff believes some stakeholders may be interested in a specific waste classification for DU, within the existing Part 61 waste classification framework. Therefore, Option 3 involves developing a generic waste classification (e.g., A, B, C, or GTCC) for DU and an associated concentration limit to be added to the waste classification tables. Staff would begin with the technical analysis described in Enclosure 1, which was consistent with the Part 61 methodology but updated to include recent advances in modeling and performance assessment techniques. The result of staff's additional analysis would be a concentration limit for a generic LLW site in the United States. Consistent with the assumptions in the original Part 61 analysis, this concentration limit would likely be based conservatively on potential disposal at a "reference" humid, eastern LLW disposal site.[10] Subsequent to completion of this analysis, staff would initiate a rulemaking to revise the waste classification tables to explicitly include DU.

The primary advantage of Option 3 is that DU would be given a specific concentration limit, similar to the other radionuclides currently listed in § 61.55, and a specific waste classification that would apply to any LLW disposal site in the United States. The development of such a generic classification could prove useful if the current LLW environment were to change drastically in the future (e.g., if several new LLW disposal facilities are proposed) because it would eliminate the need for a site-specific analysis for large quantities of DU. The primary disadvantage of Option 3 is that the concentration limit developed could be so low for a reference site that it would unnecessarily constrain disposal options at sites with significantly different characteristics (e.g., humid vs. arid). As such, this approach would be prescriptive rather than a risk-informed approach, which would take into account the performance of the waste in a specific disposal environment. Another drawback to Option 3 is that it propagates the existing waste classification system, which was developed using often conservative assumptions based on the environment for LLW at the time the Part 61 FEIS was developed; some of these assumptions are not necessarily applicable in today's environment of limited disposal options and improved performance assessment capabilities.

Option 4 – Re-examine the existing waste classification framework

A final option staff considered is to risk-inform the entire waste classification framework by using updated modeling and performance assessment techniques to evaluate and revise the existing waste classification tables for all radionuclides, if necessary, not just for DU. This revision would likely involve different methodologies and assumptions than the original Part 61 methodology for key variables, such as: disposal configurations, performance periods,

[10] "To help provide conservative bounds to potential costs and impacts of waste disposal, the reference LLW disposal facility is assumed to be sited in a humid eastern environment." Part 61 FEIS, NUREG-0945, Vol. 1, (November 1982) at 4-10.

institutional control periods, waste forms, site conditions, exposure pathways, and receptor scenarios. The existing Part 61 waste classification framework is well accepted by the LLW disposal industry, and has been used successfully for more than two decades. However, as mentioned above, some of the assumptions built into the framework could be considered conservative and inconsistent with today's movement towards risk-informed regulation. In addition, the approaches to incorporate and evaluate the impacts of uncertainty and variability were more limited than those used currently.

Staff could also consider, for example, the International Atomic Energy Agency's waste classification system to determine if it would be appropriate for use in the United States. [11] Subsequent to completion of this analysis, staff would initiate a rulemaking to revise the waste classification tables. This rulemaking would likely draw the most stakeholder input of all the options presented in this paper, as it could potentially make significant changes to the entire existing waste classification environment.

The primary advantage of Option 4 is that the waste classification framework would reflect current knowledge of the performance of LLW disposal facilities and would present risk-informed concentration limits for all radionuclides, not selectively for DU. An update of the methodology used to develop the concentration limits could result in higher or lower concentration limits than currently used, which could actually increase or decrease disposal options for some types of wastes (e.g., current Class B/C waste could become Class A waste). However, some stakeholders may view this to be "deregulation" of LLW. A disadvantage of Option 4 is that the efficiency that could be gained from updating the existing waste classification framework may not be the most effective use of agency resources, given the relatively low increase in health and safety achieved and the small number of currently operating LLW disposal facilities. Option 4 is well beyond the scope of what the Commission directed the staff to consider in Order CLI-05-20, and would require a large amount of time and resources.

RECOMMENDATIONS:

Staff concluded that large quantities of DU can be disposed of in a near-surface disposal facility under certain conditions and meet the performance objectives of Part 61. However, staff believes a change to existing regulations is necessary to ensure large quantities of DU are disposed of safely due to the unique characteristics of the waste and additional considerations required for its disposal.

The staff recommends the Commission approve:

1. Option 2 — Rulemaking to specify a requirement for a site-specific analysis for large quantities of DU in § 61.55(a)(6) and technical requirements for such an analysis. This option provides a risk-informed approach to protecting public health and safety while causing minimal disruption to the existing waste classification system, yet codifying the requirement for a site-specific analysis in Part 61 for use by NRC, Agreement States, licensees, and future license applicants.

[11] International Atomic Energy Agency, "Classification of Radioactive Waste--A Safety Guide," Safety Series No.111-G-1.1. Currently being revised. See Draft Safety Guide No. DS 390, "Classification of Radioactive Waste."

2. That staff develop a guidance document for public comment that will outline the appropriate parameters and assumptions to use in conducting a site-specific analysis for disposal of large quantities of DU.

RESOURCES:

Staff's recommended option will require 2.0 full time equivalents (FTE) in FY10 to complete the documentation of the staff's technical analysis and to finish a draft of the guidance document. An additional 0.5 FTE is required to complete the technical basis for the rulemaking and to obtain stakeholder input on the guidance document. This 2.5 FTE will be obtained through a re-allocation of the common prioritization process for FY10 rulemakings. The remaining resources are needed in FY11 and FY12, and they will be requested through the budget process and the common prioritization process for upcoming rulemakings.

Enclosure 2 presents a detailed table of the resources required for each option presented in this paper.

COORDINATION

The Office of the General Counsel has no legal objection concerning this paper. The Office of the Chief Financial Officer has reviewed this paper for resource implications and has no objections. Staff coordinated with Agreement States (Washington, Utah, South Carolina, and Texas) and DOE during the development of options for this paper.

/RA/

R. W. Borchardt
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for Operations

Enclosure:
1. Analysis of Depleted Uranium Disposal
2. Resources
3. Depleted Uranium - Additional Options Evaluated

ANALYSIS OF DEPLETED URANIUM DISPOSAL

OVERVIEW:

A screening model has been developed by staff of the performance assessment branch in the Division of Waste Management and Environmental Protection to evaluate the risk and uncertainties of depleted uranium (DU) disposal as low-level waste (LLW) with near-surface disposal at a generic site. The model was developed to understand the impacts of key variables on the risks from disposing of DU in near-surface disposal, such that staff could respond to Commission direction to consider whether the quantities of DU in the waste stream from uranium enrichment facilities warrant amending the waste classification tables in 10 CFR Part 61 (Part 61). The model was developed to evaluate the radiological risk to potential future residents and intruders (acute or chronic exposures) near or on the land overlying a hypothetical disposal facility for the large quantities of DU anticipated to be disposed of as a result of fuel enrichment facility operations. The model was designed to provide the user flexibility in evaluating different waste types and forms, disposal configurations, performance periods, institutional control periods, pathways, and scenarios.

The model was constructed with the dynamic simulation software package GoldSim®, developed by GoldSim Technology Group of Issaquah, WA. Goldsim is a Monte Carlo simulation software solution for dynamically modeling complex systems in business, engineering and science. GoldSim is used for decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems. GoldSim has been used by U.S. Nuclear Regulatory Commission (NRC) staff to risk-inform reviews of U.S. Department of Energy (DOE) performance assessments (Esh, 2002; Esh, 2006). GoldSim is used by over 30 organizations in the field of radioactive waste management. A component or modular approach can be used in GoldSim to build a performance assessment model, which is the approach used in this analysis. Main submodels include inventory, source term, infiltration, radon, groundwater transport, and biosphere. Submodels use deterministic and probabilistic input values or distributions.

The model was used to understand the impacts of key variables on the risks from disposing of DU in near-surface disposal. Key variables evaluated were: disposal configurations, performance periods, institutional control periods, waste forms, site conditions, pathways, and scenarios. Calculations were performed probabilistically to represent the impact of variability and uncertainty on the results. The analysis methodology in the current assessment was consistent with the technical analysis methodology used for the development of the environmental impact statements supporting Part 61. This approach allowed constraints to be identified for the safe disposal of large quantities of DU in near-surface disposal. Because there were a wide range of variables considered, summary conclusions are not absolute; *a site-specific analysis may demonstrate compliance with the performance objectives when the summary conclusions found below indicate otherwise*. However, the properties and characteristics of DU present constraints on approaches for disposal. The summary conclusions provide the technical framework for policy decisions. The main technical observations are:

- Depleted uranium has some characteristics that are dissimilar from commercial LLW.
  - A large percentage of the activity is associated with very long-lived radionuclides.

  - Radioactive decay results in increasing hazard with time until after 1 million years, as a result of increasing concentrations (and higher mobility) of decay products.
  - In-growth of significant quantities of a daughter in gaseous form (^{222}Rn)
- Estimated risks are sensitive to the performance period.
- Estimated risk from radon is sensitive to the disposal depth.
- Radon fluxes to the environment are very sensitive to the long-term moisture state of the system.
- Large uncertainties (and little available data) associated with some transfer factors for uranium daughter products.
- Estimated disposal facility performance is strongly dependent on site-specific hydrologic and geochemical conditions.
- Radon is limiting at arid sites and for shallow disposal.
- The groundwater pathway is limiting at humid sites.
- Grouting of the waste may improve the likelihood of an arid site meeting the performance objectives with respect to radon; however, grout may enhance the mobility of uranium in the groundwater pathway after the grout degrades.

The summary conclusions from the technical analysis are:

- Near-surface disposal (i.e., less than 30 meters [m], as defined in Part 61) may be appropriate for large quantities of DU under certain conditions. However, unfavorable site conditions can result in the performance objectives not being met. Examples of unfavorable conditions include shallow disposal (< 3 m depth) and humid sites with a potable groundwater pathway.
- Because of the in-growth of radon and other daughter products, periods of performance of 1,000 years or less result in a significant truncation of estimated risk.
- Shallow disposal (< 3m deep) is likely to not be appropriate for large quantities of DU, regardless of site conditions. Shallow disposal may be possible if robust intruder barriers, excluding the possible excavation of DU, and a robust radon barrier that can effectively limit radon fluxes over the period of performance are installed, and their performance is justified. Small quantities (1 – 10 metric tons) could be disposed of at shallow depths.
- Depleted uranium can be disposed of under arid conditions and meet the Part 61 performance objectives for 1,000 to 1 million year performance periods, if the waste disposal depth is large, or robust barriers are in place to mitigate radon.
- Disposal under humid conditions with viable water pathways is probably not appropriate for large quantities of DU.

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