Texas Authorizes Disposal of Large Quantities of Depleted Uranium at WCS - 15626

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ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) has been actively engaged in a rulemaking process that would revise Title 10 of the Code of Federal Regulations (CFR), Part 61, *Licensing Requirements for Land Disposal of Radioactive Waste,* to govern the disposal of large quantities of Depleted Uranium (DU) and Blended Waste (referred to as Unique Waste Streams). While the NRC plans to propose a Site Specific Analysis (SSA) rulemaking in early 2015, they have already issued guidance to Agreement States which identified general disposal criteria that could be used should a licensee propose to dispose of Unique Waste Streams before their rulemaking was completed.

On August 5, 2013, Waste Control Specialists LLC (WCS) submitted a major license amendment application for review and approval to the Texas Commission on Environmental Quality (TCEQ). This major license amendment request proposed, among other things, authorization to dispose of large quantities of DU at its Federal Facility Waste Disposal Facility (FWF). Pursuant to Title 30 of the Texas Administrative Code (TAC), Rule 336.709, *Technical and Environmental Analyses*, disposal of waste must be sufficient to meet the radiological dose criteria for a minimum period of performance of 1,000 years after closure or the period where peak dose occurs, whichever is longer. These regulations are more stringent than those of any other state that hosts a facility authorized to dispose of Low-Level Radioactive Waste (LLW) in the U.S.

On August 28, 2014, the TCEQ approved the major amendment request authorizing disposal of large quantities of DU. During the licensing review process, significant technical issues were successfully resolved ensuring that large quantities of DU could be safely isolated from the biosphere for long time periods after site closure. Many important lessons were learned during the licensing proceedings that have potential significant impacts to the licensed community. Namely that a modern, well designed disposal facility that is properly sited geologically and in an arid environment is ideal for ensuring that long-lived alpha emitting radionuclides are sufficiently isolated to protect public health for long into the future.

Approval of the major amendment provides support to the U.S. Department of Energy's (DOE) effort to secure a disposal pathway for the inventory (approximately 700 gigagrams) of DU that has been generated primarily at the gaseous diffusion facilities located near Piketon, Ohio and Paducah, Kentucky. Furthermore, it provides a disposal pathway for DU generated commercially at facilities involved with uranium enrichment in the U.S.

The DOE is currently finalizing plans to complete a Supplemental Environmental Analysis (EA) to support shipments of DU for disposal at WCS' FWF as required under the National Environmental Policy Act of 1970. The DOE may begin shipments of DU for disposal to WCS FWF that was licensed and constructed to support disposal of waste that is the responsibility of the federal government as stipulated in the Low-Level Radioactive Waste Policy Amendments Act of 1985.

This paper will present the regulatory history of events that initiated the NRC's rulemaking for Unique Waste Streams and the technical analysis that were conducted in support of WCS' major amendment that has been approved by the TCEQ. A description of the geological characteristics and engineering designs used to support the Performance Assessment will be included.

INTRODUCTION

On December 27, 1982, the U.S. Nuclear Regulatory Commission (NRC) promulgated regulations establishing a system for classifying Low-Level Radioactive Waste (LLW) in Title 10 of the Code of Federal Regulations (CFR) Part 61, *Licensing Requirements for Land Disposal of Radioactive Waste* [1]. During the development of the technical basis supporting the waste classification system, the NRC only analyzed the typical types of waste that were known or expected to be encountered in the commercial sector in the Draft Environmental Impact Statement (DEIS) supporting the original 10 CFR 61 rulemaking [2]. Only small quantities of Depleted Uranium (DU) were generated in the commercial sector prior to 1982. As such, the NRC did not fully analyze the potential impacts to public health or the environment related to the disposal of large quantities of DU. Waste streams containing uranium, regardless of the level of enrichment, were classified as Class A LLW.

In 2003, Louisiana Energy Services, L.P. (LES)[1] proposed constructing the National Enrichment Facility (NEF) to be located near Eunice, New Mexico, in Lea County near the southeastern corner of the state. The NEF, a commercial uranium enrichment facility, would process and separate natural uranium into enriched uranium for the purpose of fabricating fuel for nuclear reactors. Additionally, the NEF would generate large quantities of DU that would require disposal as Class A LLW in a facility licensed pursuant to the requirements in 10 CFR 61.

On December 15, 2003, LES submitted an application under 10 CFR Part 70 to construct the NEF near Eunice in Lea County, New Mexico. During the licensing proceedings, the NRC acknowledged that DU was correctly classified as Class A LLW. However, the NRC Commissioners also accepted hearing contentions, as part of a contested case hearing, regarding whether or not DU had been properly classified at the time when 10 CFR 61 was originally established in 1982. During the deliberations, the Commissioners reaffirmed the Atomic Safety Licensing Board's decision that DU was properly classified as LLW. However, they deferred a ruling whether or not DU should be classified as Class A, B, C or waste exceeding the Class C

[1] Since renamed URENCO USA.

levels (referred to as Greater-Than-Class C (GTCC) LLW). During deliberations, the Commissioners acknowledged that Class A, B and C, and perhaps GTCC LLW should be disposed of in a “near surface disposal facility at a depth up to 30 meters. However, they also acknowledged that more protective methods could also be used to land dispose of certain LLW in a deeper facility equipped with special engineered barriers, often referred to as an “Intermediate Depth Waste Disposal Facility” [3].

SITE SPECIFIC ANALYSIS RULEMAKING: SECY-08-0147

On October 19, 2005, the Commissioners acknowledged that the contention of whether or not an inadequate environmental analysis has been properly conducted as part of the DEIS that originally supported the waste classification systems for DU in the initial rulemaking for 10 CFR 61 (CLI-05-20) [4]. The Commissioners subsequently directed (SECY-08-1047) its staff to proceed with a rulemaking to specify requirements for a site-specific analysis for the disposal of large quantities of DU and the technical requirements for such an analysis; and 2) to develop a guidance document for public comment that outlines the parameters and assumptions to be used in conducting such site-specific analyses [5].

The NRC began soliciting stakeholder involvement to gather information about the manner in which DU (also referred to a “Unique Waste Streams”) could be disposed of to protect public health and the environment. They also issued guidance to Agreement States that may be relevant for reviewing Performance Assessments supporting disposal of Unique Waste Streams, including large quantities of DU on April 13, 2010 [6].

This guidance suggested that Agreement States evaluate a licensee’s SSA that could be used to support disposal of such Unique Waste Streams until such time that the Commission completed its Part 61 rulemaking. The guidance acknowledged that disposal of Unique Waste Steams may be appropriate in near surface disposal facility under certain conditions, such as use of robust engineered barriers, and disposal at deeper depths. The Agreement State guidance also recommended limiting radiation doses to 5 mSv year^{-1} (500 mrem year^{-1}) for an inadvertent intruder after expiration of the 100 year institutional period consistent with NUREG-0782 and NUREG-0945 [2] [7].

The NRC also suggested limiting the radiological impacts to 0.25 mSv year^{-1} (25 mrem year^{-1}) for the general public with a Period of Performance of 10,000 years, as well as evaluating potential changes to climatic and environmental conditions at a disposal facility following NUREG-1573 [8]. The NRC recognized that the performance objectives in Subpart C of 10 CFR 61 did not provide explicit requirements for radon and different regulatory programs and different regulatory agencies had taken a variety of approaches to assess the impact from radon. The NRC recommended evaluating the impacts of radon using the update to the 10 CFR Part 61 impact analysis (NUREG/CR-4370) to calculate and add radon doses to other impacts assessed for the intruder-agriculture scenario [9].

CHANGES IN THE REGULATORY ENVIRONMENT: SECY-10-0165

Over the next few years the NRC efforts to finalize a rulemaking to govern the disposal of Unique Waste Streams became much more complex. The NRC Commissioners directed the staff (SECY-10-0043) to include “blended waste” as a Unique Waste Stream because large scale blending of waste at the upper limits of the Class A concentration-based threshold was not previously analyzed in the DEIS [10]. The NRC staff also recommended (SECY-10-0165) an approach for a comprehensive revision to Part 61 that included risk-informing the Part 61 waste classification framework, developing site-specific waste acceptance criteria, contemplating better alignment with international approaches for waste management, and efforts to supersede direction given in Staff Requirements Memorandum (SRM) 08-0147 [11].

Almost two years later the NRC staff recommended (SECY-13-0001) a change in the approach to amend Part 61 that would have established regulations for the disposal of large quantities of DU as originally envisioned in SECY-08-0147 [12].These changes were recommended for improving the efficiency of the ongoing rulemaking efforts to update the Part 61 regulatory framework. The NRC staff recommended approval to stop further efforts involving comprehensive changes to Part 61 associated with SECY-10-0165 and to better focus on a rulemaking limited to Unique Waste Streams.

The Commissioners approved the staff recommendations on March 26, 2013 [13]. They directed the staff to first proceed with a rulemaking for disposal of Unique Waste Streams and then to subsequently then their attention initiating a second rulemaking to determine whether or not large quantities of DU should be properly classified as Class A, B, C or GTCC LLW. The logical order of establishing disposal regulations for large quantities of DU before determining whether such waste streams are properly classified could pose significant adverse unintended consequence in the near future.

RULEMAKING STATUS

On July 18, 2013, the NRC staff submitted a draft SSA rulemaking that proposed regulatory criteria for the disposal of Unique Waste Streams, including large quantities of DU for approval by the Commissioners [14]. The draft rule proposed, among other things, a two tiered approach that would include a 10,000-year[2] compliance period, a dose limit and a post 10,000 year performance period.

The Commissioners directed the staff to make significant revisions to the proposed draft Part 61 rulemaking [15]. They believed that a 10,000 year period of compliance was too restrictive and directed the staff to include a 1,000 year regulatory compliance period a dose limit of 0.25 mSv year^{-1} (25 mrem year^{-1}) in the rule. The Commissioners approved a 10,000 year intruder

[2] The NRC staff had proposed a 20,000 year Period of Compliance, but the Commissioners believed that such a requirement was too restrictive. Therefore, the NRC staff proposed a 10,000 year Period of Compliance in the draft SSA rulemaking.

assessment analysis to be part of the rulemaking. A very important part of the Commissioners' directive was ensuring that a Compatibility Level "B" was applied to the most significant provisions of the rule. The Commissioners recognized that Agreement States hosting a disposal facility had established disposal regulations that were more stringent than what they would be requiring as part of the SSA rulemaking under 10 CFR 61.While the Commissioners believed that requiring Agreement States to revise their regulations to less stringent standards, the staff should continue with their outreach efforts after a proposed rule was noticed to before making a final determination on the Compatibility Category.

Over the past year the NRC has been working to incorporate changes to the SSA rulemaking. It is anticipated that the NRC will issue a proposed rulemaking in early 2015 for public comment and that a final rule would be completed in 2016.

DISPOSAL OF LARGE QUANTITIES OF DU APPROVED IN TEXAS

On September 10, 2009, the Texas Commission on Environmental Quality (TCEQ) approved Radioactive Material License No. RML (RML) R04100 authorizing construction and operation of the first new facilities to dispose of Class A, B and C LLW in the country in the past 40 years [16]. While the geological characteristics and engineering design for a LLW disposal facility are the most robust in the U.S., the facility would never have been licensed without the tremendous support from the State, regional and local communities of west Texas and eastern New Mexico.

WCS has originally analyzed the radiological impacts of disposing 10,000 m^3 of DU in the Federal Waste Disposal Facility (FWF) located in Andrews County, Texas. They recognized that the geological characteristics and robust engineering design was well suited for the disposal of large quantities of DU. The maximum radiation dose to the public, including an inadvertent intruder was well below the regulatory requirements and for a time period beyond 100,000 years. However, the TCEQ expressed reservations regarding authorizing the disposal of large quantities of DU due to the early and on-going deliberations by the NRC as they were proceeding with establishing a regulatory framework for the disposal of these waste stream. Accordingly, TCEQ limited the disposal of DU to concentrations not to exceed 10 nanocuries per gram and placed further restrictions on the types of DU waste forms that could be accepted for disposal in RML R04100.

On August 5, 2013, WCS submitted a request for a major amendment to RML R04100 to remove the limits for Tc-99, I-129, and C-14, as well as authorizing the disposal of large quantities of DU. TCEQ's review was supported using the guidance developed for Agreement States considering authorizing disposal of Unique Waste Streams by the NRC [6].

The purpose of the major amendment was to address some limitations in the original WCS license that potentially impeded the WCS facility from disposing of certain waste streams and to remove activity limits for certain radionuclides. In particular; elimination of a table that limited waste streams and certain waste classifications to those that were presented in the license application, radionuclide inventory limits that were established by the regulator based on very conservative assumptions, and limitations on large quantities of DU.

The major amendment to RML R04100 was noticed for public comment in the Texas Register on April 25, 2014 [17]. The TCEQ Commissioners denied a contested case hearing and approved the major amendment on August 20, 2014 [18].

SITE CHARACTERISTICS, ENGINEERING DESIGN AND PERFORMANCE ASSESSMENT

The superb geological characteristics and robust engineering design of the disposal facilities in Andrews County, Texas, were ideal for the long-term performance of the facilities and ensuring that long-lived alpha emitting radionuclides could be removed from the biosphere for hundreds of thousands of year into the future.

The disposal facilities were required by regulation to be located in an arid region of west Texas that received on average less than 41 cm (16 in) of precipitation per year. Moreover, evaporation-transpiration at the site is approximately 152 cm (60 in) of water per year.

The FWF is constructed within the Dockum formation, which is a highly impermeable formation of redbed clay (hydraulic conductivity of 1 x 10^{-9} cm s^{-1}) which is over 182 m (600 ft) thick. The nearest water table is 182 m – 305 m (600-1000 ft) below grade and is not suitable for human consumption. The depth of the FWF is well over 30 m. A thick cover system that is approximately 12.2 m (40 ft) thick is designed to ensure that water will not infiltrate into the waste. The design also includes multiple engineered barriers to prevent inadvertent intrusion into the waste well into the future. Photographs of the CWF and FWF are provided in Figures 1 and 2.

The TCEQ' requirement establishing a Period of Performance of 1,000 years or "peak dose", whichever is longer, ensures that radioactive waste is effectively removed from the biosphere for at least one-thousand years and more likely hundreds-of-thousands of years into the future. This requirement measures the long-term environmental performance of the site, as well as ensures that radiation doses to current and future members of the public will be much less than 0.25 mSv $year^{-1}$ (25 mrem $year^{-1}$) and 5 mSv $year^{-1}$ (500 mrem $year^{-1}$) for an inadvertent intruder.

The original Performance Assessment in the license application was performed using the RESRAD model. This model produced very conservative results which showed that the assumed projected waste streams easily satisfied the performance objectives. The supporting analysis for the major amendment was performed using the GoldSim, Version 10.5, transport platform and a more up-to-date projected waste streams. GoldSim was an excellent platform to perform this analysis due to its transparency and versatility in being able to more realistically model the various engineered barriers and scenarios and evaluate new waste streams.

Fig. 1. WCS Texas Compact Waste Disposal Facility

Fig. 2. WCS Federal Waste Disposal Facility

The GoldSim model for the WCS disposal facility was developed and tested over a period of about two years with assistance from Neptune and Company, Inc. The WCS site model includes these important features:

- A separate model for each of the disposal cells: Compact, Federal, and RCRA exempt;
- Modeling of distinct, separate layers in the engineered cover, waste, engineered barriers, and redbed clay formations beneath the disposal cell;
- Incorporation of extensive hydrogeological data, including distributions, based on borings, inspections, and test data;
- Ability to insert user defined inventories to determine if projected and new waste streams meet the performance objectives;
- HYDRUS 2D modeling to determine infiltration rates (Note that the infiltration rate through the 10 m engineered cover was determined to be zero, even under degraded cover conditions.);
- Future climate scenario that approximately doubles the rainfall;
- Control panel that allows selection of different intruder scenarios and important pathways; and
- Ability to run the model in the probabilistic mode using the distributions for the various parameters

For purposes of the major amendment and to address the limitations in the license, various assumptions were made for radionuclide inventories and analyzed in the new GoldSim site model. These included:

- Increasing the inventories of C-14, I-129, and Tc-99 in the FWF to an amount that was about 50 times the inventory evaluated in the original license application inventory, in order to justify eliminating the inventory limits;
- Increasing the inventories of C-14 in the CWF to an amount that was about 50 times the assumed original license application inventory, in order to justify eliminating the inventory limit in the license;
- Assuming a DU inventory of 400,000 m^3 in the FWF and 100,000 m^3 in the Texas Compact Waste Disposal Facility (CWF), compared to original license application assumed inventories of 10,000 m^3 in the FWF and none in the CWF; and
- Developing new assumed waste streams for the CWF that are at the Class C limits to show that any waste up to the Class C limit are acceptable for disposal at the WCS facility.

A new base source term for the CWF was also defined based on Barnwell receipts over the last 10 years and current WCS waste receipts. The license requires that this base inventory be updated on an annual basis and a Performance Assessment be run to verify the performance objectives continue to be met.

Each of the assumed inventories was analyzed using the GoldSim site model showing that the new user defined inventories satisfied the performance objectives. In addition, as a worst case, all of the new assumed inventories were added together to show that the performance objectives were still satisfied.

The GoldSim model implements various inadvertent intruder scenarios. For this analysis, a resident is always assumed to be located directly above the waste cell, and an oil drilling scenario is assumed to directly penetrate the waste cell after the reinforced concrete engineered barriers are assumed to fail at 600 years. The exception is the scenario labeled *Deterministic with forced resident and drilling off and solubility off,* since this is the most likely scenario due to the assumption that any of these occur is very conservative. The local survey of drillers and residents that was performed for the site concluded that due to relative area differences and other factors, the probability of any of these scenarios is far less than one. This same survey also found that the probability of using the sandstone zone[3] located at a depth of 65.6 m (225 ft) below grade as a drinking water source is near zero. As such this scenario was designated as the "legacy scenario", since it was previously analyzed in the original license application with a probability of one.

In the GoldSim model not all of the solubility limits are currently populated with a distribution, but the most important ones have been and include radium, uranium, and the highly mobile radionuclides. The most important for this analysis is Tc-99. With zero infiltration, long lived, mobile radionuclides will diffuse upward affecting pathways that are sensitive to surface uptake factors. In particular, Tc-99 tends to dominate the dose for these new pathways. This is believed to be a very conservative estimate due to the fact that the upper layers are very porous and dry, which may create a barrier to further upward diffusion to this upper layer where the uptake is assumed. For these analyses the solubility box was not checked so that the results will be more conservative.

A future climate scenario was also analyzed for all assumed inventories. Future climate box assumes the Wichita scenario that was postulated in the original license application. This changes the infiltration from zero to 0.27 mm year^{-1} and shows the effects of increased infiltration. This is very conservative as the latest research indicates that the region will remain dry for a much longer period (50,000 to 100,000 years) and the future precipitation will be significantly lower.

Note that there are significant differences between the scenarios in this GoldSim model and those analyzed in the license application. Additionally, the only intruder evaluated in the license application was the resident and the driller. The resident was assumed to drill a well at the cell boundary and use the water from the well (after dilution) for drinking water, watering cattle, and irrigation of a garden with a probability of one. A smaller diameter well was also assumed to be drilled through the waste with a probability of one with external exposure to the driller and the

[3] Referred to as the "225 Sandstone".

resident from the cuttings. The scenarios in this model are more robust and are also based on actual site conditions and regional practices.

The maximum radiation does to a member of the public and an inadvertent intruder were well below the regulatory limits of 0.25 mSv year^{-1} (25 mrem year^{-1}) and 5 mSv year^{-1} (500 mrem year^{-1}), respectively, as proposed in the draft SSA rulemaking. The results of the Performance Assessment are very conservative, including the legacy scenario involving consumption of drinking water even though the 225 sandstone formation yields less than 0.4 L day^{-1}. The highest dose is an intruder resident in the FWF due to produce ingestion and attributable to diffusion of Tc-99 to the surface.

The Performance Assessment results for large quantities of DU were most impressive. The entire inventory of DU of 700 gigagrams expected to be disposed by the U.S. Department of Energy over the next 30 years was assessed during the licensing review. The Performance Assessment results were also well below the regulatory requirements for a period of performance at one million years into the future.

The results of the Performance Assessment clearly demonstrated that a modern facility developed in an arid environment that is constructed in highly impermeable geological formations with robust engineering features and well above any potable water supply sources can easily comply the performance objectives proposed in the draft SSA rulemaking under 10 CFR 61. WCS shared their perspectives on this matter with the Subcommittee of the Advisory Committee on Reactor Safeguards on December 3, 2013 [19].

The results of the Performance Assessment are summary in the Appendix.

CONCLUSIONS

The NRC's work to establish regulatory requirements for the disposal of Class A, B and C LLW, as part of the original Part 61 rulemaking, are commendable. While they were intended to address the typical waste streams known and expected to be encountered in the late 1970s they did not envision generating large quantities of DU by the commercial sector, nor did they foresee the need to account for waste intentionally blended to the upper limits for Class A LLW. Almost twenty-five years after the rulemaking was completed it was discovered that waste disposal practices that would apply to large quantities of DU as Class A LLW may not be sufficient to protect public health and the environment at times frames well into the future.

The NRC's efforts to develop a new regulatory framework governing the disposal of Unique Waste Streams have been long and seemingly arduous. The regulatory guidance prepared by the NRC for Agreement States contemplating reviews by licensees requesting to dispose of Unique Waste Streams has been extremely helpful. This guidance arguably supports the technical basis that should be considered as part of a final SSA rulemaking that may be proposed in the coming months.

Waste management practices have matured considerably over the past 40 years. The licensing, construction and operations at the WCS disposal facilities in Andrews County, Texas, clearly demonstrate that a modern, well sited facility located in an arid environment is ideal for the disposal of long-lived alpha-emitting radionuclides, such as large quantities of DU. The regulations promulgated by the TCEQ requiring a demonstration that disposal of long-lived alpha-emitting radionuclides will comply with stringent radiation protection limits for hundreds of thousands of years into the future will clearly meet future standards established by the NRC for Unique Waste Streams.

Agreement States hosting a disposal facility have already established regulations and licensed operating facilities that are more stringent than those under consideration by the NRC as they move forward with a SSA rulemaking. The important role and commitment provided by local communities supporting the existing disposal facilities cannot be overstated. The NRC should thoughtfully consider whether their future decisions to require Agreement States to promulgate less stringent but compatible regulations may be contrary to fostering an environment that garners the support by local communities will to host a radioactive waste disposal facility.

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APPENDIX

PERFORMANCE ASSESSMENT SUMMARY RESULTS

TABLE 1. Results using 2012 new expected inventory

GoldSim Options in Control Panel	Exposure Pathway and/or Receptor	Regulatory Limit mSv y^{-1} (mrem-y^{-1})	New 2012 projected inventory	
			CWF mSv y^{-1} (mrem y^{-1})	FWF mSv y^{-1} (mrem y^{-1})
Probabilistic with solubility off	Adjacent Resident Outdoor Air	0.01* (10)	4.8×10^{-6} (4×10^{-4}) @ 960 y	
	Legacy Groundwater	0.25 (25)	1.8×10^{-4} (0.018) @ 100,000 y	2.4×10^{-5} (0.0024) @ 100,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.001 (0.10) @ 620 y driller/external	1.4×10^{-4} (0.014) @ 100,000 y dry farmer/grain
Deterministic with forced resident and drilling off and solubility off	Adjacent Resident Outdoor Air	0.10 (10)	1.9×10^{-6} (1.9×10^{-4}) @ 1000 y	
	Legacy Groundwater	0.25 (25)	1.6×10^{-4} (0.016) @ 100,000 y	2.1×10^{-5} (0.0021) @ 100,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.0055 (0.55)@ 600 y driller/external	1.4×10^{-4} (0.014) @ 600 y driller/external
Deterministic with forced resident and drilling on and solubility off	Adjacent Resident Outdoor Air	0.10 (10)	1.0×10^{-6} (1.0×10^{-4}) @ 1000 y	
	Legacy Groundwater	0.25 (25)	1.6×10^{-4} (0.016) @ 100,000 y	2.0×10^{-5} (0.002) @ 100,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.012 (1.2) @ 100,000 y resident/produce	0.002 (0.200) @ 100,000 y resident/produce
Deterministic with forced resident and drilling on solubility off and future climate on	Adjacent Resident Outdoor Air	0.10 (10)	1.0×10^{-6} (1.0×10^{-4}) @ 1000 y	
	Legacy Groundwater	0.25 (25)	5.0×10^{-4} (0.05) @ 50,000 y	0.008 (0.800) @ 49,000 y
	Peak Intruder Receptor/Pathway	0.10 (10)	0.005 (0.55) @ 1000 y driller/external	1.4×10^{-4} (1.4×10^{-2}) @ 600 y driller/external

* TCEQ radiation protection requirements for air emissions of radionuclides.

TABLE II. Large quantities of DU in the FWF and CWF

GoldSim Options in Control Panel	Exposure Pathway and/or Receptor	Regulatory Limit mSv y^{-1} (mrem- y^{-1})	2012 expected and Large Quantities of DU[a]	
			CWF mSv y^{-1} (mrem y^{-1})	FWF mSv y^{-1} (mrem y^{-1})
Probabilistic with solubility off	Adjacent Resident Outdoor Air	0.10 (10)	2.4×10^{-5} (0.0024) @ 1,000,000 y	
	Legacy Groundwater	0.25 (25)	1.0×10^{-4} (1.0×10^{-2}) @ 136,000 y	2.5×10^{-5} (2.5×10^{-3})@ 152,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.007 (0.70) @ 600 y driller/external	0.0023 (0.23) @ 1,000,000 y resident/indoor air
Deterministic with forced resident and drilling off and solubility off	Adjacent Resident Outdoor Air	0.10 (10)	3.6×10^{-4} (0.036) @ 1,000,000 y	
	Legacy Groundwater	0.25 (25)	1.7×10^{-4} (0.017) @ 124,000 y	2.2×10^{-4} (0.022) @ 146,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.043 (4.3) @ 600 y driller/external	0.014 (1.4) @ 700 y driller/external
Deterministic with forced resident and drilling on and solubility off	Adjacent Resident Outdoor Air	0.10 (10)	3.6×10^{-4} (0.036) @ 1,000,000 y	
	Legacy Groundwater	0.25 (25)	1.7×10^{-4} (0.017) @ 124,000 y	2.2×10^{-4} (0.022) @ 146,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.175 (17.5) @ 1,000,000y resident/indoor air	0.063 (6.3) @ 1,000,000 y resident/indoor air
Deterministic with forced resident and drilling on solubility off and future climate on	Adjacent Resident Outdoor Air	0.10 (10)	1.9×10^{-5} (0.0019) @ 1000 y	
	Legacy Groundwater	0.25 (25)	5.0×10^{-4} (0.05) @ 49,000 y	8.4×10^{-5} (0.0084) @ 48,000 y
	Peak Intruder Receptor/Pathway	5.00 (500)	0.043 (4.3) @ 600 y driller/external	0.014 (1.4) @ 700 y driller/external

[a] Analysis was performed for 1,000,000 years.