1. INTRODUCTION

Energy*Solutions*, headquartered in Salt Lake City, is a worldwide leader in the safe recycling, processing and disposal of nuclear material, providing innovations and technologies to the U.S. Department of Energy (DOE), commercial utilities, and medical and research facilities. At the Clive Facility, located 85 miles west of Salt Lake City, Energy*Solutions* operates a commercial treatment, storage and disposal facility for Class A low-level radioactive waste and Class A low-level mixed waste.

In early 2009, the U.S. Nuclear Regulatory Commission (NRC) voted to initiate rulemaking to require a site-specific analysis for the disposal of large quantities of depleted uranium (DU). Since that time, Energy*Solutions* has received 3,577 metric tons (5,408 drums) of uranium trioxide (DUO_3) waste that has been declared surplus from the Savannah River Site (SRS). In the future, Energy*Solutions* is also considering depleted uranium from the gaseous diffusion plants at Portsmouth, Ohio and Paducah, Kentucky. As is illustrated in Figure 1-1, Energy*Solutions* has evaluated a potential Federal Cell as ultimate destination for depleted uranium. In accordance with Utah Radiation Control Rule (URCR) Section R313-25-8(2), Energy*Solutions* is required to complete and submit to the Division's Executive Secretary for approval an in-depth site-specific performance assessment for the disposal of depleted uranium. Once approved, it is Energy*Solutions'* objective to file documentation requesting its Radioactive Material License be amended to include disposal of depleted uranium.

1.1 Licensing Overview

DOE remedial activities began for the Salt Lake City Vitro mill site in February 1985 and activities were completed in May 1989. Contaminated materials that remained at the site were excavated and relocated by the State of Utah to a newly acquired site, located 85 miles west of Salt Lake City at a location known as Clive, Utah. Adjacent to this operation, Energy*Solutions* (then known as Envirocare of Utah) began disposal operations at its Clive facility in 1988 under a State license (RML UT 2300249) to dispose of Naturally-Occurring Radioactive Materials (NORM). In 1990, Energy*Solutions* submitted a license application to modify its license to allow disposal of low-activity radioactive waste (LARW). In 1991, the Division granted this amendment request by issuing a license for LARW disposal. From time to time, the LARW disposal license has been amended to address Energy*Solutions'* changing needs and those of the public interest. Eventually, the license permitted disposal of Class A low-level radioactive waste (LLRW). In 2008, the Division renewed Energy*Solutions'* license (2008 RML renewal).

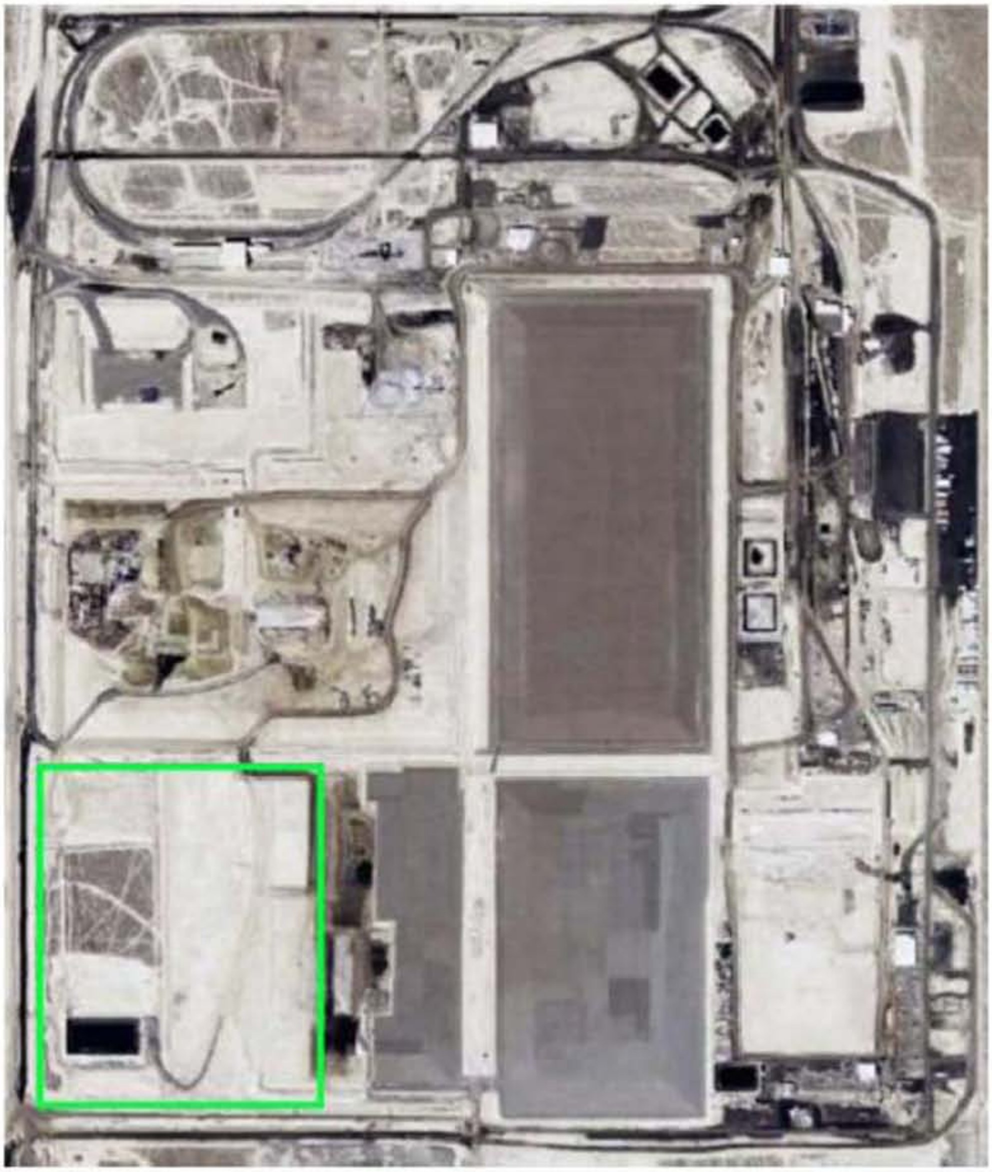

Figure 1-1, Energy*Solutions*' Proposed Depleted Uranium Disposal Location

Energy*Solutions* conducts other treatment and disposal operations in areas adjacent to its Class A embankments. These activities include mixed hazardous waste under a Treatment, Storage and Disposal (TSD) State-issued Part B RCRA Solid Waste Permit (re-issued by the Executive Secretary of the Utah Solid and Hazardous Waste Control Board on April 4, 2003). The nature of mixed waste managed at the facility includes contaminated soils, process waste, debris and sludges. The mixed waste portion of the Clive facility consists of a disposal cell, a treatment building, a storage building and an operations building. The treatment building is used for stabilization and solidification of certain waste streams and the operations building is used for alternative treatment technologies, such as macro-encapsulation and microencapsulation, as well as stabilization and storage of mixed waste.

Energy*Solutions* also disposes of uranium and thorium by-product material {11e.(2)} under a license issued by NRC as Byproduct Material License SMC-1559. Energy*Solutions*'11e.(2) license is now administered by the Division (RML UT2300478).

In conjunction with licensed activities, Energy*Solutions'* operations are also subject to the provisions of Ground Water Quality Discharge Permit (GWQDP) UGW450005, issued by the Utah Division of Water Quality (UDWQ). In 2008, Energy*Solutions* was awarded a renewal for this permit. This permit specifies that groundwater quality protection levels for radioactive constituents must be met for no fewer than 500 years following facility closure. Similarly, Energy*Solutions* also operates under Air Quality Approval Orders, issued by the Utah Division of Air Quality (UDAW).

1.2 Regulatory Summary

The Division regulates activities in the State of Utah that involve radioactive materials, some types of radioactive waste, and radiation. To assess whether Energy*Solutions*' Clive facility location and containment technologies are suitable for the disposal of depleted uranium and the continued protection of human health, specific performance objectives for land disposal of radioactive waste have been set forth in the URCR. Additionally, Energy*Solutions*' Clive facility is governed by the Department of Environmental Quality's groundwater and air regulatory requirements. Those rules potentially impacted by Energy*Solutions*' intent to dispose of depleted uranium include:

- "General Provisions" – URCR R313-12
- "Violations and Escalated Enforcement" – URCR R313-14
- "Standards for Protection Against Radiation" - URCR R313-15
- "Administrative Procedures" – URCR R313-17
- "Notices, Instructions and Reports to Workers by Licensees or Registrants—Inspections" – URCR R313-18
- "Requirements of General Applicability to Licensing of Radioactive Material" – URCR R313-19
- "Specific Licenses"- URCR R313-22
- "License Requirements of Land Disposal of Radioactive Waste" – URCR R313-25
- "Generator Site Access Permit Requirements for Accessing Utah Radioactive Waste Disposal Facilities" – URCR R313-26

- "Payments, Categories and Types of Fees" – URCR R313-70
- "Ground Water Quality Protection Rules" – Utah Administrative Code (UAC) Rule 317-6
- "Air Quality Protection Rules" – Utah Administrative Code Rule 307

1.3 Historical Management of Depleted Uranium

Large-scale uranium enrichment in the United States began as part of atomic bomb development by the Manhattan Project during World War II. Uranium enrichment activities were subsequently continued under the U.S. Atomic Energy Commission and its successor agencies, including DOE. The K-25 plant in Oak Ridge, Tennessee[1] was the first of three gaseous diffusion plants constructed to produce enriched uranium. The K-25 plant ceased operations in 1985, but uranium enrichment continues at facilities located in Paducah, Kentucky and Portsmouth, Ohio. These two plants are now operated by the United States Enrichment Corporation, created by law in 1993 to privatize uranium enrichment.

In the gaseous diffusion process, a stream of heated uranium hexafluoride (UF_6) gas is separated into a stream of UF_6 gas containing enriched U_{235} (EUF_6) and a stream of UF_6 gas depleted in U_{235} (DUF_6). The enriched uranium materials are used for manufacturing commercial reactor fuel, (typically contains 2 to 5% U_{235}), and military applications (requiring up to 95% U_{235}). The DUF_6 waste materials of interest to this Compliance Report typically contain U_{235} concentrations as low as 0.2 to 0.4%. Since the 1950s, DUF_6 waste materials have been stored at all three storage sites in large steel cylinders, similar to that illustrated in Figure 1-2.

Depleted uranium was also produced at DOE's Savannah River Site. The Savannah River Site produced depleted uranium as a byproduct of the nuclear material production programs, where irradiated nuclear fuels were reprocessed to separate out the fissionable Pu_{239}. Uranium billets were produced at the DOE Fernald, Ohio site, fabricated into targets at Savannah River Site, and then irradiated in the Savannah River Site production reactors to produce Pu_{239}. The irradiated targets were processed and fission products separated from the plutonium and uranium, which were then separated from each other. After additional purification, the depleted uranium-bearing waste stream was then processed into uranium trioxide (DUO_3). While still classified as depleted uranium, this DUO_3 also contains small quantities of waste fission products and transuranic elements. The Savannah River Site produced approximately 36,000 (55-gal) steel drums of DUO_3 during the production campaigns. This DUO_3, a solid powder at room temperature and pressure, is considered to be relatively homogeneous, based on known process controls and operations.

[1] The site of the K-25 plant is now called the East Tennessee Technology Park (ETTP), but is referred to by its original name, the K-25 site, in this Compliance Report.

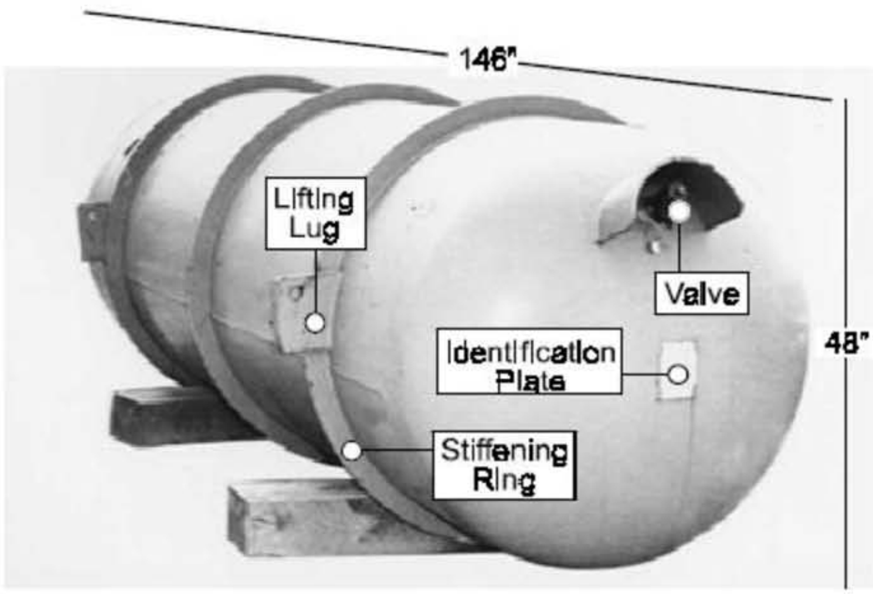

Figure 1-2, Typical Depleted Uranium Storage Cylinder (DOE, 1999)

Because storage began in the early 1950s, many of the drums and cylinders now show evidence of external corrosion and increased breach risk. When a DUF_6 container is breached, the contents react with moisture in air to form caustic hydrofluoric acid (HF) and solid uranyl fluoride (UO_2F_2). By 1998, breaches were identified in eight cylinders (two at Paducah, two at Portsmouth, and four at K-25), generally around spots previously damaged by handling activities. Similarly, a significant number of drums at the Savannah River Site have been placed into overpacks as a mitigating action for corrosion control and to prevent spills.

In an effort to reduce risks associated with container breach, Public Law 107-206, the 2002 Supplemental Appropriations Act for Further Recovery from and Response to Terrorist Attacks on the United States (commonly referred to as the "Terrorist Attack Response Act") requires DOE to design, construct, and operate facilities at Paducah and Portsmouth, for conversion of DUF_6 to the safer form, depleted triuranium octaoxide (U_3O_8). As part of this revised management strategy, all K-25 DUF_6 cylinders were shipped in 2004 to Portsmouth to be eventually converted to U_3O_8. The Terrorist Attack Response Act further required that the U_3O_8 be stored at Paducah and Portsmouth until there is a determination that all or a portion of the depleted uranium is no longer needed. At that point, the U_3O_8 is to be disposed of as low-level radioactive waste. DOE estimates the inventory of U_3O_8 that will eventually require disposal to be approximately 700,000 metric tons over a 20 to 25 year period (DOE, 2007).

Conversion to U_3O_8 is a preferential management strategy, because DUF_6 is a volatile, white, crystalline solid. Conversely, U_3O_8 is kinetically and thermodynamically stable and is the most common form of uranium found in nature. U_3O_8 can be produced in rotary kiln or fluidized-bed reactors by application of superheated steam and hydrogen (from dissociated ammonia) to DUF_6 (producing solid UO_2F_2 powder and gaseous HF). The powder UO_2F_2 is then defluorinated through heat and steam addition to create U_3O_8.

1.4 Basis for Performance Assessment

URCR R313-25-8 requires that a performance assessment be performed and approved by the Department of Environmental Quality prior to the disposal of significant quantities of depleted uranium. The required performance assessment must meet the provisions of section 2(a) of R313-25-8 that requires that the performance assessment:

> *"demonstrates that the performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules will be met for the total quantities of concentrated depleted uranium and other wastes, including wastes already disposed of and the quantities of concentrated depleted uranium the facility now proposes to dispose. Any such performance assessment shall be revised as needed to reflect ongoing guidance and rulemaking from NRC. For purposes of this performance assessment, the compliance period shall be a minimum of 10,000 years. Additional simulations shall be performed for the period where peak dose occurs and the results shall be analyzed qualitatively."*

In performance of the required performance assessment, it is useful to consider the guidance the NRC has issued to assist applicants and licensees in applying these standards as they reflect years of experience with a variety of waste streams and disposal situations. NUREG-1573 is a key NRC guidance document for conducting performance assessments(NRC, 2000). More recent guidance is contained in NUREG-1854, (NRC, 2007).

In particular, there are four areas to consider in applying the performance standards. First is the compliance period. Second is the dose methodology. Third is the dose standard for the intruder. Fourth is site stability.

Section 2 (a) addresses the time period for compliance. It states:

> *"For purposes of this performance assessment, the compliance period shall be a minimum of 10,000 years. Additional simulations shall be performed for the period where peak dose occurs and the results shall be analyzed qualitatively."*

From a compliance period perspective, 10,000 years is the time period for a quantitative analysis and is consistent with Federal rules and guidance. Given the nature of depleted uranium, a qualitative analysis out to the peak dose period is also warranted to inform the performance assessment. Use of the 10,000 year time period for compliance is consistent with federal regulations (e.g., 40 CFR 191) and NRC guidance. Extending the analysis qualitatively until peak dose is also consistent with NUREG-1573 recommendations. The NRC has taken a similar approach with the NRC Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site (NRC, 2002). It is noteworthy that the only Federal standard that goes beyond 10,000 years for compliance is the standard for Yucca Mountain (NRC, 2002). That provision provides a two-level dose standard with a higher dose limit of 100 mrem after 10,000 years.

Consequently, for purposes of applying the performance standards for protection of the general public (URCR313-25-19) and for protection of individuals from inadvertent intrusion (URCR313-25-20), the Division should chosen to use the 10,000 year compliance period with a qualitative analysis to cover the period beyond to the peak dose.

The performance standard for protection of the general public (URCR313-25-19) is based on the 1959 standards of International Commission on Radiological Protection (ICRP) Publication 2 methodology. URCR313-15 rules are based on newer ICRP guidance in Publications 26 and 30. Part 20 uses the total effective dose equivalent (TEDE) rather than the whole body dose. NRC has recognized the inconsistency between the dose methodologies and has issued guidance to allow the use of newer guidance. This approach was taken for Yucca Mountain in 10 CFR Part 63, NUREGs -1854 and 1573, and in the NRC Decommissioning Criteria for West Valley. As noted in NUREG-1573:

> *"As a matter of policy, the Commission considers 0.25 mSv/year (25 mrem/year) TEDE as the appropriate dose limit to compare with the range of potential doses represented by the older limits that had whole-body dose limits of 0.25 mSv/year (25 mrem/year) (NRC, 1999, 64 FR 8644; see Footnote 1). Applicants do not need to consider organ doses individually because the*

low value of the TEDE should ensure that no organ dose will exceed 0.50 mSv/year (50 mrem/year).”

Consequently, the Division should use for purposes of applying the performance standards for protection of the general public (URCR313-25-19) the total effective dose equivalent rather than the whole body dose.

The performance standard for protection of individuals from inadvertent intrusion (URCR313-25-20) requires “*...protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste*.” However, these regulations are silent on the specific dose standard to apply. Since Part 61 has been issued, the standard used by NRC and others for low-level radioactive waste disposal licensing has been an intruder standard of 500 mrem/yr. The 500 mrem standard is also used in DOE’s waste determinations implementing the Part 61 performance objectives (NUREG-1854). It is noted that 500 mrem/yr was also the standard proposed in Part 61 in 1981 (46 FR 38081, July 24, 1981). Additionally, the Statement of Considerations for the final rule did not object to the number. It was removed apparently at the request of EPA, because of its concern of how one would monitor it or demonstrate compliance with it, but not because EPA disagreed with it (47 FR57446, 57449, December 27, 1982). A dose standard of 500 mrem/yr is also used as part of the license termination rule dose standard for intruders (10 CFR 20.1403).

Consequently, DRC should use for purposes of applying the performance standard for protection of individuals from inadvertent intrusion (URCR313-25-20) a 500 mrem/yr threshold for the intruder dose.

The performance standard for stability requires the facility must be sited, designed, and closed to achieve long-term stability to eliminate to the extent practicable the need for ongoing active maintenance of the site following closure. The intent of this requirement is to provide reasonable assurance that long-term stability of the disposed waste and the disposal site will be achieved.

Prior to implementing Part 61, it had been a common practice at waste disposal facilities to randomly dump some waste. This practice jeopardized package integrity and did not permit access to voids between packages so that they could be properly backfilled. Consolidation of wastes would provide a less stable support which could contribute to failure of the disposal unit cover leading to increased precipitation infiltration and surface water intrusion.

To help achieve stability, NRC noted that to the extent practicable the waste should maintain gross physical properties and identity over 300 years, under the conditions of disposal. NRC believed that the use of design features to achieve stability was consistent with the concept of ALARA and the use of the best available technology. It was NRC’s view that to the extent practicable, waste forms or containers should be designed to be stable (i.e., maintain gross physical properties and identity, over 300 years). NRC also noted that a site should be evaluated for at least a 500-year time frame to address the potential impacts of natural events or phenomena should also be applied.

About the same time as Part 61 was promulgated, NRC also put in place requirements for design of uranium mill tailings piles such as the Vitro site which is right next to the Clive site. In addressing stability requirements for mill tailings, NRC recognized the need to set practicable standards. NRC specified that the design shall provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

In both cases (low-level radioactive waste and mill tailings disposal) NRC recognized the need to set practical standards that can be implemented. The design standards range from 200 up to 1,000 years. NRC recognized the design limitations and noted that reasonably achievable designs should be employed to the extent practicable. It is not practical to set design standards beyond 1,000 years.

Consequently, the Division should use for purposes of applying the performance standard for stability of the disposal site after closure (URCR313-25-22) an approach consistent with past standard setting practice.

Energy*Solutions* has demonstrated that its disposal site design and closure will provide reasonable assurance that long-term stability will be achieved and that the use of the best available technology in setting design standards in the range from 200 up to 1,000 years is appropriate to provide site stability to the extent practicable.

URCR Rule 313-25-8(2), as amended, requires Energy*Solutions* to demonstrate to the Division that proposed methods for disposal of depleted uranium will ensure that future operations, institutional control, and site closure can be conducted safely, and that the site will comply with the facility's performance objectives and the Division's regulatory requirements. Toward that end, Energy*Solutions* has conducted a detailed, site-specific, probabilistic performance assessment using GoldSim modeling software (GoldSim, 2011).

The GoldSim model, developed and managed by the GoldSim Technology Group, is a Monte Carlo simulation software solution for dynamically modeling complex systems in business, engineering and science. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems. GoldSim is a general purpose simulator that utilizes a hybrid of several simulation approaches, combining an extension of system dynamics with some aspects of discrete event simulation, and embedding the dynamic simulation engine within a Monte Carlo simulation framework. As part of a joint effort by NRC and DOE, the GoldSim model and the supporting sub-models have undergone extensive reviews concerning its use to demonstrate compliance with the individual protection standards (Pensado, et. al, 2002).

This Report demonstrates Energy*Solutions*' compliance with the URCR 313-25-8(2) and those other regulatory requirements affected by the proposed depleted uranium disposal.