Challenges Faced by the U.S. Nuclear Regulatory Commission for Activities related to U.S. Department of Energy Waste Determinations

D.W. Esh, A.C. Ridge, A.H. Bradford, S.C. Flanders, A.R. Whited
U.S. Nuclear Regulatory Commission
Two White Flint North, MS T7J8, 11545 Rockville Pike, Rockville, MD 20852
USA

ABSTRACT

Under the National Defense Authorization Act for Fiscal Year 2005 (NDAA), the Department of Energy (DOE) can determine that certain material resulting from the reprocessing of spent nuclear fuel is not high-level waste (HLW), and therefore does not need to be disposed of in a geologic repository in order to manage the risks that the waste poses. Reprocessing wastes can take a variety of forms including, but not limited to, liquid and sludge waste stored in underground tanks, waste removed from tanks and disposed of elsewhere after processing, and equipment that was utilized in waste processing which has been prepared for disposal. Section 3116 of the NDAA requires DOE to consult with the Nuclear Regulatory Commission (NRC) regarding DOE’s non-HLW determinations performed pursuant to the NDAA. The NDAA also requires the NRC to monitor DOE’s disposal actions to assess compliance with 10 CFR 61, Subpart C. The NDAA applies only to the States of Idaho and South Carolina. Although the NDAA applies only to the States of Idaho and South Carolina, similar waste determinations may be performed at DOE's Hanford site and West Valley Demonstration Project. The NRC expects to perform similar technical reviews for waste determinations performed at those sites. The Commission directed the staff to take the time necessary to complete its reviews to ensure protection of public health and safety, to make decisions that are transparent, traceable, complete, and as open to the public as practical, and to inform the Commission on how the staff intends to implement its monitoring responsibilities. NRC’s waste determination reviews under the NDAA are watched closely by many stakeholders, including environmental groups, other Federal and State agencies, and the public.

The complexity associated with the key aspects of making a non-HLW determination imposes significant challenges on the NRC staff. This paper provides an overview of the technical challenges faced by the NRC after passage of the NDAA and describes how those challenges are being addressed. The main challenge addressed in this paper is the differences between disposal of non-HLW and traditional low-level waste. Secondarily, this paper briefly addresses how to ensure consistency of technical reviews, and how to develop risk insights for a complicated system including estimating the impact of real-world features and complexity with simplified computer models.

INTRODUCTION

Although the NRC has been involved in the historical development of the incidental waste criteria and has reviewed some of DOE’s previous incidental waste determinations, the role prescribed by the NDAA is new to the NRC. In its consultative role under the NDAA, NRC performs technical reviews of DOE's waste determinations but does not have regulatory authority over DOE's waste management activities. To carry out its consultation activities and assist with establishing the scope of its monitoring activities, the NRC conducts technical reviews that typically consist of assessing whether DOE can meet the criteria specified in the NDAA. The criteria are: 1) the waste does not need to be disposed of in a geologic repository; 2) the waste has had highly radioactive radionuclides removed to the maximum extent practical; and 3) the waste meets Class C concentration limits and will meet the performance objectives of 10 CFR 61 Subpart C, or if the waste exceeds Class C concentration limits, will meet the performance objectives of 10 CFR 61 Subpart C, and will be disposed of pursuant to plans developed in consultation with the NRC. The performance objectives of 10 CFR 61 Subpart C provide criteria for protection of the public, including workers, during operation of the facility, protection of the public (both offsite and onsite) after closure of the facility, and stability of the disposal site after closure. Determining whether the criteria of the NDAA can be met poses difficult technical challenges.

Typically, a performance assessment model is developed to estimate the future radiological dose to potential receptors (e.g., to determine whether the requirements of 10 CFR 61.41 can be met) through the simulation of the release and transport of radionuclides, and exposure of the receptors to radionuclides. A performance assessment may be a single model or a collection of models used to represent a variety of processes. These processes typically include: infiltration of water to waste, degradation of concrete and grout, performance of engineered barriers used to mitigate water contacting the waste or other release processes, transport of radionuclides through the environment (if released), and resultant radiological impacts to receptors through exposure of contaminants from a variety of pathways. Although performance assessments are commonly simplifications of the real world, they may still be extremely complex calculations. The key question a reviewer typically asks themselves when faced with review of a complicated model is: *How should I perform this review and what should I focus on*? The challenges discussed in this paper are derived directly from attempting to answer this basic question.

REVIEW CHALLENGES

In fulfillment of consultation responsibilities under the NDAA, many challenges are faced by the NRC. These challenges range from technical and policy issues to practical considerations. The challenges addressed in this paper are primarily technical and include: understanding and considering the differences between disposal of non-HLW and traditional low-level waste, ensuring consistency of technical reviews, and developing risk insights for a complicated system.

Comparison of non-HLW and traditional LLW

The objective of a waste determination is to determine that certain materials resulting from the reprocessing of spent nuclear fuel is not high-level waste, and therefore does not need to be disposed of in a geologic repository in order to safely manage the risks that the waste poses. NRC has a regulation (10 CFR Part 61) and numerous associated guidance documents for the commercial disposal of low-level waste. For LLW disposal, it has been NRC's regulatory philosophy that disposal is different and distinct from storage. Disposal is isolation of radioactive wastes from man and the environment with no intention of retrieving the waste.

Disposal requires confidence in the actions taken such that the need for maintenance should be minimal, and monitoring should generally be confirmatory in nature. Until recently, with issuance of the draft standard review plan for non-HLW, the NRC staff had not developed internal or external guidance specifically for non-HLW [1]. This was mainly because if non-HLW can be safely managed as LLW, there should not be a need to develop guidance specific for non-HLW or to apply a different regulatory philosophy than for LLW. However, 10 CFR Part 61 and the associated guidance was developed for the specific technologies and scenarios envisioned for commercial LLW disposal more than two decades ago. Commercial LLW and non-HLW have similarities that reinforce the use of some aspects of 10 CFR Part 61 guidance for non-HLW determinations. Commercial LLW disposal and non-HLW also have some interesting differences that may need to be considered when applying 10 CFR Part 61 guidance to non-HLW determinations. Finally, there are some areas that are perceived as being substantially different (between commercial LLW and non-HLW) that are not actually very different.

Commercial LLW comes from a variety of sources including academic, government, industrial, medical, and utilities. The physical form and radiological composition can be quite variable and may include wastes such as compacted trash or solids, laboratory waste, adsorbed liquids, spent resins, and irradiated components. Utility-generated waste provides the dominant activity percentage. 10 CFR Part 61 provides a classification scheme to determine what class a waste may be. LLW is separated into three classes: A, B, or C and the disposal requirements are different for the different classes of waste. Class C waste, because of higher concentrations compared to class A or B, must be disposed of deeper than 5 m below the surface or with an intruder barrier that will prevent contact for 500 years. Commercial LLW disposal has occurred at a variety of sites including Beatty, Nevada; Maxey Flats, Kentucky; West Valley, New York; Sheffield, Illinois; Richland, Washington; Barnwell, South Carolina; and Clive, Utah. The first four sites are no longer operating. Early disposal practices used shallow-land burial reliant on the delay afforded by the natural system and the relatively short half lives of most isotopes in LLW (e.g. generally less than 30 years). Limits were placed on the allowable concentrations of long-lived radionuclides that could be disposed of in a commercial LLW disposal facility. Disposal practices have evolved; currently much greater emphasis is placed on the engineering of the disposal facilities.

Reprocessing wastes can take a variety of forms including, but not limited to, liquid and sludge waste stored in underground tanks, waste removed from tanks and disposed of elsewhere after processing, and equipment that was utilized in waste processing which has been prepared for disposal. The definition for HLW is a source-based definition that only implicitly considered the risk the material posed. In general, first-cycle waste from the reprocessing of spent nuclear fuel would have high concentrations of a variety of radionuclides and contain relatively high concentrations of long-lived radionuclides such that it should be managed as high-level waste. However, the reprocessing of spent nuclear fuel generates many different types of waste, other than first-cycle waste, that have a continuum of long- and short-lived radionuclide concentrations. Non-HLW determinations are used to determine if these wastes can be safely managed without geologic disposal.

Table I is the estimated radiological inventory (in Curies) for select radionuclides at a variety of

TABLE I Estimated Radiological Inventory of Select Radionuclides (Ci) for a Variety of Disposal Sites

Nuclide	Half life (yr)	LLW Sites[A]					Reprocessing Waste - Onsite Disposal[B]		Tank Residuals[C]			
		Barnwell	Clive	Beatty	Richland	WV-SDA	WV-NDA	Saltstone	SRS	INL	WV	Hanford
Tc-99	211,000	750	41	3.1	50	1.5	10	33,000	4.1	0.53	0	0.17
I-129	1.57E+07	8	3.4	0.17	5.6	3.3	0.02	18	3.E-05	5.E-04	7.E-04	NA
Sr-90	29.1	12,000	41.99	2,200	44,000	180	29,000	7,400	730	62	12,000	66,000
Cs-137	30.1	96,000	630	15,000	120,000	20,000	37,000	1.4E+06	31,000	1,100	1.E+05	1,500
Co-60	5.3	3.7E+06	2,200	28,000	1.5E+06	11,000	30,000	110	5.8	0.04	0	18
U-234	245,000	32	390	2.4	2.8	98	0.58	7.7	1.3	0.09	0.22	0.001
Np-237	2.1E+06	2.3	0.06	0.03	NA	0	0.16	2.1	0.07	0.03	0.11	0.05
Am-241	433	18	9.6	48	460	430	1,800	95	43	0.63	70	65
Pu-238	87.4	13	6.7	1.1	11,000	27,000	380	14,000	47	8.3	33	2.7
Pu-240	6,560	2	0.11	0.06	2,000	110	400	180	35	1	5.1	3.6
Decay Corrected?		No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Waste Volume (m^3)		272,000	390	5,300	394,000	67,000	10,000	627,000	45	26	29	11
Reference #'s		2,3,4	2,4	2,4	5	6	7	8	9	10	11,12,13	14

[A] The inventories for Barnwell, Clive, and Beatty are partial inventories and waste volumes only, obtained from DOE Environmental Management Manifest Information Management System (MIMS) at http://mims.apps.em.doe.gov [2]. They are not decay corrected, which would only be significant for short-lived radionuclides (e.g. less than 30 years). The Barnwell waste volume represents roughly 34% of the estimated waste volume [3]. There were some significant discrepancies between the inventory provided by MIMS and that provided in other sources for Barnwell [3]. The Beatty waste volume in the table represents only about 5% of the total waste volume. It is unknown what fraction of the inventory is represented (e.g., this may not be a representative sample) [4].

[B] Other reprocessing waste has been disposed of on-site, these are only two illustrative examples.

[C] Inventory values provided for SRS tank residuals is the average for Tanks 18 and 19 [9]. Inventory values provided for the INL tank residuals is the average for eleven tanks [10]. Inventory values provided for West Valley is the average of three tanks (the site has four tanks, one which contains very little inventory) [11,12,13] The inventory provided for Hanford is for tank C-106, the only tank where waste retrieval has reached a point to attempt tank closure [14]. NA = not available disposal sites. The first five sites (Barnwell, Clive, Beatty, Richland, West Valley – State licensed disposal area (WV-SDA)) are commercial LLW disposal sites. The second two sites (Savannah River Site (SRS) – Saltstone, West Valley – NRC licensed disposal area (WV-NDA)) are onsite disposal of reprocessing wastes. The last four sites (SRS, Idaho National Laboratory (INL), WV, and Hanford) are the residual inventories per tank estimated to remain in tanks used to store HLW after they have been emptied and cleaned. Only a small fraction of the total number of tanks at SRS and Hanford have been cleaned, therefore there is a significant amount of uncertainty as to whether the information is representative for tanks that have not undergone waste retrieval and cleaning. Tanks which have not been cleaned may have waste of different origin that has higher concentrations of radionuclides and may be more difficult to remove, but better technology may be developed to facilitate removal and cleaning. For commercial low-level waste disposal facilities, radiological inventory information is in some cases sparse. It was common in the 1960’s and 1970’s that waste generators only recorded volume and dose rate, or the dominant radionuclide in a disposal container. Recording and documentation of the radiological inventory of disposed LLW has improved dramatically in the past two decades. For Barnwell, Beatty, and Clive, the DOE-developed Manifest Information Management System was used to generate the radiological inventory in a given disposal volume. The disposal volumes provided in Table I for these three commercial LLW disposal facilities are partial volumes of what the facilities have received. The commercial disposal facilities and the onsite disposals for reprocessing wastes have much larger volumes of material, and in many cases, larger total inventories than the average tank residual. The row titled ‘Decay Corrected?’ represents whether the inventory has been decayed to a recent date (approximately within five years of the present). The data obtained from MIMS is not decay corrected while the other values have been. The impact of this uneven comparison is minimal, as most radionuclides in the table are sufficiently long-lived for the decay impacts to be insignificant, the exceptions being Cs-137, Sr-90, and Co-60. Co-60 has been included in the table to illustrate that a large portion of the inventory received at commercial LLW facilities is very short-lived activated metals.

Table II is the average radionuclide inventory for the three different types of disposal facilities considered (commercial LLW, onsite disposal of reprocessing wastes, and HLW tank residuals). The average radionuclide concentration in each disposal type is provided for select radionuclides. The overall quantity of radionuclides disposed of in the commercial LLW facilities compared to the onsite disposal of reprocessing wastes is similar, with two exceptions. First, the large quantity of Tc-99 to be disposed of at the Saltstone disposal facility at SRS stands out. Second, the commercial LLW facilities contain much more Co-60. At first glance, the tank residual inventories appear to be lower than the other two types. However, the table values for tank residuals are for an “average” tank and therefore the totals would need to be scaled to make an even comparison. When scaled, the total inventory values would be on the same order of magnitude as the commercial LLW disposal facility values and the onsite disposal of reprocessing waste values.

Whereas the total inventories may be similar, the concentration values are not. The commercial LLW facility concentrations are generally less, but not significantly less, than the values for onsite disposal of reprocessing wastes. However, the commercial LLW facility concentrations are significantly less than the HLW tank residuals. The HLW tank residuals are comparable in magnitude but the total inventory is contained in a much smaller volume. Therefore the natural

Table II Disposal Inventory (Ci) and Average Concentration by Disposal Type

Nuclide	Half life (yr)	Commercial LLW[1]	Reprocessing Wastes[2]	Tank Residuals[3]
Tc-99	211,000	170	17,000	2.4
I-129	15,700,000	4.1	9.0	0.0004
Sr-90	29.1	12,000	18,000	20,000
Cs-137	30.1	50,000	690,000	33,000
Co-60	5.3	1,000,000	15,000	6.0
U-234	245,000	110	4.1	0.4
Np-237	2,100,000	0.6	1.1	0.1
Am-241	433	190	940	45
Pu-238	87.4	7,400	7,000	23
Pu-240	6,560	410	290	11
Tc-99	Ci/m^3	0.02	0.03	0.07
Cs-137	Ci/m^3	1	3	1,100
Pu-238	Ci/m^3	0.09	0.03	0.7
Am-241	Ci/m^3	0.008	0.09	2.4

[1] The commercial LLW disposal inventory is in some cases a partial inventory, therefore the totals are low. The concentration values should be reasonably accurate.

[2] Reprocessing wastes values are represented by the Saltstone disposal facility at SRS and the NRC-licensed disposal area at West Valley.

[3] Values shown in the table are for an average tank. Need to scale the disposal inventory by the total number of tanks in a tank farm to compare the totals.

LLW facility concentrations represent the average concentration over all waste types. Typically a small fraction of the disposed waste by volume is Class C waste, but that small volume contains a large portion of the activity. A number of factors need to be considered when evaluating safety of the disposal, not just quantity and concentration. Table III provides a summary of some of the relevant considerations, in addition to the source, that would impact the risk from a disposal facility. The following text explains the table entries for Table III:

Disposal Type: The primary technology used for the disposal system. Commercial LLW disposal has used some form of shallow land burial, primarily in trenches on the order of 3 to 5 m deep with 1 to 3 m of cover prior to facility closure. Early practices used very little engineering. More recent disposal has used lined trenches and concrete vaults. Disposal at the WV-NDA used a variety of disposal technologies. Some high activity waste was placed in excavations more than 15 m below the land surface. Steel-lined concrete chambers were used for some waste. The SRS saltstone reprocessing wastes will be grouted into an engineered wasteform comprised of blast furnace slag, fly ash, and cement. The engineered wasteform will be poured into large, reinforced concrete vaults located at grade. Upon closure, the vaults are to be covered with a thick engineered cap. Tank residuals are grouted inside large underground storage tanks that were made of either carbon or stainless steel. Many of the tanks have secondary containment in the form of reinforced concrete vaults.

Table III Summary of Disposal Site Characteristics

Site	**Barnwell**	**Clive**	**Beatty**	**Richland**	**WV-SDA**	**WV-NDA**	**Saltstone**	**SRS**	**INL**	**WV**	**Hanford**
Disposal Type	Trench	Trench	Trench	Trench	Trench[a]	Variable[b]	Grouted wasteform in concrete vaults, at grade	Below grade carbon steel tanks filled with grout	Below grade stainless steel tanks filled with grout	Below grade carbon steel tanks filled with grout	Below grade carbon steel tanks filled with grout
Minimum Cover Depth[c] (m)	2.3	1.7	3	1.5	1.6	1.2	0.5	1	3.1	2.4	2.1
Waste Depth (m)	> 2.3	1.7	> 3	6.5	TBD	TBD	4.5	13	13	> 6	11
Stabilized[d]	No	No	No	No	No	No	Yes, with grout	Yes, with grout	Yes, with grout	Yes, with grout	Yes, with grout
LLW Siting Criteria	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Institutional Controls (time)	100 years	100 years	> 100 years	> 100 years	TBD	TBD	> 100 years	> 100 years	> 100 years	TBD	> 100 years
Site Ownership	State	State	State	Federal	State	State	Federal	Federal	Federal	State	Federal
Depth to Water (m)	10	5	90	70	< 5	< 5	23	1	140	2	80
Potable Water	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Buffer Zone	30 m	100 m	300 m	> 10 km	TBD	TBD	10 km	1600 m	> 10 km	TBD	> 10 km
References (#)	3,4	4	4	4,5,15	6	7	8	9	10	16,17	14

[a] Disposal type is primarily trenches 10 m wide, 6 m deep, 180 m long. Higher activity waste was placed in concrete vaults or deeper holes.

[b] High activity waste was placed up to 17 m deep in hole type excavations. Other wastes were buried in wider, shallower excavations. Steel-lined concrete chambers were used for some waste.

[c] Some facilities, including saltstone and West Valley, will install thicker covers at final closure.

[d] Indicates whether waste has been engineered to improve stability at disposal, or disposed of as-is. Although some commercial LLW has been stabilized in ordinary cement prior to disposal, it is unstabilized on a relative basis with respect to most reprocessing wastes.

Minimum Cover Depth: The minimum amount of cover that currently exists over the waste disposal system. Minimum cover depths are generally in the range of 1 to 3 m.

Waste Depth: Waste depth is the minimum depth where a significant fraction of the activity in the disposal facility could be encountered. Information on the final closure cover thickness for Barnwell and Beatty were not obtained. Final site closure and decommissioning decisions have not been made for West Valley. Preliminary designs were considering options ranging from continued control (for the WV-NDA and WV-SDA) to very thick (> 5 m) engineered closure covers (for the HLW tanks) [16]. HLW tank 8D-2 has a ring of contamination on the wall of the tank, therefore the waste depth presented is less than the depth of the waste layer on the bottom of the tanks (> 10 m) [11]. A thick engineered cover has been proposed for the Richland LLW facility [15].

Stabilized: This row of Table III is used to indicate whether the waste has been engineered to improve stability or whether it has been disposed of as-is. For commercial LLW disposal, liquid waste is not accepted and many wastes are disposed of in various types of containers. Some waste has been stabilized in ordinary Portland cement by the waste generator prior to disposal. Therefore, "no" may not be completely accurate. However, commercial LLW would be predominantly considered to be unstabilized on a relative basis compared with most reprocessing wastes. Reprocessing wastes are mixed, when possible, with engineered grouts to increase physical and chemical durability. When mixing is limited or not possible, reprocessing wastes are overlain by thick layers of engineered grout to limit water contact and engineer the disposal environment to favorable chemical conditions.

LLW Siting Criteria: The LLW siting criteria row in Table III is used to indicate whether the facility is located in an area that would generally satisfy the LLW siting criteria provided in 10 CFR 61. All of the commercial LLW facilities, even those sited prior to 10 CFR 61 being promulgated, would satisfy the LLW siting criteria with the exception being the State-licensed disposal area at West Valley. The disposal areas at the West Valley site would likely not satisfy the LLW siting criteria because of the potential for high rates of erosion that could impact waste isolation. Some of the HLW tanks at SRS are located in the zone of potential water table fluctuation, which is an excluding site characteristic in 10 CFR Part 61.

Institutional Control: The period of time that the disposal site may be controlled. Commercial LLW facilities are required to be controlled for 100 years. The timeframe for control of the West Valley site has not yet been determined, but will be decided through the decommissioning process. Without extensive cleanup, the site will likely be controlled longer than 100 years. Because of the location of the Beatty, NV facility with the respect to the Nevada Test Site and the location of the Richland, WA facility in the middle of the Hanford site, use and access of the site for public receptors is likely to be longer than 100 years. The institutional presence of the federal government at the sites with high-level waste storage tanks is currently envisioned to be longer than 100 years.

Site Ownership: Indicates who the land is owned by. In many cases the land is leased, either by a private company from a State, or by a State from the federal government.

Depth to Water: The vertical distance to a groundwater aquifer at each site, which is a rough measure of the natural system's ability to contribute to waste isolation. Of course this is a gross simplification, as the particular geologic material at a site and its chemical and physical properties are very important to limiting transport of waste from a site. Sites range from humid sites with shallow aquifers to arid sites with deep aquifers.

Potable Water: Whether the site has potable groundwater in the primary aquifer(s) that may be contaminated by the facility and whether the yields of the aquifer would be sufficient to support domestic uses of the water. The Clive, UT facility does not have potable water whereas the primary aquifer expected to be impacted by the WV-SDA and WV-NDA does not have sufficient yields. The Barnwell facility has a potable aquifer of sufficient yield, but the primary receptor is a surface water receptor where the groundwater outcrops. Current water use in the area is from deeper aquifers that are not expected to be impacted by contamination from the Barnwell facility.

Buffer Zone: The offset distance around the disposal facility that will be used to monitor and maintain the facility and will limit access to the waste. After the institutional control period ends, passive controls will be in place. Intruder receptors are evaluated inside the buffer zone, other public receptors are evaluated outside the buffer zone. Currently, the buffer zone associated with the federal facilities is much larger than envisioned for commercial LLW facilities. The size of the buffer zone will be determined by the long-term ownership and control of the site. The buffer zone size assumed in the technical analysis for a site may be different from the current buffer zone that is maintained or expected to be maintained.

The risk from a disposal facility is strongly influenced not only by the magnitude of the source, but how that source has been managed. The accessibility of the source to potential receptors and the stabilization of the source will influence the risk that the source may impose to human health and the environment. From the descriptive information provided above and the data in Tables I, II, and III, it is apparent that there are a number of similarities between commercial LLW facilities and facilities for disposal of reprocessing wastes, including tank residual waste. The similarities lend credence to the philosophy of using a risk-informed process for safely managing reprocessing wastes. There are also differences between commercial LLW and reprocessing wastes that create technical challenges for the review of non-HLW determinations under the NDAA. In general, tank residual waste is more highly concentrated than the average waste distributed over a commercial low-level waste facility (e.g., the average over all classes of waste), and tank residual waste is more likely to be located in an area that would not satisfy the LLW siting criteria (i.e., SRS tanks and West Valley). However, tank residual waste is buried substantially deeper, has more engineering of the wasteform, and may be expected to have longer periods of institutional control associated with federal ownership of the sites compared to commercial LLW facilities.

The higher concentrations of tank residual waste, particularly the long-lived radionuclides, combined with the greater amount of engineering of the wasteform places a larger burden on the review of the long-term performance of the wasteform and engineered systems in order to assess compliance with the performance objectives of 10 CFR 61, Subpart C. Evaluating long-term performance requires substantially more review effort because more processes and events need to be evaluated for the analysis period and the compound impacts of multiple processes and events becomes more likely. For example, consider a facility that uses an engineered cover to limit infiltration to the waste. If the source term was predominantly Co-60 (half life 5.3 years) the engineered cover may only be needed for a period of 100 years or less. If the source term has large quantities of Tc-99 (half life 15,700,000 years) the engineered cover may need to limit infiltration for a much longer period of time. The analysis for the longer period of time may need to consider slower processes such as soil pedogenesis, clogging of drainage layers by colloidal or other material, disturbance by animals, or plant succession that would not be expected to occur to a significant degree over 100 years but that may become important for the longer period of time. As the amount of performance of the waste form and engineered systems becomes larger either in terms of magnitude or duration, the reviews become more challenging.

The LLW siting characteristics were specified in 10 CFR 61 in order to prevent siting a LLW facility at a location that has a characteristic which may result in unacceptable performance. They were also intended to avoid complexities that may cause significant challenges (financial, technical, or otherwise) in generating technical information to support analysis of the processes in the licensing process. For example, the disposal site suitability requirements for land disposal at 10 CFR 61.50 specify the disposal site must provide sufficient depth to the water table that groundwater intrusion, perennial or otherwise, into the waste will not occur. LLW disposal is not permitted in the zone of fluctuation of the water table. A facility that is located in the zone of water table fluctuation, perennial or otherwise, introduces technical challenges to evaluate the impact of the processes on the demonstration of compliance with 10 CFR 61.41, which is usually dominated by risk from the groundwater pathway.

The dominant scenario used to develop the concentration values specified in 10 CFR 61.55 for waste classification was a resident intruder scenario, where an intruder would excavate a foundation for a house directly on top of the waste disposal facility after the institutional control period had ended. The waste classification values were also intended to provide a limit on the type of material that was suitable for disposal in near surface disposal facilities. Tank residual waste is generally buried much below a depth of 5 m (refer to Table III). Therefore, the applicability of the concentration values listed under 10 CFR 61.55 to tank residual waste was considered by NRC staff. To address this challenge, staff issued new concentration averaging guidance applicable to non-HLW determinations [1]. The revised guidance considered that for classification purposes it was appropriate to consider more mixing than may have actually occurred between the waste and stabilizing materials because the waste is deeper than assumed in development of the 10 CFR 61.55 table values. The concentration averaging guidance had to be consistent with past NRC principles, and apply to all types of non-HLW, which may include material that is buried deeper than 5 m as well as materials that are shallower than a 5 m depth, such as contaminated transfer lines. Therefore a simple approach was taken in the draft standard review plan for waste determination reviews [1]. Further guidance may be developed that allows more risk-informed approaches.

Ensuring Consistency of Technical Reviews

The technical challenges resulting from the differences between disposal of reprocessing wastes and the disposal of commercial LLW impose a burden on the NRC to ensure that reviews are performed consistently by different teams of reviewers. The assessment of a non-HLW determination typically involves technical review of a large quantity of technical information in a variety of different disciplines, including but not limited to hydrology, geochemistry, materials science, and health physics. Usually the reviews are completed by teams of subject matter experts. In order to ensure consistency of the technical reviews completed concurrently for different non-HLW determinations, the NRC decided to develop a Standard Review Plan (SRP) for waste determination reviews [1]. The SRP provides technical guidance to NRC staff performing reviews of waste determinations and helps to ensure consistency among reviews. The SRP emphasizes that reviews of waste determinations should be performance-based and risk-informed. A performance-based review is focused on the predicted performance of a facility, rather than prescriptive review criteria. A risk-informed review is focused on those aspects most important to health and safety. Therefore, the staff is expected to emphasize the aspects of the disposal system that are expected to have the most significant effect on the dose to potential receptors.

The SRP is intended to provide specific guidance to NRC staff reviewing waste determinations, but is not intended to introduce new interpretations of regulations. Thus, while the guidance in the SRP is tailored to the review of waste determinations, the guidance is, in general, based on and consistent with NRC=s existing LLW guidance. The SRP provides technical guidance on concentration averaging, receptor location, probabilistic and deterministic analysis, and analysis timeframe, among others. The SRP provides general review procedures to evaluate the system description, data sufficiency, data uncertainty, model uncertainty, and model support. Specific review procedures are provided and are devoted to the review of particular technical topics (e.g., infiltration, barrier degradation, or radionuclide release). For a summary of the Standard Review Plan, see the associated paper in this conference’s proceedings.

Development of Risk Insights for a Complicated System

As previously indicated, typically a performance assessment model is developed to estimate the future radiological dose to potential receptors (e.g., 10 CFR 61.41) through the simulation of the release and transport of radionuclides to receptors, and exposure of the receptors to radionuclides. The NRC performs a review of DOE’s performance assessment, which typically includes analysis of processes such as infiltration, degradation of concrete and grout, performance of engineered barriers used to mitigate water contacting the waste or other release processes, and, if released, transport of radionuclides through the environment projected for 10,000 years. The uncertainty associated with predicting the performance of the waste disposal system over this time period is significant and must be considered in NRC’s review. NRC has approached its reviews in a risk-informed manner, focusing on those features and modeling parameters that are most likely to impact radiological risk to the public, workers and the environment. If a prescriptive review process was used, the time to complete the reviews and the efficiency in completing the reviews would be diminished with respect to performing a risk-informed review.

The performance assessment documentation will commonly provide the justification for the data used, a description of the models used, verification of and support for the models, and an evaluation of the impact of data and model uncertainty. To evaluate uncertainty, a variety of techniques typically are used, including deterministic analysis with sensitivity analysis, and probabilistic analysis with uncertainty and sensitivity analyses. The results of the sensitivity analysis may be used to conduct a risk-informed evaluation through the in-depth review of those parameters and processes most important to system performance with respect to meeting the performance objectives.

In general, different approaches to performance assessment calculations (e.g., deterministic, probabilistic) have their advantages and disadvantages. A deterministic approach can be very valuable when the analysis is clearly conservative, because it makes the demonstration of meeting the performance objectives more straightforward and it can be significantly easier to interpret results and explain them to stakeholders. While deterministic analysis can be a suitable methodology for performance assessment, it can also present a challenge when used to represent a system that responds in a highly nonlinear fashion with changes in the independent variables. In addition, when there are numerous inputs (e.g., data or models) that are uncertain, the evaluation of the impacts of the uncertainties on the decision can be a challenge with a deterministic analysis. Typical one-off type of sensitivity analysis (e.g., where a single parameter is increased or decreased) will only identify local sensitivity within the parameter space, such that it may not clearly identify the risk implications of the uncertainty in the parameter. A probabilistic approach can have distinct advantages when there are a number of uncertainties that may significantly influence the results of a performance assessment or when the interdependence of parameters or assumptions is not clear (e.g., for highly nonlinear problems). However, there are limitations to probabilistic analysis, such as limited data to define parameter distributions and inappropriate impacts on the performance metric (e.g., peak mean dose) resulting from selection of overly broad parameter distributions, particularly for parameters that affect the timing of doses. Even with a probabilistic approach, conceptual model uncertainty may not be explicitly represented and therefore could not be assessed with uncertainty analysis.

In its NDAA reviews thus far, NRC has identified certain key assumptions in DOE’s analyses that are important to the ability of the waste disposal system to meet the performance objectives in 10 CFR 61, Subpart C, and will need to be confirmed via monitoring as disposal operations proceed. To identify key assumptions, parameters, and models, NRC reviews DOE’s analysis and supplements the DOE analysis with independent analysis. Most of DOE’s performance assessment analyses provided for non-HLW determinations have been deterministic. In past reviews, the NRC has asked for supplementation of limited sensitivity analysis provided by DOE, particularly looking at combinations of uncertainties [18, 19]. In addition, NRC staff has developed their own probabilistic performance assessments with the GoldSim general purpose simulation package to inform its review [20, 21, 22]. When the system is potentially complex and simplifications have been made in the performance assessment, it is imperative that the sensitivity and uncertainty is sufficiently comprehensive so that it can be determined if the appropriate level of complexity has been included in the analysis.

CONCLUSIONS

In fulfillment of consultation responsibilities under the NDAA, many challenges are faced by the NRC. This paper provided a detailed discussion of the similarities and differences between the disposal of non-HLW and traditional low-level waste. The magnitude of the inventory of a variety of select radionuclides was fairly similar in commercial LLW facilities, facilities for the onsite disposal of reprocessing wastes, and closed HLW storage tanks containing residual waste, with a few exceptions. The concentration of select radionuclides in HLW tank residual waste was significantly higher than the other two types of disposal facilities. However, HLW tank residual waste is buried deeper and has more engineering of the wasteform, possibly offsetting the higher concentrations of radionuclides compared to commercial LLW.

The differences between reprocessing wastes and commercial LLW have created review challenges. The review challenges have resulted in the NRC developing a Standard Review Plan for waste determination reviews to ensure consistency of the reviews. Because of technical complexities at the DOE sites and the higher concentration of long-lived radionuclides, greater focus is placed on review and support of the engineered aspects of the disposal facilities than would be performed for a commercial LLW facility. The complexity of the issues and long time period for the analysis require the analysis of sensitivity and uncertainty to be more thorough. The NRC staff have developed their own independent probabilistic performance assessments to develop risk insights to focus their reviews.

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REFERENCES

1. U.S. Nuclear Regulatory Commission (NRC). ‘Standard Review Plan for Activities Related to U.S. Department of Energy Waste Determinations: Draft Report for Interim Use and Comment.’ NUREG-1854, US Nuclear Regulatory Commission, Washington, DC, May 2006.

2. Information obtained from DOE-EM Manifest Information Management System (MIMS) at http://mims.apps.em.doe.gov/

3. Chem-Nuclear Systems, ‘Interim Site Stabilization and Closure Plan for the Barnwell Low-Level Radioactive Waste Disposal Facility 2005 Closure Plan,’ PL-CNS-05-001, Chem-Nuclear Systems, Barnwell, SC, June 2005.

4. DOE, 'Directions in Low-Level Radioactive Waste Management: A Brief History of Commercial Low-Level Radioactive Waste Disposal,' DOE/LLW-103, Rev. 1, U.S. Department of Energy, Idaho Falls, ID, August 1994

5. Rood, A. S., 'Groundwater Concentrations and Drinking Water Doses with Uncertainty for the U.S. Ecology Low-Level Radioactive Waste Disposal Facility, Richland, Washington, K-Spar Inc., Rigby ID, March 2003.

6. Wild, R. E., 'SDA Radiological Characterization Report,' URS, Orchard Park, NY, September 2002.

7. Wild, R. E., 'Estimated Radionuclide Inventory for the NRC-Licensed Disposal Area at the West Valley Demonstration Project,' URS, Orchard Park, NY, August 2000.

8. NRC. ‘Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal.’ Letter from L. Camper to C. Anderson, DOE. US Nuclear Regulatory Commission, Washington, DC December 2005.

9. DOE, 'Draft 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site,' DOE, Aiken, SC, September 2005.

10. DOE, 'Draft Section 3116 Determination Idaho Nuclear Technology and Engineering Center Tank Farm Facility,' DOE/NE-ID-11226, Rev. 0, U.S. Department of Energy, Idaho Falls, ID, September 2005

11. Fazio, J. M., 'High-Level Waste Tanks 8D-1 and 8D-2 Radionuclide Inventory Report as of September 1, 2002,' RIR-364-001, West Valley Nuclear Services Company, West Valley, NY, September 2002,

12. Fazio, J. M., 'Waste Storage Tank 8D-3 Radioisotope Inventory Report,' RIR-403-003, West Valley Nuclear Services Company, West Valley, NY, September 2002,

13. Sharma, V. K., 'Waste Storage Tank 8D-4 Radioisotope Inventory Report,' RIR-403-006, West Valley Nuclear Services Company, West Valley, NY, November 2002,

14. Sams, T. L., 'Basis for Exception to the Hanford Federal Facility Agreement and Consent Order Waste Retrieval Criteria for Single-Shell Tank 241-C-106,' RPP-20658, Rev. 1, CH2M Hill Hanford Group, Inc., Richland, WA, June 2004

15. WDOH, 'Draft Environmental Impact Statement: Commercial Low-Level Radioactive Waste Disposal Site, Richland Washington', Washington Department of Health, Olympia, WA, August 2000.

16. Zadins, Z. Z., 'Closure Engineering Report Conceptual Approach for Implementing Decommissioning EIS Alternative 3,' WSMS-WV-05-2003, Washington Safety Management Solutions LLC, West Valley, NY, September 2005.

17. Elmore, M. and C. Henderson, ‘Functions and Requirements for West Valley Demonstration Project Tank Lay Up,’ PNNL-13898, Pacific Northwest National Laboratory, Richland, WA, March 2001.

18. NRC, ‘NRC Review of Idaho Nuclear Technology and Engineering Center Draft Waste Incidental to Reprocessing Determination for Tank Farm Facility Residuals - Conclusions and Recommendations.’ Letter from L. Kokajko to J. Case, DOE. US Nuclear Regulatory Commission, Washington DC, June 2003.

19. NRC, ‘REQUEST FOR ADDITIONAL INFORMATION ON THE DRAFT SECTION 3116

DETERMINATION FOR SALT WASTE DISPOSAL AT THE SAVANNAH RIVER SITE,’ Letter from Scott C.Flanders to Mark A. Gilbertson, US Nuclear Regulatory Commission, Washington, DC, May 26, 2005.

20. Esh, D.W., A.H. Bradford, K.L. Banovac, and B.J. Davis, ‘Risks and Uncertainties Associated With High-Level Waste Tank Closure,’ *Proceedings Scientific Basis for Nuclear Waste Management XXVI*, Materials Research Society, Pittsburgh, PA, 2002.

21. Esh, D. W, Ridge, A. C., ‘Development of Risk Insights for Regulatory Review of a Near-surface Disposal Facility for Radioactive Waste,’ Waste Management ’06 Conference, February 26 – March 2, 2006, Waste Management ’06 Symposia,Tucson, AZ, 2006.

22. GoldSim, GoldSim Technology Group LLC, Issaquah, WA, 2004.