March 21, 2013

MEMORANDUM TO: Gregory Suber, Chief
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Division of Waste Management
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THRU: Chris McKenney, Chief **/RA/**
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FROM: Leah Parks, Systems Performance Analyst **/RA/**
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SUBJECT: TECHNICAL REVIEW UPDATED COST-BENEFIT ANALYSIS FOR REMOVAL OF ADDITIONAL HIGHLY RADIOACTIVE RADIONUCLIDES FROM TANK 18

The U.S. Nuclear Regulatory Commission (NRC) staff has performed a technical review of the subject document prepared by the United States Department of Energy (DOE) addressing the costs and benefits of additional radionuclide removal from Tank 18. This technical review activity supports monitoring factor 1.5 “Waste Removal (As It Impacts ALARA)”, in NRC staff’s FTF monitoring plan (NRC, 2013). NRC staff concludes that DOE presents satisfying arguments as to why the costs of additional clean-up at this point in time outweigh the benefits for the reference case. However, NRC staff notes that many additional costs were due to the length of time that had passed between the decision to cease removal activities and the time at which the cost-benefit analysis was performed. DOE does not expect this lapse in time for future cost-benefit analysis for other tanks. In the future, DOE anticipates that NRC will be provided the opportunity to comment on the cost benefit analysis earlier in the process whether

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it be in coordination with the State of South Carolina during the public comment period, or as a potential onsite observation activity. NRC staff discussed questions pertaining to this review in a teleconference with DOE on July 26, 2012 (NRC, 2012). There are no open issues identified in this review. DOE should consider engaging with NRC early in the decision-making process when deciding to cease cleaning activities as part of NRC monitoring efforts under the as low as reasonably achievable provisions of 10 CFR Part 61, Subpart C for future tanks.

Docket No.: PROJ0734

Enclosure:
Technical Review of Updated Tank 18
Cost Benefit Analysis

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Technical Review of Tank 18 Cost Benefit Analysis

Date: March 21, 2013

Reviewer: Leah Parks

Documents: *Cost-Benefit Analysis for Removal of Additional Highly Radioactive Radionuclides from Tank 18, F-Area Tank Farm Savannah River Site*, SRR-CWDA-2012-00026, Revision 1, March 2012.

Summary:

The U.S. Department of Energy (DOE) prepared a new, more rigorous cost-benefit analysis, evaluating the benefits of additional waste removal from Tank 18 versus the costs and risks associated with additional removal and delaying of operational closure of Tank 18, to address U.S. Nuclear Regulatory Commission (NRC) technical evaluation report (NRC, 2011) comments and recommendations in this area. Because the cost-benefit analysis can also be used to support the as low as reasonably achievable (ALARA) criteria in 10 CFR 61.41, NRC staff reviewed the updated cost-benefit analysis in partial fulfillment of its monitoring responsibilities under 10 CFR 61.41 in accordance with the National Defense Authorization Act for Fiscal Year 2005.

This document analyzes the costs and benefits of additional Highly Radioactive Radionuclide (HRR) removal from Tank 18. DOE identified 50 potential technologies and fully evaluated the following four technologies: (1) robotic crawler such as the Sand Mantis with liquid mobilization and vacuuming; (2) articulating arm with liquid mobilization and vacuuming; (3) feed and bleed with mixing and recirculation using pumps; and (4) direct acid cleaning with robotic support. DOE assumes additional cleaning would remove 100 percent of the HRR inventory inside Tank 18. DOE applied the following decision criteria to determine if the benefits outweighed the costs: (1) worker dose should not exceed the 50-year averted dose to a member of the public; (2) unit monetary cost of dose reduction should not exceed $200,000 per person-Sv ($2000 per person-rem) by a significant amount; (3) unit risk reduction cost[1] should be significantly greater than the unit risk reduction cost for other representative DOE remediation projects; and (4) closure should not be delayed unless there is significant benefit. Note that the fourth criterion was only considered if all three of the first criteria were met. DOE evaluated these four criteria for the reference case and two sensitivity cases.

The reference case (based on the period of peak dose within 10,000 years) assumes the benefit of additional removal is a 0.03 mSv/yr (3 mrem/yr) reduction because the Special Analysis (DOE, 2010) predicted that 0.03 mSv/yr (3 mrem/yr) out of the 0.034 mSv/yr (3.4 mrem/yr) peak

[1] DOE actually uses the "unit risk reduction cost" as a measure of the relative benefit of a particular remedial project. The unit risk reduction cost is calculated by dividing the potential risk reduction associated with execution of a particular remedial activity by the cost of the activity. Therefore, a project with a larger unit risk reduction cost would be more cost-beneficial then a project with a lower unit risk reduction cost. The potential risk reduction associated with hypothetical removal of additional waste from Tank 18 is calculated using the risk factor of 8E-04 risk of cancer per rem of exposure. Use of the unit risk reduction cost is consistent with The Decommissioning Handbook (ASME 2004).

can be attributed to Tank 18 [SRR, 2010]. The cost for the least expensive technology (Sand Mantis) is estimated to be $38 million, and the worker dose of 0.032 Sv (3.2 rem) would be 20 times greater than the averted dose over 50 years. The unit cost of averted dose to the future member of the public is $25.3 million per mSv ($253,000 per mrem), which accounts for averting 0.03 mSv/yr (3 mrem/yr) over 50 years. The unit risk reduction cost is lower than for other typical remediation projects (see Table 1). Therefore, none of the three decision criteria are met in the reference case (see Table 2).

The two sensitivity cases include: (1) cost uncertainties, and (2) the potential reduction in peak dose within 40,000 years. The bounding case considering cost uncertainties assumes the cost is reduced by $4.5 million, or $33.5 million. The averted dose is assumed to be the same as the reference case. This cost reduction is not great enough to meet any of the decision criteria. The second sensitivity case assumes that HRR removal is effective at removing half the Tank 18 Pu-238 inventory as opposed to 100% in the reference case, which reduces the peak from 5 mSv/yr to 2.5 mSv/yr (500 mrem/yr to 250 mrem/yr), or a total of 1.25 Sv (12.5 rem) over 50 years. In this scenario, the averted dose is greater than the worker dose of 0.032 mSv (3.2 mrem) so the first criterion is met. For the second criterion, DOE concludes that the $3.0 million unit cost of dose reduction is still greater than the $2000 per unit value that NRC assigns to averted collective dose. DOE also concludes that the unit risk reduction cost of 3E-10 is not significantly greater than other DOE remediation projects (see Table 1). Therefore, DOE concludes that the costs outweigh the benefits in all sensitivity cases (see Table 2).

Table 1 – Risk Reduction Cost Comparison (from Table 7-1 of SRR-CWDA-2012-00026)

Project	Dose Reduction (Over 50 yrs)	Risk Reduction Factor	Estimated Dollar Cost	Risk Reduction/ Cost
Tank 18 additional HRR removal Reference Case	1.5 mSv (150 mrem or 3 mrem over 50 yrs)	1.2E-04	3.8E+07	3E-12
Tank 18 additional HRR removal Sensitivity Case 1	1.5 mSv (150 mrem or 3 mrem over 50 yrs)	1.2E-04	3.35E+07	4E-12
Tank 18 additional HRR removal Sensitivity Case 2	0.125 Sv (12.5 rem or 250 mrem over 50 yrs)	1.0E-02	3.8E+07	3E-10
INL Technical Area North-607	NA	3.3E-03	3.4E+07	8E-10
INL TRA Hot Cells	NA	2.0E-01	6.3E+06	3E-08
INL Engineering Test Reactor Complex	NA	3.3E+04	2.0E+06	2E-10
West Valley Demonstration Project	1.01 Sv (101,000 mrem)	8.08E-2	1.2E+09	7E-11

Table 2. Summary of DOE Decision Criteria and Results

Project	Criterion 1 The 50-year averted dose to a member of the public must be less than worker dose of 0.032 Sv (3.2 rem)	Criterion 2 Cost of dose reduction should not exceed $2000 per person-rem by a significant amount	Criterion 3 Risk reduction per unit cost should be significantly greater than for other representative projects
Tank 18 Reference Case	1.5 mSv (150 mrem)	$253 million/person-rem	3E-12
Do benefits outweigh costs?	NO	NO	NO
Tank 18 Sensitivity Case 1	1.5 mSv (150 mrem)	$223 million/person-rem	4E-12
Do benefits outweigh costs?	NO	NO	NO
Tank 18 Sensitivity Case 2	0.125 Sv (12.5 rem)	$3.0 million/person-rem	3E-10
Do benefits outweigh costs?	YES	NO	NO

NRC Evaluation:

NRC staff evaluated DOE's list of alternative technologies and considers the list to be adequate for the purpose of performing the cost-benefit analysis. In the Technical Evaluation Report (TER), NRC staff recommended that DOE consider long-term risks associated with Pu-239 in Tank 18 in the selection of alternative technologies given that Tank 18 is arguably the single-most risk-significant tank in F Tank Farm (FTF). DOE concluded that there would not be significant benefit in targeted removal of additional Pu-239 to reduce or eliminate this predicted dose because: (1) the review did not identify any technologies that would likely be more efficient at additional HRR removal than use of the modified Sand Mantis coupled with washing the tank walls with water under high pressure, and (2) the Special Analysis shows that uncertainty surrounding the timing of the 40,000-year dose peak is not sufficient for it to impact facility performance within the 10,000-year performance period. Given that the reference case conservatively assumes that 100 percent of the Tank 18 inventory would be removed by use of the Sand Mantis coupled with washing the tank wall, NRC staff finds the first statement reasonable. NRC evaluates uncertainty in the timing of Tank 18 releases and dose in a separate Technical Review Memo of the Tank 18 and 19 Special Analysis.

While Pu-239 is risk-significant in the longer term, Pu-238 is the most significant contributor to peak dose during the 10,000 performance period due to its progeny Ra-226. DOE notes that since the majority of the Pu-238 inventory in Tank 18 is associated with corrosion products on the tank wall, significant reduction in the corrosion products from the wall would be required to remove this portion of the inventory. DOE acknowledges that none of the four technologies evaluated could be used by itself to remove HRRs from all areas of the tank wall. The 2012

Systems Engineering Evaluation (SEE) that DOE completed states that a hydro-lance could be used for cleaning the walls. DOE sprayed the walls of Tank 18 walls water in 2003. The available video technology at that time did not produce evidence that scale or corrosion products were removed using the spray. DOE cites this lack of video evidence in questioning the effectiveness of a hydro-lance wash of the walls of Tank 18. However, NRC staff note that hydro-lance technology was applied for a second cleaning of the walls of Tank 19, which left no discernable material on the stiffening bands or walls after cleaning. The video technology for Tank 19 was an improvement over that of Tank 18, so the fact that Tank 18 video did not show evidence of removal of corrosion products may be an artifact of the video quality and not an indicator of the effectiveness (or lack thereof) of hydro-lancing. DOE has explained to NRC that while a second washing of the Tank 19 wall removed residue, a second washing was not carried out for the Tank 18 walls because the original overhead video was not of high enough resolution to show discernable residual material, and therefore, DOE did not believe a second washing would be necessary for Tank 18 at the time.

Given the difficulty in predicting technology effectiveness, DOE assumes that the Sand Mantis technology is able to reduce the inventory by 100 percent, and that development, installation, and operation of the washing technology such as a hydro-lance for the tank wall would add no additional costs. While NRC staff note that the experience with Tank 19 walls could be used as evidence of the effectiveness of a second wall washing on removing waste present on tank walls, NRC staff agrees that DOE's assumptions overestimate the potential benefit for the purposes of cost-benefit analysis and are therefore conservative.

With regard to the estimated costs of remedial alternatives, NRC staff note that the costs of additional removal are escalated due to the isolation of Tank 18 and progress that has been made on the tank. For example, the $38 million total cost includes $13 million of direct costs, which is considered to be accurate within 35 percent. The $13 million is higher than the previous $8 million estimate (DOE, 2011a). DOE states the reasons for the higher cost being: (1) $3.5 million for contingency and risk escalation, (2) costs for restoration of systems that have been isolated from the tank farm, (3) additional modeling to support the Special Analysis, (4) rework of the FTF 3116 Basis Document and regulatory documents. NRC staff noted in the teleconference that many of these increases in direct costs would not have been incurred had cleaning continued before isolation of the tank and final documentation. In the teleconference, DOE clarified that these additional costs were due to the length of time that had passed between the decision to cease removal activities and the time at which the cost-benefit analysis was performed. DOE pointed out that this lapse of time would not be expected for future cost-benefit analysis for other tanks. In the future, DOE anticipates that NRC will be provided the opportunity to comment on the cost benefit analysis earlier in the process whether it be in coordination with the State of South Carolina during the public comment period, or as a potential onsite observation activity.

In addition to the $13 million in direct costs, DOE estimates $1 million/yr for tank maintenance during the resulting 5-yr operational closure delay, and $20 million for the approximate 1-month delay in preparing a sludge batch for Defense Waste Processing Facility. The impact of the 1-month delay to the system plan was determined by evaluating performing the cleaning activities in the 2014 to 2016 timeframe against System Plan, Revision 17. The system plan is based upon closing tanks "just in time" to meet the Federal Facilities Agreement (FFA) commitments and the SEE determined that under certain processing scenarios, a 1-month slip

in sludge batch preparation could result. NRC staff note that since the impact of the delay in the liquid waste management system on the program life cycle is dependent upon when the cleaning would have been performed, there is uncertainty surrounding the $20 million which makes up over half of the estimated total cost. However, this type of uncertainty was not discussed or considered in the sensitivity analysis. During the teleconference with DOE on July 26, 2012 (NRC, 2012), DOE clarified that these indirect costs were specific to the timing of the Tank 18/19 cost benefit analysis. Future indirect costs will be evaluated on a case-by-case basis and are not expected to be the same for all tanks. NRC staff expressed its desire for the ability to comment on the cost benefit analysis earlier in the process to ensure that all issues are addressed prior to proceeding with disposal actions that could significantly impact the cost-benefit analysis.

With regard to the occupational dose, NRC staff note that the worker dose estimate for the Sand Mantis in this analysis is 0.032 person-Sv (3.2 person-rem) while, in a prior reference, DOE predicted the worker dose for additional removal using this technology to range from 0.0025 person-Sv to 0.012 person-Sv (0.25 person-rem to 1.2 person-rem) (DOE, 2011a). During the teleconference DOE pointed to a detailed breakdown of 0.032 person-Sv (3.2 person-rem) in Appendix 5.4.1 of the analysis and clarified that this dose estimate is more representative of actual doses received while performing similar tasks.

As indicated in NUREG-1854, the $200,000 per person-Sv ($2,000 per person-rem[2]) conversion factor that NRC uses in some contexts (e.g., regulatory analyses, ALARA analyses for license termination) may *not* be a useful metric to apply to waste determination reviews because the metric is based on collective dose and it is designed to be applied with economic discounting. The long performance period relevant to waste determinations hinders the use of any metric based on collective dose because it is unrealistic to attempt to predict what the population near a disposal site will be for thousands of years after site closure. In addition, NRC staff previously recommended that the monetary value associated with averted future doses not be discounted in analyses relevant to 10 CFR Part 61 (NRC, 2000). Notwithstanding issues with use of the $200,000 per person-Sv ($2000/person-rem) metric communicated in NRC staff guidance, DOE does not actually calculate collective dose when computing the normalized cost of averted dose for comparison to NRC's decommissioning metric. DOE simply considers the total dose averted to one individual over 50 years which is 1.5 mSv (150 mrem) for the reference case or 1.25 Sv (12.5 rem) for the long-term case. During the teleconference, NRC asked for clarification on the assumptions regarding the time period and number of persons considered in the collective dose calculation. DOE indicated that the 50 year time frame was the lifetime of a single individual. DOE clarified that it only assumed a single individual was impacted; DOE did not attempt to estimate a population or collective dose. Because doses comparable to the peak dose from Tank 18 occur over several thousands of years, it is not clear to NRC staff why DOE elected to consider a dose to one hypothetical individual over 50 years in its cost-benefit analysis for comparison to the $200,000 per person-Sv ($2000 per person-rem) factor.

DOE indicated in the teleconference that this particular criterion was supposed to be applied as more of a qualitative analysis, but it acknowledged that, in the way the criterion was worded, the intent to be qualitative was not clear. NRC stated that its guidance recognizes the problems with use of collective dose for long-term analyses. However, if such an approach is used, NRC

[2] The basis for NRC's $2,000 per person-rem metric is discussed in NUREG-1530 (NRC, 1995).

indicated that the metric is based on a quantitative analysis of collective dose to a population. NRC staff cautioned that, depending on the assumptions used in the quantitative calculation, removal of additional activity could either be above or below the threshold for being cost beneficial. Therefore, it may be misleading to indicate that additional radionuclide removal is clearly not cost beneficial based on DOE's calculation and use of this metric.

With regard to DOE's third criterion on the unit cost of risk reduction, NRC staff questioned DOE's basis for requiring the unit cost of risk reduction to be *significantly greater than* as opposed to *comparable to* other projects. DOE clarified in the teleconference that the wording in the report is not clear and it is in agreement with the NRC on how this metric should be applied. DOE stated that, while the numbers presented in Table 7-1 of the report are approximate estimates and should not be interpreted as exact, DOE does attempt to uniformly apply cost-benefit analyses across its various projects. DOE was in agreement with the NRC that similar projects would merit additional cleaning if the costs and benefits are comparable, and that the FTF tank project need not be *significantly* more cost effective to merit additional cleaning.

Because there is no specified evaluation period associated with ALARA analyses and because there is uncertainty in the timing of peak dose from Tank 18, NRC staff thinks it would be more appropriate to perform the cost-benefit analysis using the overall peak dose of 5 mSv/yr (500 mrem/yr) that is predicted by DOE to occur within 40,000 years. Therefore, NRC staff believes the reference case should be the long-term sensitivity analysis. NRC staff also notes that DOE did not combine the two sensitivity cases which would simultaneously assume lower cost and longer-term benefit.

With regard to the assumed averted dose for the sensitivity case, the key radionuclides contributing to peak dose within 10,000 years (Ra-226) and 40,000 years (Pu-239) for Tank 18 are not shown to be preferentially removed. Therefore, it is reasonable to assume that only 50 percent of the residual waste remaining in Tank 18 could be removed with additional cleaning based on effectiveness of waste retrieval operations in Tank 19 that had approximately 50 percent of the estimated volume remaining in Tank 18. However, greater removal estimates (e.g., 75 percent removal) could have been evaluated in sensitivity analyses. It is also important to consider that waste which is on the walls could potentially be more risk significant since it could bypass the tank grouting whereas floor inventory has more potential to be reduced by the grout than the wall inventory.

During the teleconference, NRC staff requested an explanation regarding the separation of the impact of cost uncertainty and benefit uncertainty. DOE reiterated that in its perspective, the appropriate reference case is the 10,000 year scenario. However, DOE acknowledged that NRC raised a valid question, and stated it will consider aggregating cost and benefit uncertainties in future analyses.

Teleconference or Meeting:

NRC staff discussed questions pertaining to this review in a teleconference with DOE on July 26, 2012 (NRC, 2012). Topics discussed included: application of the $200,000 per person-Sv ($2000 per person-rem) decision criterion, definition of the unit risk reduction criterion, direct and indirect costs of additional removal, worker dose estimates, and the sensitivity analysis.

Follow-up Actions:

DOE has described its process to meet Criterion 2 of the National Defense Authorization Act as it proceeds with closure of tanks in the FTF that includes a cost-benefit analysis. However, as noted in the TER (NRC, 2011), DOE's description of how the cost-benefit analysis is to be carried out (DOE, 2011b) does not provide sufficient detail for these analyses to be carried out consistently for each tank or group of tanks. NRC recommended in the TER that DOE continue to involve NRC with the cost benefit analysis development as tank farm closure progresses, and also noted that NRC plans to monitor DOE's efforts in this area under the ALARA provisions of 10 CFR Part 61, Subpart C. Therefore, DOE should consider completing a thorough and consistent cost-benefit analysis early-on as part of the decision process for ceasing cleaning operations in future tanks. In performing the quantitative cost benefit analysis as early as practical DOE can avoid the escalated costs associated with redoing modeling analysis and revising documentation.

Given the problems associated with applying the $200,000 per person-Sv ($2,000 per person-rem conversion factor), DOE should use caution when applying this metric. DOE should be clear about its use of the metric and the uncertainties surrounding calculation of collective dose. If DOE chooses to use this metric for future cost benefit analyses, DOE should compare the metric to collective dose and not individual dose. NRC staff does not consider the dose to one hypothetical individual over 50 years an appropriate comparison to the metric.

DOE should consider revising the way that Criterion 3 is worded so that it is clear that the Criterion is analyzing whether risk reduction per unit cost is comparable to other representative projects as opposed to significantly greater than other projects.

As discussed in the teleconference, DOE should consider aggregating cost and benefit uncertainties in future analyses.

Open Issues:

There are no Open Issues.

Conclusions:

DOE prepared a more rigorous cost-benefit analysis, evaluating the benefits of additional waste removal from Tank 18 versus the costs and risks associated with additional removal. While DOE presents satisfying arguments as to why the costs of additional clean-up at this point in time outweigh the benefits for the reference case, it is NRC staff's position that the long-term analysis should be the reference case, and NRC staff note that many additional costs were due to the length of time that had passed between the decision to cease removal activities and the time at which the cost-benefit analysis was performed. In the long-term sensitivity analysis the first criteria is met. It is the NRC staff position that DOE's use of the second criteria in not appropriate, and if DOE had calculated collective dose then it is possible that the second criterion may have been met in some cases. It is also the NRC's position that the third criteria should be tested on a comparable level instead of requiring the risk reduction associated with this project to have a significantly higher risk reduction per unit cost. DOE agreed that this was

their intention in use of this metric. Therefore, one could argue that the third criterion would also have been met for the long-term sensitivity case since its unit risk reduction is comparable to other projects. The fourth criterion (operational closure of Tank 18 should not be delayed in the absence of significant benefit.), would still have had to have been addressed. NRC staff plans to engage with DOE early in the process when DOE is deciding to cease cleaning activities as part of NRC monitoring efforts under the ALARA provisions of 10 CFR Part 61, Subpart C for future tanks. This will help to ensure a robust analysis prior to proceeding with disposal actions that could significantly impact the cost-benefit analysis.

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