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Comment No.	Issue/Finding	Comment Summary	Resolution
1.	General – PA Critical Issues	The EMDF PA "base case" radionuclide transport and dose assessment modeling is bounded by assumptions rather than structured to evaluate mechanistic modeling of all applicable events and processes. The RESidual RADiation (RESRAD)-OFFSITE model used to generate these base case results is highly dependent on several critical assumptions: i. The physical integrity of the EMDF landfill cover will not be significantly compromised during the 1000-yr and 10,000-yr time periods evaluated. Specifically, with respect to the groundwater exposure pathways, the long-term degradation of the engineered cover will result in no more than approximately a twofold increase in the original infiltration rate (excluding the geomembrane barrier) during the model evaluation time periods. ii. Radionuclide mobility is realistically estimated for all domains of the transport model, including waste, vadose, and saturated zones, and will remain consistent over time. iii. The rate of infiltration through the cover will never exceed the rate of drainage through the liner system, so bathtubbing will not occur. No leakage from the facility will ever occur except that passing through the liner system. iv. Chronic exposure of potential future receptors will never occur on the EMDF facility. The base case all-pathways model does not consider the possibility of human intrusion into the facility or human occupants on the facility. Inadvertent human intrusion (IHI) is considered in a separate analysis, but the maximum exposure in IHI scenarios is limited to dose resulting from a garden contaminated with drill cuttings from a well drilled into waste. The PA's Executive Summary provides three key assumptions for PA compliance, and a second set of five key conceptual model	The PA was developed in accordance with the guidance provided in DOE-STD-5002-2017 *Disposal Authorization Statement And Tank Closure Documentation*. The appropriateness of the PA was verified by an independent LFRG review team and approved by the LFRG. The PA report and Neptune review report both identify the key assumptions upon which the compliance determination is based. • Critical Assumptions i. Assumed normal evolution of engineered barriers is pessimistic in the 1000-year timeframe (refer to PA Critical Issue 3). ii. Mobility assumptions (PA Critical Issue 4) are pessimistic for the compliance period given that release model does not credit waste forms or waste packaging (PA Critical Issue 5) and that cover performance assumption is pessimistic (PA Critical Issue 3). iii. The EMDF PA identifies key conceptual model assumptions in Sect 1.7.2, including assumptions about failure of engineered barriers, cover system performance, and liner system performance, including the probability of bathtub conditions developing within the 1000-year compliance period. iv. The exposure scenarios in the EMDF PA are consistent with DOE guidance for technical analysis of LLW disposal facility performance assessment.

Comment No.	Issue/Finding	Comment Summary	Resolution
		assumptions. Collectively, the four critical assumptions highlighted above by Neptune encompass the PA's eight assumptions.	
2.	PA Critical Issue 1 Conceptual Model Assumptions	• The PA is bounded by assumptions rather than revealed by modeling; without active institutional controls in perpetuity at the site, these assumptions are unlikely to remain valid • The modeled saturated zone travel times are inconsistent with BCV field observations • The scope of the uncertainty analysis (UA) is inappropriately constrained/simplified • There are uranium concentration peaks that are predicted to occur after 10,000 years but the corresponding peak doses are not presented • There is inadequate screening of all possible Features, Events, and Processes (FEPs) that could affect EMDF performance	The PA was developed in accordance with the guidance provided in DOE-STD-5002-2017. The appropriateness of the PA was verified by an independent LFRG review team and approved by the LFRG. • The EMDF PA identifies key conceptual model assumptions in Sect 1.7.2, including assumptions about failure of engineered barriers, cover system performance, and liner system performance. • Model-predicted saturated zone travel times are addressed in the responses to PA Critical Issue 4 and PA Key Finding 2.2.1. • The objective of the sensitivity and uncertainty analysis is to inform understanding of the system to make a decision about compliance during the 1000-year post-closure period. The UAs presented in Appendix G, Sect.G.6.3 combine pessimistic assumptions inherent in the PA (e.g., cover performance during the first 1000 years) with reasonable simplifications (e.g., limited number of radionuclides) made to facilitate the process by which single-factor model parameter sensitivity analysis informed the iterative development of the final set of probabilistic input parameter distributions. It is reasonable to limit the scope of the UA performed with the system-level model. Fully probabilistic modeling approaches are not commonly used for DOE or State/NRC PAs and would be inconsistent with recommendations from the ICRP and DOE guidance. Also refer to the responses to PA Critical Issue 7. • The 10,000-year modeling runs, augmented by >10,000-year simulations to provide additional perspective on long-term performance, were conducted in accordance with DOE expectations. Longer time periods recognize long-lived, less mobile radionuclides, but assumptions are not as refined because overall uncertainty for modeling of such time frames is much greater. Given the uncertainty regarding the validity of the pessimistic instantaneous desorption assumption for releases of uranium, and the limitations of the RESRAD-OFFSITE model in capturing the extent to which the EMDF

Comment No.	Issue/Finding	Comment Summary	Resolution
			design and the vadose zone below the disposal facility contribute to long-term performance of the disposal system (refer to PA Sect. 3.3.5.1 and Appendix G, Sect. G.5.6), the RESRAD-OFFSITE peak dose predictions beyond 10,000 years have little quantitative significance. • The 10,000-year UA results presented in PA Sect. 5.4.2 and Appendix G, Sect. G.6.3.4 suggest increased probability (after 8000 years) of uranium radionuclide doses >25 mrem/year associated with larger values of cover infiltration (Fig. G.60). If appropriate in the future, this possibility will be evaluated as part of the PA maintenance process. • Consistent with other DOE PAs, development of the EMDF PA employed a "top-down" analysis of disposal system features, safety functions, and processes that could limit safety functions, rather than a comprehensive FEP screening (bottom-up approach). The safety functions analysis is described in the introduction to Appendix C, Sect. C.1 and the results are summarized in Sect C.5.
3.	PA Critical Issue 2 Bathtubbing Assessment	• The bathtub scenario is excluded from the EMDF base case (normal evolution scenario) • The current bathtub scenario groundwater impact analysis indicates potential violation of groundwater protection standards	• The key assumption regarding liner performance relative to cover performance is identified in Sect. 1.7.2 (key conceptual model assumption #3). Given the pessimistic assumption regarding cover performance over 1000 years, development of bathtub conditions is unlikely during the compliance period. This justifies treatment of the bathtub scenario as a separate case (unexpected performance condition) rather than including bathtubbing in the base case. • The bathtub analyses presented in the PA Appendix C, Sect C.3 applies very simplified conceptual models and methods for estimating leachate concentrations and potential groundwater and surface water concentrations. This simplified modeling does not support quantitative evaluation of compliance with water resource protection requirements; more detailed modeling is required to estimate water resource impacts with greater confidence. • The assumed scenario for normal evolution of engineered barriers (and the assumed increase in cover infiltration for the bathtub condition analysis) is pessimistic within the 1000-year timeframe, given that only 100 years of institutional control

Comment No.	Issue/Finding	Comment Summary	Resolution
			and cover maintenance are credited, and the realistic expectation that the composite infiltration barrier (synthetic geomembrane and amended clay) in the cover will substantially limit infiltration for at least 1000 years. • Groundwater impact of the bathtub scenario is an open LFRG secondary issue (EMDF-S05-PA06-02) that remains to be addressed prior to approval of an ODAS for EMDF.
4.	PA Critical Issue 3 Cover Degradation	• Assumed maximum cover infiltration rate is too low • HELP model inputs for long- term degraded performance not justified • Supporting rationale is not provided for the magnitude and rate of performance degradation • Uncertainty in long-term cover performance within the PA model should include a quantitative evaluation of the consequences of return to native recharge • Assumptions of minimal cover degradation control the long-term performance of the disposal system to a far greater extent than the model inputs that are varied in the probabilistic uncertainty and sensitivity analyses	Cover degradation was modeled assuming complete loss of the HDPE geomembrane and that maximum degradation of the amended clay layer occurs during the 1000-year compliance period. This assumption is pessimistic, not “optimistic” or resulting in “minimal cover degradation” as suggested by the Neptune report. Partial design performance of a combined HDPE/clay system that can limit infiltration relative to background recharge is likely to extend well beyond 1000 years. • The PA report acknowledges that long-term cover performance is a significant uncertainty in the analysis. • Degradation of the clay cover infiltration barrier (increased hydraulic conductivity) will be significantly delayed relative to the base case assumption for cover failure (progressive failure from 200 to 1000 years post-closure), because the overlying protective materials (biointrusion and drainage layers and HDPE membrane) will function effectively for much longer than 200 years. • The input values applied in the HELP modeling (Appendix C, Sect. C.2) regarding degradation of the lateral drainage function of the cover system are very pessimistic because the coarse materials of the biointrusion layer above the drainage layer (PA Fig. 2.41) will provide lateral drainage even in the event of disintegration and/or clogging of the underlying engineered drainage materials. • The compliance period probabilistic analysis includes runs with earlier, more rapid cover degradation (Appendix G, Fig. G.50) and higher maximum cover infiltration (Fig. G.51, 40% of the simulations have cover infiltration greater than 1 in./year, 5% are greater than 2 in./year). The range of cover infiltration evaluated is much larger than is reasonably expected during the 1000-year compliance period, given the

Comment No.	Issue/Finding	Comment Summary	Resolution
			likely service life of the combination of HDPE membrane and amended clay supplemented by other components in the cover system. • The compliance period probabilistic analysis suggests that I-129 Kd values rather than cover performance input parameters are the primary control on EMDF performance relative to the 25 mrem/year performance objective.
5.	PA Critical Issue 4 Radionuclide Mobility	• Very little element-specific partition coefficient (Kd) data is presented in the PA, and the statistical distributions used in the probabilistic evaluation of uncertainty are not adequately supported • The waste zone Kd adjustment not justified: "If half of the material has one Kd value and the other half has a different Kd value, averaging the two Kd values is improper". • Proper assignment of partition coefficients to radionuclides present in waste as different chemical species may require modeling desorption from waste for each chemical species separately or a probabilistic approach rather than using an average value (the assumed uranium Kd 50 ml/g is too high for mobile species) • The assumption of equilibrium partitioning used in the PA is not supported. The fractured and weathered Maryville and Nolichucky Formations transmit solute too readily for the assumed equilibrium partitioning throughout the media to be realized. • Kd values derived in laboratory settings where equilibrium between phases may be achieved are not applicable in the in-situ geologic media. • To the extent possible, field-scale measured retardation of key elements in representative fractured bedrock and saprolite should be applied for this portion (saturated zone) of the transport model •	• All available laboratory Kd data for ORR materials were considered; the data are not sufficient to confidently derive probability distributions that represent uncertainty in material properties and future geochemical conditions. The basis for assigning distributions is explained in detail in Appendix G, Sect. G.6.3.2.1. • The simplifying assumption applied to assign a waste zone Kd value (PA Sect. 3.2.2.6) is not based on a simple average of two Kd values representing different waste forms. The approach is a rough approximation adopted as part of the corrective action for two LFRG PA Key Issues, and is intended to account for uncertainty in waste forms and radionuclide release mechanisms, and to credit the sorptive capacity of uncontaminated clay-rich fill added to fill voids during waste placement. • The conceptual model for saturated zone radionuclide transport in porous media is acknowledged in Sect. 3.2.3 of the PA as a simplified approach adopted due to data limitations for input parameters required to implement more detailed modeling approaches (e.g., fracture flow and solute transport paths, non-equilibrium, concentration dependent sorption, etc.). • Conceptual uncertainty in the saturated zone transport model is evaluated with a MT3D model sensitivity run that assumes a high hydraulic conductivity (2.65E-04 cm/s) for the upper 20 m of the saturated zone (PA Fig. 3.38). The results of the sensitivity run (for Tc-99) are similar to the base case saturated zone results of the RESRAD-OFFSITE model. • The cited field studies of transport of conservative tracers injected at a single points in space and time are not appropriate analogues for long-term release from EMDF,

Comment No.	Issue/Finding	Comment Summary	Resolution
			however evidence from these tracer studies suggests significant interaction with the matrix even for non-reactive, non-sorbing solutes. • Uncertainty in saturated zone performance is evaluated in the probabilistic analysis to capture the potential more rapid flow paths. The RESRAD-OFFSITE uncertainty analyses include sampled technetium and iodine Kd values and saturated zone hydrogeologic parameters that yield calculated 100-m retarded contaminant travel times for both elements that are as small as the base case groundwater 100-m travel time (approximately 15 years). The 5th percentiles of retarded 100-m travel times (45 years and 187 years for technetium and iodine, respectively) are less than one half of the base case retarded travel times (94 and 460 years).
6.	PA Critical Issue 5 Waste Leaching	• The description of waste forms and contamination does not support an assumption of the loss of much of the inventory of C-14, H-3, and Tc-99 during the operational period • Assuming instantaneous equilibrium desorption is not protective for the operational period. • Several aspects of the release model parameterization appear incorrect, or are difficult to understand based on the description 1. The releasable fraction should begin at approximately 0.5, not zero, because at year 200 the infiltration rate is approximately 50% of the final (steady-state) value of 0.88 in/yr. 2. The explanation for why the Tc-99 results should be applied globally to all radionuclides regardless of their leachability is insufficient. Such extrapolation is not intuitive and seems to be contradicted by discussion of relative model performance for less-mobile radionuclides. 3. The initial releaseable fraction is inconsistent among nuclides	• The EMDF PA base case scenario is conceptually consistent in applying a common release model to pre- and post-closure periods. Taking credit for waste forms and containers to limiting leaching in the operational period would be more pessimistic for highly mobile radionuclides, but DOE and LFRG do not endorse adopting worst case technical assumptions for Order 435.1 compliance determinations. • The PA report includes sensitivity evaluations for the release model assumption (PA Fig. 5.6) and the assumed magnitude of operational period radionuclide inventory reductions (PA Fig. 5.8). The results suggest that these assumptions are not critical for the determination that EMDF will meet Order 435.1 dose performance objectives during 1000-year compliance period or for the 10,000-year simulation period. • With respect to the base case RESRAD-OFFSITE release parameter assignments: 1. For the Rev 2 PA, implementation of the conceptual model for cover degradation for all models was revised to represent a linear increase in cover infiltration from zero at 200 years (300 years for the base case RESRAD INITIAL RELEASE TIME) to the maximum value at 1000 years. The RESRAD-OFFSITE base case INITIAL RELEASABLE FRACTION is correctly set to zero for all radionuclides other than H-3 and C-14 (explanation below).

Comment No.	Issue/Finding	Comment Summary	Resolution
			2. The RESRAD-OFFSITE release model parameters (five bullets on pg 22 of the Neptune report) are assigned to represent cover system degradation over time and therefore are not specified individually for each radionuclide, with the exception of H-3 and C-14. RESRAD-OFFSITE provides the flexibility to assign release parameters for each nuclide to represent differences in mobility due to waste forms, containers, etc., but model implementation for the EMDF PA does not take that approach. The increase in the base case RESRAD INITIAL RELEASE TIME from 200 years to 300 years based on comparison of MT3D and RESRAD-OFFSITE results for Tc-99 was applied to all radionuclides consistent with the conceptualization of the release model parameters as representing cover degradation. The focus on Tc-99 results was appropriate given that: a. The INITIAL RELEASE TIME parameter affects timing only (for long-lived radionuclides), and the timing of the Tc-99 peak dose relative to the 1000-year compliance period was a significant uncertainty, given the range of Kd values considered for technetium. b. For less-mobile radionuclides, the change from 200 to 300 years was less significant than for Tc-99 in terms of timing of the peak dose. c. For more mobile radionuclides (H-3 and C-14) release model results were more sensitive to other RESRAD-OFFSITE release model parameters that were altered to account for differences between process model results and RESRAD results. 3. For radionuclides assumed to have Kd=0 (H-3 and C-14), the RESRAD-OFFSITE base case release model parameterization adopted for other radionuclides produced results inconsistent with the MT3D model results for C-14. Adjustments to values of INITIAL RELEASABLE FRACTION (increased from zero to 75%) and RELEASE DURATION (decreased from 800 to 500 years) were applied for these highly mobile radionuclides to produce C-14 peak concentrations similar to the MT3D model

Comment No.	Issue/Finding	Comment Summary	Resolution
			predictions. These release model parameter adjustments to address differences between process model and system-level model results are fully described in the PA Sect. 3.3.4.2 and Appendix G, Sect. G.4.3.5.2.
7.	PA Critical Issue 6 Inadvertent Human Intruder (IHI) Scenario	• There is no logical basis for excluding groundwater pathways in a Chronic Post-Drilling residential scenario that includes exposure to cuttings from a groundwater supply well. Both of these exposure pathways should be included in this exposure scenario • The PA should evaluate a resident chronic intrusion scenario	• The PA IHI performance analysis is consistent with DOE guidance [DOE Manual 435.1-1, Chapter IV, Sect. P.(2)(a)]. The suggested onsite residential scenario is not consistent with DOE Manual 435.1-1 guidance. • DOE addresses water use considerations by committing to meet applicable water resources standards (which are much more limiting than the 100 mrem/year chronic intruder standard).
8.	PA Critical Issue 7 Probabilistic Uncertainty and Sensitivity Analyses	• Modeling tool limitations and computing limitations are used to justify an inadequate SA and US • The probabilistic uncertainty analysis (UA) and the sensitivity analysis (SA) are over simplified and incomplete, and the basis of the distributions applied in the UA are inadequately defended • The very limited scope of the UA severely limits its value. Multivariate probabilistic analysis should not be limited to a pre-selected set of variables; It is particularly important not to restrict distribution development to parameters for which good information is available for developing a distribution. • A global SA should be performed as the result of a fully probabilistic PA to assure that the most significant contributors to uncertainty in the results are identified	• The sensitivity analysis and uncertainty analysis provided in the R2 PA are consistent with the DOE Manual 435.1-1, Chapter IV, Sect. P.(2)(e) requirement. Most other PAs have a mix of process models to evaluate key included FEPs and less detailed system models to evaluate the effects of uncertainty. • “Fully probabilistic” approaches are not commonly used for DOE or State/NRC PAs and would be inconsistent with recommendations from the ICRP and DOE guidance. • The EMDF PA applied single factor (one at a time) and multi-factor sensitivity cases to the process models, and single factor sensitivity runs with the system-level (RESRAD-OFFSITE) model. • The multivariate regression analysis is part of the RESRAD-OFFSITE probabilistic UA. The basis for assigning distributions is explained in detail in PA Appendix G, Sect. G.6.3.2.1 and Attachment G.3, Table G.3.2. • An uncertainty analysis does not need to include all radionuclides and all parameters to be useful. The uncertainty analysis incorporates variability in all but one (see next bullet) of the most important factors affecting performance, including climate (precipitation, water table elevation, groundwater flow); the timing and magnitude (max infiltration) of cover degradation; material properties (permeability, porosity, density) and radionuclide mobility (Kd) in the source, vadose,

Comment No.	Issue/Finding	Comment Summary	Resolution
			and saturated zones; and controls on surface water and well water concentrations. • Radionuclide inventory uncertainty is not included in the RESRAD-OFFSITE uncertainty analysis, but because the release model does not incorporate solubility limits, predicted aqueous concentrations and dose will scale with inventory variation (refer to PA Fig. 5.8). In addition, the estimated radionuclide inventory is considered to be pessimistic (refer to the response to PA Key Finding 2.2.1).
9.	PA Critical Issue 8 Water Resource Analysis	• Uranium transport from disposal sites in groundwater in Bear Creek Valley and Melton Valley indicates that uranium can certainly migrate through groundwater from sources at the rate of at least one meter per decade, giving a lower bound of 1000 years for the advective travel time to the POA. Much faster transport is likely, depending on the hydrogeology of the particular site and the chemical form of uranium • Long travel times through vadose zone saprolite predicted by STOMP and RESRAD OFFSITE are the consequence of conceptual model assumptions that limit infiltration through the cover and require that groundwater infiltration and radionuclide release be spatially uniform over the facility footprint • Nonuniform barrier failure should be expected and would lead to local increases in relative saturation and more rapid solute transport. STOMP simulations incorporate non uniformity in saturation at a larger scale due to waste cell geometry, but the sensitivity of the all pathways model to non-uniform release was not adequately addressed. • More realistic modeling of vadose zone solute transport would result in larger concentrations of radionuclides such as Tc-99, I-129, and uranium at the POA within the compliance period • A modeling strategy that yields results more consistent with experience in field situations at Oak Ridge is needed.	• DOE does not agree that evidence of uranium migration from other contaminated areas in BCV is indicative of how uranium will migrate from within the RCRA-compliant designed and constructed EMDF. Notably, the EMDF will be constructed as a robust, double-lined disposal facility where only solid wastes may be disposed. Uranium migration from legacy contamination sites in BCV is highly dependent on the form of the contaminated material, the presence or absence of barriers, location relative to the water table, etc. • Compliance period cover performance is a pessimistic assumption (refer to PA Critical Issue 3 response). It is unlikely that significant release from EMDF will occur during the compliance period. • Non-uniform cover infiltration and radionuclide release does not imply larger peak well concentrations. Larger than predicted compliance period well concentrations due to faster vadose zone transport (or higher water table elevation, PA Fig. G.31) or larger than expected average cover infiltration (PA Fig. G.25) are possible, but unlikely given expectations for cover performance over a few centuries.
10.	PA Critical Issue 9 Radon Ground Surface Flux Analysis	• The radon flux analysis applies a deprecated methodology for calculating radon flux, and it uses default rather than site-specific input parameters • The free-air diffusion coefficient for radon gas should be 0.11 cm^2/s (Rogers and Nielson 1991). The R2 PA does not document	• The Rogers et al. (1984) radon flux model is simplified and does not incorporate aqueous phase diffusion of Ra-226 and other radon parents. Use of this model is appropriate for a setting where abundant precipitation maintains the flux of water through the upper layers of the cover (above the

Comment No.	Issue/Finding	Comment Summary	Resolution
		the value used in the Appendix H analysis • Radium is not adsorbed deeply into the matrix, its decay will generally produce radon in the air- and waterfilled pore spaces in the cover material. This would correspond to an E/P ratio for materials other than waste of 1 • The EMDF PA radon evaluation should evaluate the impact of uncertainty in long-term erosion rates on radon surface flux. • Calculation of radon flux in the R2 PA is limited to an example at 1000 yr. The radon flux calculation needs to be evaluated through time in order to determine its actual peak.	composite infiltration barrier), limiting the accumulation of radon parents near the cover surface. • Table H.4 in Appendix H indicates that default values for the radon water/air partition coefficient and the Rn-222 decay constant were applied, whereas site-specific values for EMDF cover material properties were applied as appropriate. The assumed free-air diffusion coefficient value for radon gas is 0.07 cm^2/s, as given in the formula for the diffusion coefficient in Table H.4. • The Rogers/NRC model does not incorporate the E/P parameter for the cover materials above the waste and the assumed value of 0.25 for the waste matrix is consistent with the underlying conceptual models. • The model is applied to the EMDF as a screening analysis that calculates the Rn-222 flux at four locations in the cover profile including the waste surface (i.e., no cover present), and the result at the top of waste is less than 5% of the radon flux performance objective. A sensitivity case presented in Appendix H, Sect. H.7 addresses uncertainty in the Ra-226 inventory at 1000 years; for a Ra-226 concentration over eight times larger than the compliance case assumption, the Rn-222 flux at the top of the waste is only 6.7 $pCi/m^2/s$, or approximately one third of the radon flux performance objective. These results suggest that more detailed modeling of Rn transport and release at the EMDF cover surface, or the application of different input parameter values is unlikely to challenge the compliance determination. • The EMDF PA radon evaluation evaluated the impact of uncertainty in long-term erosion rates on radon surface flux by estimating the Rn-222 flux at four locations in the cover profile, including the waste surface (i.e., no cover present). • The radon flux performance objective applies to the 1000-year compliance period, and the Ra-226 inventory is at the compliance period maximum at 1000 years. The DOE Manual 435.1 and LFRG technical guidance do not require estimation of peak radon flux beyond the compliance period.
11.	PA Key Finding 2.2.1 Conceptual Model	Regarding the 3 key PA parameter assumptions for EMDF compliance:	• Uncertainty in vadose and saturated zone performance is evaluated in the probabilistic analysis. The RESRAD-

Comment No.	Issue/Finding	Comment Summary	Resolution
	Assumptions	• I-129 sorption will be insignificant in the fractured portion of the saturated zone (PA key parameter assumptions 1,2) • Assuming 14% operational period I-129 loss is not protective, lacking supporting documentation regarding the waste form (PA key parameter assumption 3) • Assumed operational period losses of all soluble radionuclides is not protective • Reduced iodine sorption and faster transport in vadose and saturated zones is possible for the EMDF site and implies significantly higher of I-129 dose prior to 1000 years post-closure. The timing of impacts at the POAs will depend primarily on the timing of release from the engineered facility, rather than vadose and saturated zone travel times. Key assumptions not explicitly acknowledged: • The saturated zone transport model that assumes equilibrium partitioning is unrealistic and inconsistent with field evidence, • Comprehensive FEP analysis is not provided, neglecting significant erosion events and processes, bathtubbing, failure of cover system, and future occupation of the disposal unit • The EMDF PA RESRAD model assignment of a zero-erosion rate is not defensible; gullying and hillslope failure will eventually undermine any engineered cover design leaving wastes exposed at the ground surface • Waste subsidence uncertainty was not addressed in the R2 PA • Biotically induced contaminant transport, such as plant root uptake, is omitted from the modeling with incomplete justification • The effect of climate change on precipitation, infiltration, and erosion of the EMDF cover system has not been adequately addressed • The assumption of perpetual IC is optimistic, not pessimistic, since there is no evaluation of an on-site resident.	OFFSITE uncertainty analyses include sampled technetium and iodine Kd values and saturated zone hydrogeologic parameters that yield calculated 100-m retarded contaminant travel times for both elements that are as small as the base case groundwater 100-m travel time (approximately 15 years). Also refer to the response to PA Critical Issue 4. • The estimated I-129 inventory is pessimistic (refer to UCOR presentation to EPA/TDEC of November 11, 2019, slide 33 of 33). The key parameter assumption regarding I-129 inventory does not credit the predicted operational period losses. With respect to operational period losses assumed for C-14 and Tc-99, refer to the response to PA Critical Issue 5. • The assumed cover performance is considered pessimistic for the compliance period. The RESRAD-OFFSITE uncertainty analyses includes the impacts of earlier, more rapid, and more severe (higher infiltration) cover degradation. • The conceptual model for saturated zone radionuclide transport in porous media is acknowledged in PA Sect. 3.2.3 as a simplified approach adopted due to data limitations for input parameters required to implement more detailed modeling approaches (e.g., fracture flow and solute transport paths, non-equilibrium, concentration dependent sorption, etc.). • Development of the EMDF PA employed a “top-down” analysis of disposal system features, safety functions, and processes that could limit safety functions, rather than a comprehensive FEP screening (bottom-up approach). This approach is consistent with LFRG expectations for PAs. • The exposure scenario for the all-pathways dose analysis does not include direct exposure to waste that results from erosion of the cover system, damage to perimeter berm or release of waste at the surface, consistent with the conceptual model assumptions identified in Sect 1.7.2. • Waste subsidence, cover erosion, and climate changes are incorporated into the conceptual model of cover degradation, and represented in the PA analyses as uncertainty in the long-term average cover infiltration (maximum cover degradation). The PA considered sensitivity to precipitation

Comment No.	Issue/Finding	Comment Summary	Resolution
			(HELP model, PA Fig. 3.13) and cover infiltration (STOMP and RESRAD models) and uncertainty in the timing and severity of cover degradation. Also refer to the response to PA Critical Issue 3. • PA Section 3.2.2.1 addresses biointrusion and biologically driven release through the cover. Radionuclide uptake by plants on the cover is considered as possible but pathways to human exposure leading to significant dose contributions (via consumption of wild plants or animals) are limited. RESRAD-OFFSITE modeling included radionuclide uptake by plants in the dwelling and agricultural areas. • The PA does not assume perpetual institutional control.
12.	PA Key Finding 2.2.2 Bathtubbing Assessment	• The bathtub analysis did not evaluate the ingrowth of short-lived radionuclides during the modeling period • The PA should provide information regarding whether higher seepage rates could present a risk of erosion and/or undermining.	• The analysis assumes that bathtub conditions could develop within 1000 years; ingrowth of uranium decay products over this time period can be neglected because of the long half-lives of the predominant uranium isotopes in the EMDF estimated inventory. • The bathtub scenario is an open LFRG secondary issue (EMDF-S05-PA06-02) that remains to be addressed prior to approval of an ODAS for EMDF.
13.	PA Key Finding 2.2.3 Cover Degradation	• The PA does not provide a basis for the rate of cover degradation or an explanation for why degradation ceases at model year 1000	• The PA report acknowledges that long-term cover performance is a significant uncertainty in the analysis. Appendix C, Sect. C.1.3 describes the basis for the base case conceptual model of cover degradation, including the argument that complete degradation within 1000 years is pessimistic. • The RESRAD-OFFSITE uncertainty analysis includes simulations with both earlier and later times for complete cover degradation (releasable fraction = 1). For 25% of the simulations for the compliance period UA, cover degradation is complete prior to 1000 years. The time to complete cover degradation is greater than 1000 years in more than half of the simulations. • Maximum simulated cover infiltration is 3.2 in./year (compliance period UA) and 3.4 in./year (10,000-year UA). • Also refer to the response to PA Critical Issue 3.

Comment No.	Issue/Finding	Comment Summary	Resolution
14.	PA Key Finding 2.2.4 Radionuclide Mobility	• Potential contributors to radiological dose and risk have been practically omitted from the analysis due to a combination of relatively large assumed Kd values and an assumption of negligible degradation of the performance of the engineered cover • The issue of the exclusion of doses from progeny (and specifically external doses from radon progeny) is not addressed in the R2 PA. • The PA models a variety of materials using the same Kd values • RESRAD runs with default Kd values will give different results	• Dose contributions of uranium (and radon) progeny, including Pb-210+Daughters, are included in the RESRAD-OFFSITE dose calculations. • The 10,000-year UA provides examples of much earlier and larger uranium dose contributions associated with lower uranium Kd values and more rapid/severe cover degradation (Appendix G, Figs. G.58, G.59, & G.60). The uncertainty regarding modeled uranium release and transport is acknowledged in PA Sect. 3.3.5.1 and Appendix G, Sect. G.6.3.4.5. • The bases for selection of base case Kd values are described in PA Sects. 3.2.2.6, 3.2.2.7, and 3.2.2.8, including the decision rules for application of local data, previous ORR modeling efforts, or generic data compilations in selecting values for each element. • The basis for assuming a common Kd value for all engineered and natural materials (outside the waste zone) is explained in PA Sect. 3.2.2.9. Model sensitivity to the assumed Kd value for waste, vadose zone, and saturated zone materials is evaluated in PA Appendix E (Sect. E.3.3.1, Figs. E.32 and E.33) and Appendix G (Sect. G.6.2.2, Figs. G.19 and G.20). The RESRAD-OFFSITE UA includes variation between vadose and saturated zone Kd values (independently sampled and re-grouped to provide correlated sampled values).
15.	PA Key Finding 2.2.5 IHI Scenario	• The PA should explore cases where IC is lost shortly after closure • The assumption of a 100 m buffer is not consistent with loss of IC • Groundwater paths other than GW ingestion should not be excluded • A residential IHI scenario should not be excluded	• The IHI scenarios assume temporary loss of IC at or after 100 years, consistent with DOE Manual 435.1-1 , Chapter IV, Sect. P.(2)(h). • The acute and chronic IHI scenarios do not incorporate a 100-m buffer assumption. • Exclusion of groundwater exposure pathways is consistent with DOE/LFRG expectations for IHI scenarios. DOE addresses water use considerations by committing to meet applicable water resources standards (which are much more limiting than the 100 mrem/yr chronic intruder standard). • Screening of a residential IHI scenario is consistent with DOE and NRC guidance for LLW disposal facility

Comment No.	Issue/Finding	Comment Summary	Resolution
			performance analyses. • Also refer to response to PA Critical Issue 6.
16.	PA Key Finding 2.2.6 Conceptual Model for Groundwater Pathway	• The "modelability" of EMDF site for near-surface disposal of radioactive waste has not been adequately demonstrated • The adequacy of a 2-D implementation of STOMP model is not justified	• With respect to the challenges in modeling the EMDF site, refer to the response to EPA/TDEC PA comment #62 (email May 18th, 2020). • The sensitivity of saturated zone model results to the possibility of 3-D non-uniformity in release from EMDF was evaluated using the 2-D STOMP model to approximate the release pattern for the 3-D MT3D model. These results are presented in PA Sect. 3.3.5.2 (Fig 3.39) and Appendix F, Sect. F.4.2.
17.	PA Key Finding 2.2.7 Evaluation of Peak Dose	• The Neptune RESRAD implementation (Appx B) indicates potential for large uranium dose contributions beyond 10,000 years • The PA should acknowledge that complete degradation of EMDF and exposure of waste over long time frames is certain (without maintenance in perpetuity), and hence the EMDF represents a perpetual environmental liability	• The results of Neptune RESRAD implementation (Appendix B) are consistent with R2 PA modeling in terms of the potential for uranium dose impacts within 10,000 years. • The 10,000-year UA provides examples of much earlier and larger uranium dose contributions associated with lower uranium Kd values and more rapid/severe cover degradation (Appendix G, Figs. G.58, G.59, & G.60). The uncertainty regarding modeled uranium release and transport is acknowledged in PA Sect. 3.3.5.1 and Appendix G, Sect. G.6.3.4.5. • Complete degradation of EMDF and exposure of waste within the 1000-year compliance period is very unlikely; this end state is not considered in the PA analysis.
18.	PA Key Finding 2.2.8 Surface Drainage DW-10	• The influence of D-10W on long-term EMDF performance has not been addressed • Although OREM has proposed filling in the surface expression of D-10W, this does not preclude its subsurface behavior as a drain; subsurface influence of D-10W could remain as a deeper constant head boundary. • D-10W could re-emerge as surface drainage via subsurface processes, compromising integrity of the EMDF engineered features	• If native subsurface materials below the engineered structural fill and berm material along the axis of D-10W enhance groundwater drainage toward Bear Creek or maintain a constant head at depth, the effect will be to limit the water table elevation below the liner and complement the hydrologic isolation that is provided by the engineered surface drainage features. • The potential for long-term subsurface denudation along the D-10W axis is speculative, and is outside the range of natural processes considered in the conceptual model of EMDF performance evolution developed for the PA.

Comment No.	Issue/Finding	Comment Summary	Resolution
19.	PA Key Finding 2.2.9 Radionuclide Screening	• Some short-lived parents have long-lived progeny (e.g., Cf-252 > Cm-248) and the mass of these parents was lost in the radionuclide screening. • The phase-2 screening is inadequate because exposure pathways in addition to water ingestion can cause potentially significant dose. • Ingrowth of short-lived progeny, such as Ra-228 and Th-228, was not considered in developing the radionuclide source term.	• Ingrowth of progeny was not included in the development of the estimated EMDF radionuclide inventory at closure; as explained in Sect. 2.3.2 of the PA, short-lived progeny including Ra-228 and Th-228 were not screened on the basis of half-life. • As noted in Sect. 2.3.2, the Phase-2 screening incorporates pessimistic assumptions to avoid screening potentially significant radionuclides including: 1. Use of pessimistically high screening source concentrations (Table 2.16). 2. Assuming no engineered barriers limit waste infiltration (native recharge of 8.8 in./year). 3. Applying Kd values decreased by a factor of 20 or more (Table 3.4). 4. By demonstrating that the total dose associated with the screened radionuclides was less than the screening criterion. • With respect to the particular progeny cited in this Key Finding: 1. Decay of the entire estimated inventory of Cf-252 would increase the estimated inventory of Cm-248 by less than 0.5%. Cm-248 was not screened from the PA dose analysis 2. There is no reason to expect large quantities of Pm-147 or Sm-147 to be present in EMDF waste. Sm-147 has a very long half-life (1.06E+11 years) and decays to stable Nd-143 and therefore would not be expected to be a significant dose contributor, 3. Decay of Th-232 (half-life 1.4E+10 years) to produce Ra-228 and Th-228 over (for example) 100 years would cause a negligible increase (<1E-08%) relative to the modeled source concentrations of those two Th-232 progeny that were applied in the PA dose analyses.

Comment No.	Issue/Finding	Comment Summary	Resolution
20.	PA Key Finding 2.2.10 Upwards Migration Pathways Other than Radon Flux	• Upwards migration pathways other than radon flux were not considered • This approach neglects the upward migration of radon parents (e.g., Ra-226) • Buildup of progeny (Pb-210 and Po-210) resulting from the decay of radon near the ground surface needs to be accounted for in exposure pathways that are dependent on surface soil concentrations	• In addition to the response to PA Critical Issue 9, it is noted that the synthetic geomembrane in the cover will limit upward liquid phase diffusion during the compliance period. • RESRAD-OFFSITE output for the all-pathways scenario includes contributions from Pb-210 and progeny (including Po-210) in the dose estimates for Pu-238, U-238, U-234, and Ra-226 for release to groundwater exposure paths other than water ingestion, including external ground radiation and ingestion of soil in agricultural fields and ingestion of fish and agricultural products.
21.	PA Key Finding 2.2.11 Waste Characterization	• Uncertainty in radionuclide inventory is likely to be a primary PA uncertainty and is not included in the EMDF PA uncertainty analysis. • It is not clear how the PA intends to treat Cl-36, one isotope for which the PA provides no estimate of the inventory in the waste • The use of EMWMF profiles for ORNL and Y-12 waste is of limited utility and the PA does not identify which EMWMF waste lots were used in deriving the EMDF waste inventory estimates. • Isotopes that are likely to be present at some level in the waste are excluded from the inventory due to lack of information • Estimated uranium inventories changed between Rev1 and Rev2 • The assumption that the estimated post-closure inventory assumed for the purposes of this performance assessment has resulted in a pessimistic bias is not supported. • Safety analyses are performed for a very different purpose than are PAs, and should not be relied upon for PA inventory development • Estimated inventories of C-14, Tc-99, and I-129 are small and could be larger; the assumed EMDF facility average concentrations would be hard to measure • The R2 PA conclusion that only I-129 inventory uncertainty is important for determination of EMDF compliance with the all-pathways performance objective (Section 1.7.1) is conditioned on assuming significant loss of the as-disposed inventories of C-14 and Tc-99 during landfill operation.	• Radionuclide inventory uncertainty is not included in the RESRAD-OFFSITE UA, but because the release model does not incorporate solubility limits, predicted aqueous concentrations and dose will scale with inventory variation (refer to PA Fig. 5.8). • A unit concentration of Cl-36 is included in the phase 2 radionuclide screening model, which provides a screening-level waste concentration limit (single radionuclide soil guideline) that can be used to evaluate the potential impact of observed Cl-36 levels on EMDF performance. The limitations of using EMWMF waste lots and facility safety analyses to support inventory estimation are acknowledged in PA Appendix B, Sect. B.3.1, which also explains the utility of using these surrogate data sources to estimate radionuclide concentrations in anticipated EMDF waste streams. • Changes in the estimated inventory between the Rev 1 and Rev 2 PA (including changes in uranium activities) resulted from a comprehensive QA review of the radiological data. In addition to minor corrections, the QA review led to the elimination of several SORTIE data sets that could not be confirmed from the original sources. Several less commonly reported fission products were excluded from the Rev 2 inventory as a result • Appendix B, Sect. B.6 provides support for the assertion that estimated inventories for key radionuclides of concern including C-14, Tc-99, and I-129 are pessimistic. With respect to the estimated I-129 inventory, refer to UCOR presentation to EPA/TDEC of November 11, 2019, slide 33 of 33.

Comment No.	Issue/Finding	Comment Summary	Resolution
		• In Sect 5.1 there no basis is provided for stating that Tc-99 is representative of other radionuclides with respect to uncertainty in Kd.	• Facility average activity concentration for use in the PA is estimated from a range of calculated waste volumes and concentrations, and adjustments to account for addition of clean fill and operational period losses (PA Sect. 3.2.2.5). With respect to operational period losses of mobile radionuclides and their significance for the EMDF compliance determination, please refer to the response to PA Critical Issue 5. • The STOMP model Kd value sensitivity analysis in PA Sect 5.1 is not meant to represent the uncertainty in Kd values for all radionuclides. Uncertainty in Kd values is evaluated in the RESRAD-OFFSITE UA for technetium and other elements. It is true that quantitative model sensitivity to the range of Kd values (a factor of 2) evaluated in Sect. 5.1 would be expected to vary with the magnitude of the assumed Kd value. However, the results for elements less mobile than technetium would be qualitatively similar to the Tc-99 example. The text was not meant to imply quantitative similarity in sensitivity to variation in Kd values.
22.	PA Key Finding 2.2.12 Land Use and Exposure Scenarios	• It isn't necessarily protective to evaluate a true "farmer" who uses surface water for irrigating large fields A home garden and fruit trees irrigated with well water, and home-raised poultry, is a more credible and protective scenario for evaluating food pathways when the endpoint is individual dose for a hypothetical resident • The vapor and biointrusion pathway analysis is not coupled to important upward transport pathway mechanisms of upward diffusion of radon in pore air and of most other radionuclides in water. The biointrusion maximum depth of 1 m selected for the RESRAD-OFFSITE run does not have any information to support it. • A residence located off-site for the entire performance period is inconsistent with assuming IC effective for only 100 years; the IHI analysis required by DOE does include an on-site resident so doses to an on-site resident should be evaluated against the 100 mrem/yr performance standard. • No basis is provided for the crop irrigation rate of 0.15 m/yr, or for the landscaping irrigation rate of 0.015 m/yr.	• The EMDF PA resident farmer scenario does not assume commercial scale agricultural production. • Although it is true that alternative assumptions regarding irrigation water source and food consumption could result in larger or smaller doses, DOE and LFRG do not endorse adopting worst case technical assumptions for Order 435.1 compliance determinations. • The arguments to support screening radionuclide release through the cover in Sect 3.2.2 are primarily qualitative, but pessimistic assumptions regarding inventories of H-3, C-14, and I-129, the thickness of the cover, (no) loss of mobile radionuclides via leaching, and human exposure duration are incorporated into the quantitative cover release screening model analysis presented in Sect 3.2.2.3. • The RESRAD-based screening models for mechanisms driving release through the cover do not explicitly incorporate the physics of fluid-phase diffusion, but the simplified screening modeling is likely to over predict the impact of upward transport of radionuclides through the cover

Comment No.	Issue/Finding	Comment Summary	Resolution
			especially given the potential for water flux through the upper layers of the cover system (above the clay infiltration barrier) to limit upward diffusive radionuclide flux. Unrealistic assumptions for some screening scenarios regarding cover thickness and the mixing depth (≤1 m) are related to RESRAD-OFFSITE limits on input parameter ranges. • The EMDF PA resident farmer scenario is considered an onsite residential scenario. With respect to the chronic IHI exposure scenario, please refer to the responses to PA Critical Issue 6 and PA Key Finding 2.2.5. • The basis for the irrigation rates assumed for the agricultural and residential areas is provided in the last column of the input parameter table provided in Appendix G, Attachment G.1.
23.	PA Key Finding 2.2.13 ALARA Analysis	• The PA does not provide an ALARA evaluation of collective dose • The PA should specifically describe how the information presented in the EMDF Remedial Investigation/Feasibility Study (RI/FS) and draft Proposed Plan satisfies the requirements of an ALARA analysis	• Review and revision of the ALARA analysis was identified in the LFRG review as a PA secondary issue; this issue (EMDF-S17-PA18-01) was resolved for the R2 PA. • Sect. 1.5.4 of the PA states: “The scope of this ALARA analysis is restricted to: (1) presenting evidence to support the finding that only a qualitative ALARA analysis is required; and (2) describing the CERCLA process for identifying LLW disposal options for the ORR CERCLA cleanup, the basis for the EMDF preliminary design and selection of the CBCV site for EMDF.” • The PA provides an ALARA evaluation of collective dose in the third paragraph of Sect. 1.5.4. • The last paragraph of Sect. 1.5.4 describes how the EMDF RI/FS meets some requirements for an ALARA analysis. The text was not meant to imply that the RI/FS completely satisfies ALARA requirements. As noted in the first paragraph of this section, “The scope of ALARA considerations for the EMDF includes design optimization, disposal protocols for worker and public protection during operations, and the development of WAC by the FFA parties. These three aspects are not included in this ALARA analysis for the EMDF PA…”

Comment No.	Issue/Finding	Comment Summary	Resolution
24.	PA Key Finding 2.2.14 Development of Waste Acceptance Criteria (WAC)	• The PA should address development of waste acceptance criteria (WAC) to support benefit-cost evaluation for construction of the facility. • The WAC for the EMDF should be developed from the results of the PA and CA to determine the amounts of radioactive materials that can be disposed at the EMDF while maintaining compliance with the annual dose threshold.	• Development of protocols for WAC compliance will be completed by the FFA parties as a post-ROD primary document requiring approval by the FFA parties prior to EMDF operations.
25.	CA Critical Issue 1 MCL Analysis	• The PA MCL analysis is insufficient, particularly in the context of composite impacts to BCV	• The EMDF PA analysis of water resources protection is not required or intended to address composite impacts of BCV disposal facilities. • The CA has no explicit water resources protection requirement under DOE Order 435.1.
26.	CA Critical Issue 2 Lack of Dose Estimate	• Compliance analysis based on assuming CERCLA risk goals are achieved, No consideration is given to scenarios where these goals cannot be met. • Meeting CERCLA goal implies IC and site maintenance in perpetuity	• The CA is an internal DOE planning tool that in this case applies assumptions based on the existing Bear Creek ROD. This approach is reasonable and consistent with the approach outlined in Sect. 3 of DOE-STD-5002-2017. • The CA base case and sensitivity case scenarios assume that IC fails to prevent chronic exposure of a resident in BCV at the POA. • The CA does evaluate a sensitivity case in which ROD goals are not met at BCK 9.2 (CA Sect. 5.2). • Section 7 of the CA specifically addresses the BCV ROD, future remediation in BCV, and changes in radionuclides and radionuclide concentrations in Bear Creek. It commits to an evaluation of the results of the CA using the referenced procedures in the event that conditions differ from those evaluated.
27.	CA Critical Issue 3 Inventory of Other BCV Sources	• No methodology or plan is cited in the CA regarding how the risk goals described in the RODs, and used as the basis for the CA, will be achieved • The inventory of other BCV sources is poorly understood. Without an understanding of the nature of these sources, a CA cannot be adequately developed	• The CA is an internal DOE planning tool that in this case applies assumptions based on the existing Bear Creek ROD. This approach is reasonable and consistent with the approach outlined in DOE-STD-5002-2017. • The BCV CERCLA remedy selection is outside the scope of DOE Order 435.1 CA requirements (BCBG is pre-1988). The CA provides an overview of other BCV sources, uncertainties, and the approach to estimating dose for the other BCV

Comment No.	Issue/Finding	Comment Summary	Resolution
			sources (Sects. 2.4 and 2.5 of the CA).
28.	CA Critical Issue 4 EMWMF Modeling Assumptions	• The parameters used in groundwater modeling of upper Bear Creek Valley produce unrealistic travel times through groundwater. • Assumptions used for EMWMF are biased toward underprediction of near-term impacts on water resources • Mobility and transport model assumptions are inconsistent with leachate collection uranium output • The EMWMF failure scenario does not consider groundwater intrusion, bathtubbing, or a liner breach • Alternative POA assumptions for the CA are possible.	• The CA evaluates a post-1000 year maximum dose (Sect. 5.3 of the CA) that includes contributions from uranium released from EMWMF, which are predicted by the model to occur after 10,000 years (CA Appendix B, Table B.7). Impacts from highly mobile radionuclides released from EMWMF occur within the 1000-year compliance period. These dose impacts are not under predicted due to unrealistic travel times. • The assumption of 0.4 in./year cover infiltration (partial design performance assuming HDPE membrane is gone) after the first two centuries is highly pessimistic, based on expected cover membrane longevity. • The conceptual model of EMWMF facility failure is consistent with EMWMF performance modeling for DOE Order 435.1 compliance and with EMDF PA assumptions. • Several alternatives to the POA in the base case assessment were evaluated in Sect. 5 of the CA (Sects. 5.1, 5.5, 5.6, and 5.8). Sect. 5.9 of the CA evaluates impacts at an alternative POA that encompasses the entire ORR. • Section 7 of the CA specifically addresses changes in radionuclides and radionuclide concentrations in Bear Creek. It commits to an evaluation of the results of the CA using the referenced procedures in the event that conditions differ from those evaluated.
29.	CA Key Finding 1 CA POA	• The CA includes an incomplete technical basis for identifying the POA for the CA. • At least one appropriate POA, then, is at the mouth of Poplar Creek where upstream contamination from White Oak Creek, Bear Creek, East Fork Poplar Creek, and Poplar Creek itself are integrated	• The technical basis for the POA is explained in Sect. 1.2.2 of the CA. Several alternatives to the POA in the base case assessment were evaluated in Sect 5 of the CA Sect. 5 (Sects. 5.1, 5.5, 5.6, and 5.8). • Sect. 5.9 of the CA evaluates impacts of the dose from the BCV sources at Poplar Creek and the Clinch River (an alternative POA that encompasses the entire ORR). • The ORR ASER risk assessment also provides additional context for the CA compliance determination.
30.	CA Key Finding 2 Remediated BCV	The CA does not describe how, or if, environmental contamination remaining in the subsurface from remediation of the S-3 Ponds,	• Sect 2.5.1 of the CA explains how other existing BCV sources are accounted for.

Comment No.	Issue/Finding	Comment Summary	Resolution
	Sources	Boneyard/Burnyard, and similar facilities has been accounted for.	• Refer to responses to EPA/TDEC comments #46, #49, #51 (email May 18th, 2020).
31.	CA Key Finding 3 BCV Remediation	BCV remediation is not completed; achieving ROD risk target is an assumption inconsistent with current conditions	• The approach used for the CA is reasonable and consistent with the approach outlined in DOE-STD-5002-2017. • A dose for the current conditions in BCV was quantified in Sect. 5.2 of the CA. • Section 7 of the CA specifically addresses the BCV ROD, future remediation in BCV, and changes in radionuclides and radionuclide concentrations in Bear Creek. It commits to an evaluation of the results of the CA in the event that conditions differ from those evaluated. • Refer to responses to EPA/TDEC comments #41, #46, #49 (email May 18th, 2020).
32.	CA Key Finding 4 Remediation of Bear Creek Burial Grounds	• It may not be practicable to achieve the goals of the Phase I ROD. • The CA does not consider the uncertainty in releases from BCBG.	• Uncertainty is addressed through the required maintenance of the CA. Section 7 specifically addresses the BCV ROD, future remediation in BCV, and changes in radionuclides and radionuclide concentrations in Bear Creek. It commits to an evaluation of the results of the CA in the event that conditions differ from those evaluated. • Current surface water concentrations at BCK 9.2 were utilized to quantify the release from BCBG and other BCV sources for sensitivity case # 1 (CA Sect. 5.2). • Refer to responses to EPA/TDEC comments #46, #49, #51 (email May 18th, 2020).
33.	CA Key Finding 5 Uranium release from BCBG	• The CA does not consider the uncertainty in future releases from BCBG, or add the BCBG seepage flux of uranium to the baseline release from other BCV sources. • Mobility and transport model assumptions used for the EMDF PA and for modeling release from EMWMF are inconsistent with rapid uranium release from BCBG.	• Uncertainty is addressed through the required maintenance of the CA. Section 7 specifically addresses changes in radionuclides and radionuclide concentrations in Bear Creek. It commits to an evaluation of the results of the CA in the event that conditions differ from those evaluated. • Uranium release from legacy sites is not a good conceptual analogue for release from the robustly designed and constructed EMWMF and proposed EMDF. Also refer to the response to PA Critical Issue 8. • Refer to responses to EPA/TDEC comments #41, #46, #49 (email May 18th, 2020).

Comment No.	Issue/Finding	Comment Summary	Resolution
34.	CA Key Finding 6 BCBG and BCV Phase 1 ROD	The CA suggests that BCBG has no ROD that identifies a remedy. If the primary sources of uranium in the BCV are not subject to the codified 10-5 ELCR risk goal, then this goal cannot be used to represent the future risks or doses that these sources present. The CA should clarify the relationship of the BCBG to the Phase I BCV ROD.	• Phase 1 ROD goals are to be met at the downstream integration point at BCK 9.2; monitoring data at BCK 9.2 (which includes releases from BCBG) is the basis for evaluating compliance with the ROD.
35.	CA Key Finding 7 Non-radioactive contaminants	• The CA does not present a technical justification for the assumption that radionuclides will account for 100% of the 10–5 ELCR risk value that was used to represent the contribution of upstream sources. • Some or all of the 10–5 ELCR risk target could be accounted for by non-radiological constituents and could significantly affect the plausibility of actually achieving this goal.	• In the context of the CA assumption that the ROD risk goal is met, excluding the contribution of non-radiological contaminants represents a pessimistic approach to demonstrating BCV dose compliance with DOE Order 435.1 performance objectives. • Also Refer to response to EPA/TDEC comments #42 (email May 18th, 2020).
36.	CA Key Finding 8 PATHRAE is Outdated	• The use of PATHRAE, a computer program developed in 1986 by Rogers and Associates Engineering, is a simple screening-level model unsuited for evaluating release and transport from radiological sites in the complex terrain of BCV. • It is not clear that this program meets the software quality assurance requirements of the American Society of Mechanical Engineers (ASME) NQA-1 (nuclear quality assurance	• Refer to responses to EPA/TDEC comments #52, #79 (email May 18th, 2020). • Sects. 2.1.2 and 5.6 of the Quality Assurance Report for the BCV PA and CA modeling documents software quality assurance requirements for the PATHRAE-RAD code.
37.	CA Key Finding 9 Surface water concentrations are underestimated	• Concentration is inversely related to stream flow for a given groundwater contaminant flux • Using an average flow rate underestimates average concentration	• With respect to the PA implementation, the effective long-term average annual radionuclide concentration in irrigation water would depend upon the interaction of groundwater contaminant flux and streamflow rates. That interaction reflects complex variations in precipitation, runoff, groundwater recharge, stream baseflow, and radionuclide release to the saturated zone. The uncertainty associated with the simplified mixing model is acknowledged and evaluated in the PA report (PA Appendix G, Sect. G.6.7.2.3, Fig. G.34, and Sect. G.6.3.3.4, Table G.26, Fig. G.47). • For the CA dose analysis, the 'other BCV sources' is the largest dose contributor. The CA used the average flow rate, along with other assumptions as a basis for calculating mixing ratios (dilution) between pairs of locations on Bear Creek, but the concentrations used to calculate the dose for the other BCV sources are not based on the estimated flow rates. • Increasing the combined EMWMF and EMDF dose contributions by a factor of 3 does not impact the compliance

Comment No.	Issue/Finding	Comment Summary	Resolution
			determination for the CA. • Similar LFRG concerns with respect to flows in Bear Creek as used in the CA have been addressed in the corrective action to CA issue EMDF-S03-CA14.
38.	CA Key Finding 10 Land use assumed for BCV	• The proposed EMDF is inconsistent with end state land use currently assumed in the Phase 1 ROD for BCV, Zone 2. • The CA assumes regulatory and community acceptance of this and other similar DOE proposals.	• The proposed EMDF is inconsistent with the end state land use assumed in the BCV ROD; however, the end state land use for Zone 2 (location of proposed EMDF) is modified through the EMDF ROD to be consistent with waste disposal. This is explained and evaluated in CA Sect. 5.1. • An approved ROD documents regulatory and community acceptance. In the event that the EMDF ROD is not approved, the assumption made for the CA would be reviewed as part of the DOE Order 435.1 PA/CA maintenance process for the EMWMF.
39.	CA Key Finding 11 Hydraulic isolation of BCV	Because surface drainage divides do not always correspond to ground water divides, and because karst pathways may not correspond to surface drainage patterns, there is uncertainty in identifying sources in the upper BCV (at the divide with UEFPC) that could release radionuclides to BCV.	• The Upper BCV groundwater flow model captures underflow across the boundaries of BCV tributary catchments. • This finding appears to confirm that there is not significant exchange of groundwater between the Bear Creek watershed and the Upper East Fork Poplar Creek watershed at the west end of the Y-12 plant.
40.	CA Key Finding 12 Unrealistic groundwater travel times	Much of the delay until peak dose results from unrealistic modeling assumptions that fail to properly define the most probable paths for contaminants to reach surface water and do not realistically represent groundwater flow and solute transport in Bear Creek Valley.	• Model-predicted saturated zone travel times are addressed in the responses to PA Critical Issue 4 and PA Key Finding 2.2.1, and in CA Critical Issue 4.

Comment No.	Issue/Finding	Comment Summary	Resolution

ALARA = as low as reasonably achievable
ASER = Annual Site Environmental Report
BCBG = Bear Creek Burial Grounds
BCK = Bear Creek kilometer
BCV = Bear Creek Valley
CA = Composite Analysis
CBCV = Central Bear Creek Valley
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EMDF = Environmental Management Disposal Facility
EMWMF = Environmental Management Waste Management Facility
E/P = escape to production ratio for radon
EPA = U.S. Environmental Protection Agency
FFA = Federal Facility Agreement
FEP = features, events, and processes
HDPE = high-density polyethylene
HELP = Hydrologic Evaluation of Landfill Performance
IC = institutional control
ICRP = International Commission on Radiological Protection
IHI = inadvertent human intrusion
LFRG = Low-level Radioactive Waste Disposal Facility Federal Review Group
LLW = low-level (radioactive) waste
NRC = U.S. Nuclear Regulatory Agency
ODAS = operating Disposal Authorization Statement
ORR = Oak Ridge Reservation
PA = Performance Assessment
POA = Point of Assessment
QA = quality assurance
RCRA = Resource Conservation and Recovery Act
RI/FS = Remedial Investigation/Feasibility Study
ROD = Record of Decision
STOMP = Subsurface Transport Over Multiple Phases
TDEC = Tennessee Department of Environment and Conservation
UA = uncertainty analysis
WAC = waste acceptance criteria