DOE Moab UMTRA Responses to Nuclear Regulatory Commission (NRC) Staff Comments on “Crescent Junction Disposal Site Alternative Final Cover System 90 Percent Design Report”

By letter dated April 6, 2022, the U.S. Department of Energy, Office of Environmental Management (DOE-EM) and Moab Uranium Mill Tailings Remedial Action Project submitted for the U.S. Nuclear Regulatory Commission (NRC) staff’s review and comment, a report titled, “Crescent Junction Disposal Site Evapotranspiration Cover System 90 Percent Design Report,” (Design Report) (NRC Agencywide Documents Access and Management System Accession No. ML22096A243). Consistent with the approach used in the review of the 2008 Remedial Action Plan (RAP) (ML080920459), the NRC staff’s review process was informed by the “Final Standard Review Plan for Uranium Mill Tailings Radiation Control Act Title I Mill Tailings Remedial Action Plans” (ML110190562), and more recent applicable technical guidance in NUREG-1620, Revision 1, “Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978.”

On November 2, 2021, the NRC staff provided feedback on DOE-EM’s 60 percent design for the Crescent Junction cover system (ML21298A067). Staff reviewed the 90 percent design to understand how the design has changed in response to our comments. Staff’s comments from the 60 percent design have not been repeated below, unless the comment pertains to an issue that remains relevant.

In its comments below, the NRC staff uses the terms “existing cover” and “proposed cover.” The term “existing cover” refers to the rock cover approved in 2008 (and shown in Figure 1 of the Design Report). The term “proposed cover” refers to the evapotranspiration (ET) cover profile shown in Figure 5 of the Design Report. From top to bottom, the proposed cover consists of a 2-foot-thick gravel/soil admixture, a 4-foot-thick shale layer (which serves as the radon barrier), and a 1-foot-thick interim cover layer on top of the residual radioactive material (RRM). Additionally, the staff understands that that DOE is not changing the angle of the side slope of the disposal cell, but is considering re-evaluating the minimum rock diameter and thickness to provide erosional stability. Staff appreciates that DOE is narrowing its design approach. The NRC staff continues to develop a better understanding of ET cover system design and performance. Our comments on the 90 percent design may focus on slightly different areas, as staff continues to gain knowledge and experience with ET covers

Comments Related to Geotechnical Stability

NRC Comment 1:

1. In Section 6 and Appendix B of the Design Report, DOE discusses unsaturated modeling of the proposed cover. The Design Report describes the input parameters used in UNSAT-H and provides a summary of the output. The NRC staff appreciates the extent of the modeling that has been done to support the 60 percent design and understands the approach taken to design the proposed cover. ET covers rely on storage of water within the cover and removal of the water by evaporation and transpiration to limit percolation through the bottom of the cover. Conventional covers rely on a low permeability layer to limit percolation through the bottom of the cover.

Because of these fundamentally different processes for management of water, the NRC staff offers the following comments for DOE's consideration.

a. The design of the cover system is based heavily on the moisture retention properties of the cover soils as well as the properties of the vegetation. The NRC staff's comments on the 60 percent design provided feedback on the relationship between the design calculations and the Technical Specifications. In addition to the particle size requirements that were in the 60 percent design, staff recognizes that DOE has modified the Technical Specifications to include agronomic testing to determine if organic material or other soil additives are needed to support vegetation. This change is helpful. It may be worth further discussion to better aid the NRC staff's understanding of the relationship between the design and the Technical Specifications.

DOE Reply 1:

The soil intended for the upper portion of the cover (generally top foot) will be tested for agronomic properties. The reason for this is to determine whether soil amendments may be required to better establish native vegetation. The addition of any amendments will be done during seeding operations. Any amendments should have no significant impact on the cover soil's hydraulic properties. Thus, agronomic testing and potential soil amendment on cover soil will have no impact on the cover sensitivity simulations.

Modeling showed that the point of diminishing returns (PODR) is reached at a depth significantly less than the cover depth and therefore, water balance is not the critical factor to determine the cover depth. The PODR is generally the depth of cover whereby an additional inch of soil depth no longer reduces percolation. In every case, it was the depth that produced an annual zero flux rate. The Design Report, Appendix B included multiple sensitivity analyses that included varied soil input parameters. The cover soil borrow material comes from on-site excavations. There are generally two soil textures - overburden or alluvium and the underlying Mancos shale. Multiple samples of each soil texture were measured. These unsaturated hydraulic property values were each modeled separately to determine the set of values that would require the thickest cover to produce the PODR. The intent of the sensitivity analyses were to make sure that the proposed cover profile effectively minimizes flux due to meteoric water and, in addition, to qualify all on-site cover soil borrow sources. Values from the literature for similar soil textures, as well as values produced from similar soil textures on the Grand Junction project, were included in the sensitivity analysis to determine the worst case set of hydraulic priorities (values that required the deepest PODR). The worst-case alluvium properties and the worst-case Mancos shale properties were then combined into a second set of sensitivity analyses in a proposed cover profile. The worst-case vegetation properties were also evaluated.

The combined worst case input parameters (soil and vegetation) are included in the Profile 2 graph that shows the PODR for the beyond worst-case scenario using the wettest year on record while forcing 100% infiltration of all precipitation applied in consecutive years. The output from these sensitivity analyses showed little sensitivity to the soil input parameters. The worst-case soil texture with the worst-case vegetation parameters subjected to the beyond worst-case climate scenario resulted in

a PODR of 140 cm. That is, zero flux is produced with a cover depth of 140 cm (PODR was 89cm to 140 cm depending on the soil textures utilized as input. Refer to the Design Report, Appendix B, Table B-10). Additional sensitivity analyses performed utilizing Grand Junction soil properties suggested in a previous review resulted in a worst case PODR of only 109cm (PODR was 83cm to 109cm). Our cover depth is 213 cm. Consequently, water balance is not driving the depth of cover and further altering soil texture or vegetation properties will have no impact on the cover design. Keep in mind that if one simply compares the proposed cover design results to the existing UMTRA cover profile, the proposed ET Cover reduces recharge to zero while the existing UMTRA cover profile allows recharge at close to the precipitation rate at the site.

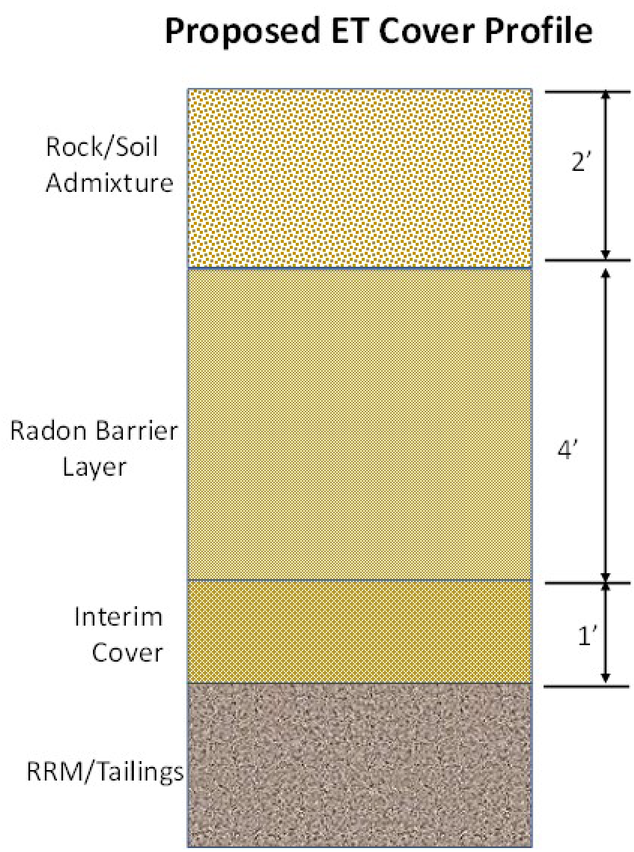

Figure 1. Proposed ET Cover with 2ft Surface Admixture Layer

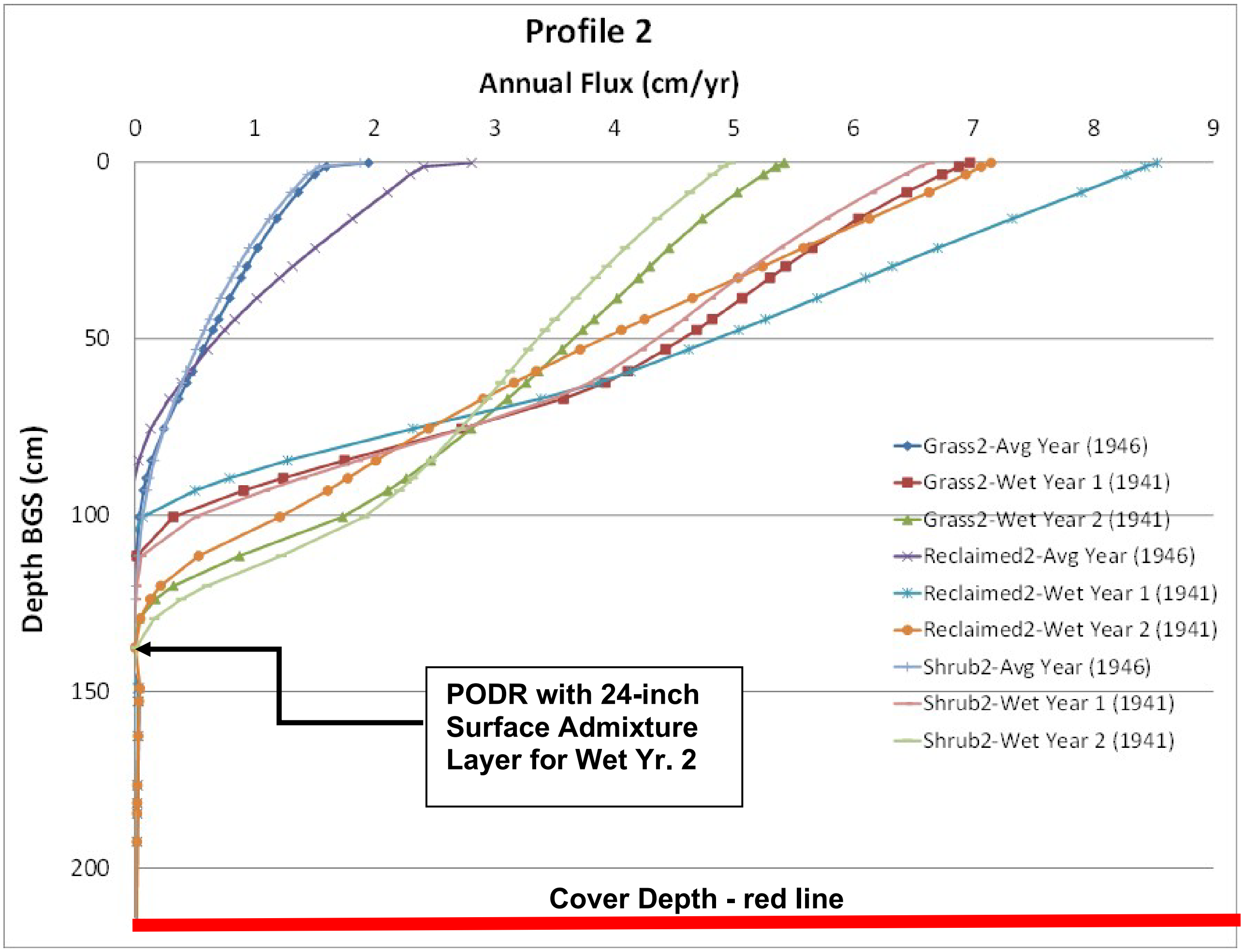

Figure 2. PODR Results for Profile shown in Figure 1

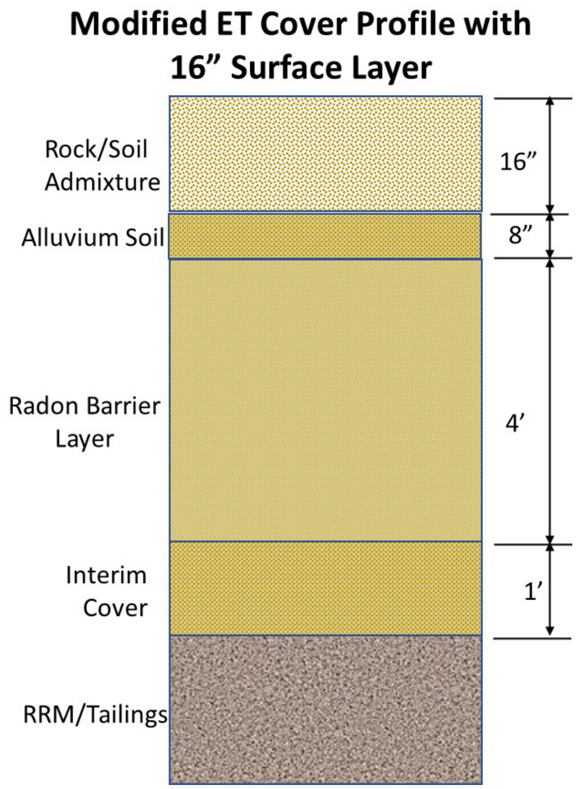

Figure 3. Profile with Thinner 16" Surface Admixture Layer

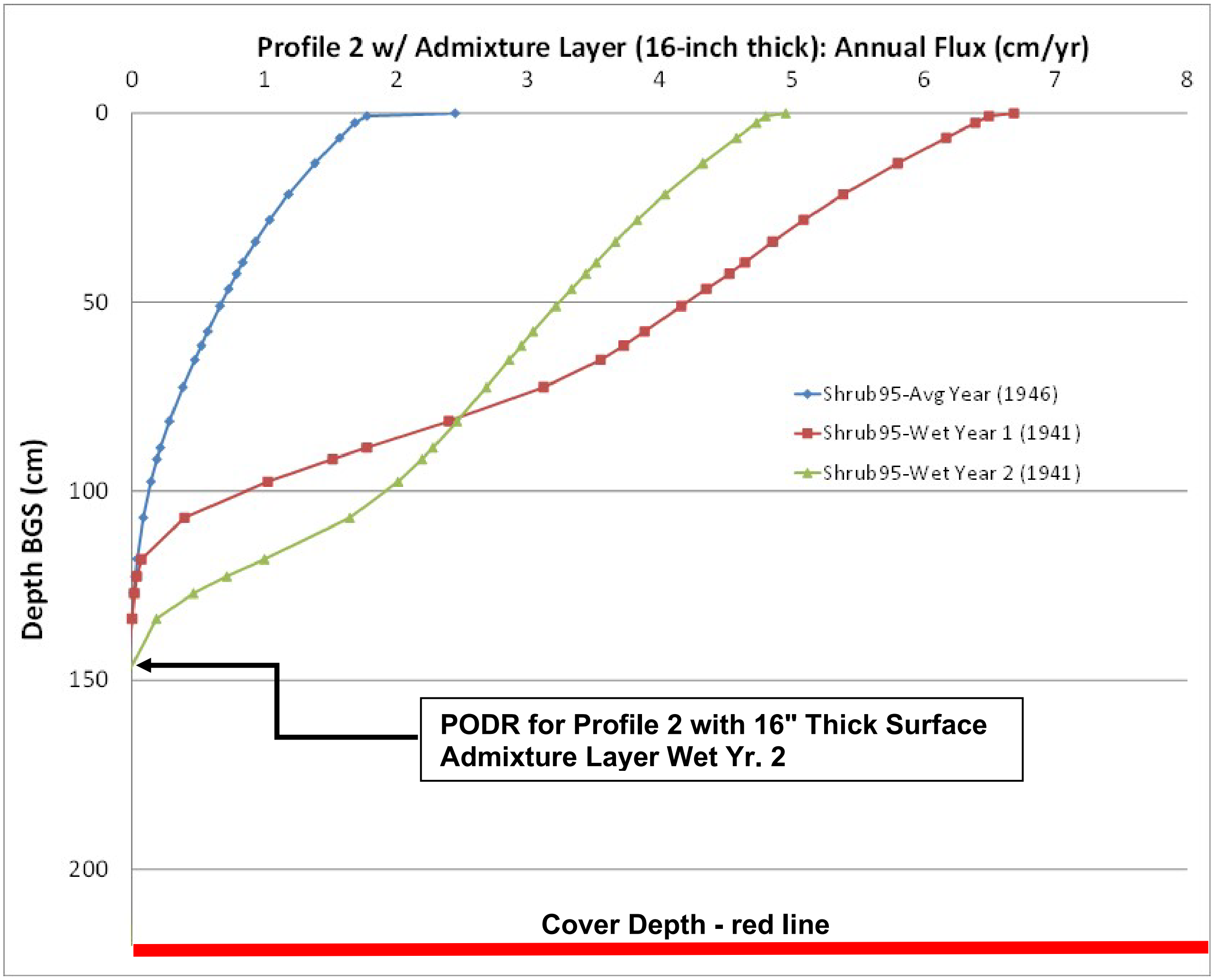

Figure 4. PODR with Results from Simulations Using Profile show in Figure 3

NRC Comment 2:

2. As mentioned in the NRC staff's comments on the 60 percent design, settlement challenges have become apparent at several Title I and Title II disposal cells. This is potentially an issue at sites with relatively long and shallow top slopes. The settlement analysis approach used in Appendix D is reasonable as it considers the mixing of RRM that occurs prior to placement in the disposal cell. However, as currently presented, the settlement analysis is based on the conditions at one location. As a result, the analysis does not consider variability in the material properties that could become apparent over longer distances. The NRC staff recognizes that DOE-EM has significantly more control over the mixing of RRM and placement of RRM when compared to past practices at other Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I and Title II sites. This ability to mix materials may minimize variations in material properties and a corresponding decrease in the potential for differential settlement. The NRC staff is not asking for a new or additional analysis at this time, but it may be worth identifying a tolerable amount of differential settlement so that resources are appropriately focused for DOE-Office of Legacy Management (DOE-LM) during long-term surveillance.

DOE Reply 2:

The settlement analysis evaluated the worst-case condition - shallowest tailings compared to deepest tailings to ensure that ponding is not possible. This means the full slope length of the cover was evaluated. The conservative consolidation results estimate a potential slope change of 0.1% compared to the design slope of 2% to 2.5%, therefore, there is no possibility of producing ponding on the cover due to differential settlement. Settlement issues at other DOE sites were discussed with DOE Legacy Management (LM). DOE LM informed us that settlement issues at other UMTRA sites generally resulted from slimes and saturated conditions as well as equipment disposal within slime tailings. At Crescent Junction, all RRM is placed in a controlled manner. The RRM is mixed and dried in Moab and then transported and placed within the Crescent Junction disposal cell based on approved procedures included in the Remedial Action Plan. There are no saturated conditions and thus no primary consolidation in a saturated soil that is traditionally the larger portion of total consolidation. The calculations conservatively assumed that there would be primary consolidation. Second, all RRM is placed at similar densities and moisture contents with a controlled compaction specification that requires the soil be placed at 90% of the maximum dry density per ASTM D698. Third, there are no untreated slimes placed in the disposal cell. Furthermore, we have proposed that large equipment that pose a differential settlement threat be buried adjacent to the RRM to further ensure there is no unexpected differential settlement in the RRM area of the disposal cell.

NRC Comment 3:

3. Section 10 of the Design Report addresses slope stability. The current design has the same slope and material properties as what was evaluated in the 2008 RAP and accepted by the NRC staff. There is no expectation for an updated slope stability analysis at this time. This comment is included as a reminder or placeholder in the event that a change is made to the design that is different from what was considered in 2008 (i.e., thicker, heavier soils are used, or the cover system on the 5H:1V side slopes is modified), the slope stability analysis should be updated.

DOE Reply 3:

Slopes will not change; thus, slope stability analyses will not be updated. The outer slope lengths will actually decrease some due to the thinner cover (7 ft thick instead of the UMTRA profile of 9ft) thus slightly improving slope stability factors of safety.

Comments Related to Surface Water Hydrology and Erosion Protection

NRC Comment 1:

1. The NRC staff reviewed the erosion calculations in Section 3 and Appendix F of the Design Report and appreciates the explanations and modifications that DOE has provided in the 90 percent design. The NRC staff is familiar with the methodology used to design the surface admixture. However, the NRC staff remains concerned about the erosion control aspects of the cover at Crescent Junction, particularly given the relatively thin amount of soil on top of the radon barrier. The staff understands that the

design calls for a gravel/soil admixture at a 30 percent rock to 70 percent soil uniformly mixed through the 24-inch depth. The gravel/soil admixture will overlie the 48-inch-thick shale layer that will serve as the radon barrier. Staff remains concerned in the ability of the gravel/soil admixture to resist erosion without forming gullies or erosion rills. The design calls for the rock component of the admixture to have a D50 of 2.3-inches. Staff has not been able to identify an overall gradation of the gravel/soil matrix; the Design Report and Technical Specifications do not clearly articulate what the final grain size distribution will be for this component of the cover system. Further input on this topic is available in the comments related to soil properties below. Without understanding the final grain size distribution of this layer, staff is concerned that it may be susceptible to erosion and the formation of gullies. This may represent a long-term maintenance issue for DOE-LM. Although not explicitly stated in the guidance document, NUREG-1623, "Design of Erosion Protection for Long-Term Stabilization," was developed around the concept of rock-to-rock contact. With a gravel/soil matrix consisting of 30 percent gravel, the rock-to-rock contact will not be as prevalent as was envisioned in NUREG-1623. As a result, the design may be more susceptible to erosion. Guidance from the U.S. Army Corps of Engineers (USACE) in Engineering Manual 1110-2-1601, Hydraulic Design of Flood Control Channels (USACE, 1994) suggests that well graded riprap be used and identifies target values for the D85 to D15 ratio. Options to consider with the design to make it more resistant to erosion include: increasing the rock size in the gravel/soil matrix; concentrating the gravel in the upper portion of the admixture and filling in the voids with smaller diameter particles (similar to what was done at the Monticello, UT site); or utilizing a shallower slope on the top deck of the disposal cell. Staff recognizes the need to consider erosion resistance, the ability to support vegetation, and the ability to limit percolation can be counter to each other. Further discussion may be warranted to arrive at a design that satisfies each of those goals.

DOE Reply 1:

Albright et al 2010, Dwyer et al 2007 (Reference Provided, File Dwyer et al 2007) and EPA 909-R-11-007 (Reference Provided, File EPA-909-R-11-007) state that rock/soil surface admixtures mitigate soil loss due to erosion and prevent rill and/or gully formation. Abt et al 1988 (NUREG/CR-4651) states that results of rock mixed with soil are more stable than riprap only. During communication with Ted Johnson during early work on the design of closure for the Northeast Church Rock UMTRA site, Ted and Steve Dwyer discussed the rock/soil admixture design summarized in Dwyer et al 2007 with his concurrence. He suggested using the NUREG 1623 "Design of Erosion Protection for Long-Term Stabilization" to satisfy NRC requirements prior to formal acceptance of the rock/soil admixture design by NRC staff. If finer portions of the soil are removed by erosive forces, the larger particles (rock) remain behind and form an "armored" surface, sometimes referred to as a "desert pavement."

This surface is much more stable and resistant to surface erosion due to both surface water runoff and wind erosion. The NRC staff states the soil layer is relatively thin. It is 2-ft thick; although, a 16-inch layer was also analyzed with a higher rock to soil ratio. The NRC states that the grain size distribution is not clearly articulated. It consists of alluvium soil mixed with rock at 30% by volume. Grain size distribution of installed cap rock is submitted with these comments (Reference Provided, File Cap Rock) and the

alluvium soil properties are contained in the DBSA soil testing report (Reference, DBS&A Northwind Portage (Crescent Junction) Laboratory Report, 9-9-20) as well as the FRAP, Attachment 5 found at: https://www.energy.gov/em/moab/crescent-junction-disposal-site. The NRC suggests additional options to consider with the design to make it more resistant to erosion. These include: increasing the rock size in the gravel/soil matrix; concentrating the gravel in the upper portion of the admixture and filling in the voids with smaller diameter particles (similar to what was done at the Monticello, UT site); or utilizing a shallower slope on the top deck of the disposal cell.

The rock soil admixture is designed to prevent rill/gully formation. The rock was sized to prevent movement due to erosive forces from the probable maximum precipitation event (PMP). Any erosion of fine-grained soil will leave rock in place that will eventually be rock to rock if enough soil erodes. The rock size is conservatively the largest rock based on the entire disposal cell footprint and combination of Dwyer admixture calculations and NUREG 1623 Long-Term Stability of Rocky Soil Cover. For example, the upper part of the slope length requires rock with 1/3-inch diameter. Refer to provided tables for calculated rock sizes required as a function of slope length A D50 of 2.3-inch is currently recommended for the entire disposal cell cover (Tables 1 and 2). The only portion of the disposal cell cover that actually requires the larger rock is the base of slope along the south slope. The remainder of the cover requires a much smaller rock size. Thus, including larger rock is very conservative. The consideration to place a greater ratio of rock near the surface would be dictated by the site conditions. That is, if precipitation or wind events allowed for some erosion of the finer grain soil, the rock portion would not be dislodged and thus it would become naturally more of the ratio near the surface. Finally, the soil to be mixed with rock is soil excavated from the site which is the overburden or alluvium above the Mancos shale layer. This soil is less fine than the Mancos shale soil, and it is basically what you currently see at the site on the surface. There is no significant rill/gully formation at the site on similar grades, and this soil is best suited to maintain a natural blend of native vegetation.

Table 1. Rock Size – South Slope

Slope Length (ft)	Rock Size D_c (in.)	use Rock Size D_c (in.)
1,300	2.3	2.3
1,200	2.2	2.3
1,100	2.1	2.3
1,000	2.0	2.3
900	1.8	2.3
800	1.7	2.3
700	1.5	2.3
600	1.4	2.3
525	1.2	2.3
500	1.2	2.3
400	1.0	2.3
350	0.9	2.3
300	0.8	2.3
200	0.6	2.3
100	0.3	2.3

Table 2. Rock Size - North Slope

Slope Length (ft)	Rock Size D_c (in.)	use Rock Size D_c (in.)
548	1.0	2.3
500	0.9	2.3
400	0.8	2.3
300	0.7	2.3
200	0.5	2.3
100	0.3	2.3

Based on the NRC comment, an alternative thinner (16") surface admixture was analyzed having 8" thick layer of rock mixed with an 8" thick layer of soil:

Evaluation of the surface rock/soil admixture was evaluated based on this comment to increase the ratio of rock to soil to 50% each by volume. That is, an 8-inch layer of rock (D50 2.3") would be evenly mixed with an 8-inch layer of alluvium cover soil to produce a 16-inch-thick surface rock/soil admixture layer. This revised layer satisfies the erosion performance objectives. It was also modeled altering the upper 2-ft to include the thinner surface rock admixture with the altered hydraulic properties based on the increased rock content overlying a thin alluvium soil layer on the 4-ft radon barrier. No significant change to water balance results. The modeled cover is still 7-ft thick. The PODR is a little deeper in the profile but still produces a net zero flux within the cover profile. Furthermore, the altered profile was modeled without vegetation and the PODR is satisfied within the cover profile. A graphical summary of these modeling results is shown below the ET Cover Vegetation Comment #2 response which summarizes results without vegetation. Thus, the water balance performance objectives are also satisfied with the thinner admixture layer and a higher rock content.

Abt and Johnson (1991) recommends a minimum rock layer thickness 2 times the D50. The riprap design for the side slopes utilized this while the prior analysis of the surface rock and drainage trenches with slopes less than 10%, a thickness of 3 times D50, was used. In the case of the surface rock/soil admixture; an armorment thickness of rock is actually greater than 3 times the D50. The D50 is 2.3-inches while the depth of rock is 8-inches resulting in an armorment thickness ratio of 3.5. Details of the modeling results from the profile with the thinner surface admixture layer will be made available upon request.

NRC Comment 2:

2. As discussed in our comments on the 60 percent Design Report, the potential for the presence of dispersive soils within the cover at Crescent Junction is not addressed in the submittal. The presence of dispersive soils may make it more challenging to meet the longevity requirements in Title 40 of the Code of Federal Regulations Part 192, “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,” and also represents a long-term maintenance concern for DOE-LM. This is an issue that needs to be resolved for the NRC to be able to concur on the revision to the design. A joint discussion between DOE-EM, DOE-LM, and NRC may be helpful in addressing this issue.

DOE Reply 2:

Testing was completed on dispersive soil, and the results were submitted to the NRC. There were two sets of tests completed on soil samples taken from within the existing disposal cell cover and borrow sources. First a series of tests featuring the crumb test (ASTM D6572) were performed. This is a relatively simple test and perhaps the most applicable for our site. It is most applicable because it simulates the change from unsaturated to saturated conditions that would be of concern given erosion due to precipitation on the surface of the cover. All crumb tests showed the soil was Grade 1 - nondispersive. Second, a series of pinhole tests were performed (ASTM D4747). These are less applicable to cover surface erosion because they attempt to simulate

the potential for piping that could happen in an earthen dam. These tests produced results of nondispersive soil from grade 1 to grade 3. Test results are included in this submittal (File, Soil Dispersion Testing Results 1-25-22).

NRC Comment 3:

3. The NRC staff reviewed the drainage rock calculations in Appendix C of the Design Report. As presented in the 90 Percent Design Report, the NRC staff understands that the rock cover on the 20 percent (5H:1V) side slope is not being altered, but DOE plans to modify the rock contained in the drainage trenches at the base of the side slopes. Additionally, the NRC staff understands that DOE intends to resize the rock for the trenches at the base of the side slopes. The narrative discussion in Section 4 of the Design Report only discusses modifying the rock around the perimeter of the final cover system. If the intent is to modify the rock diameter on the side slope, please clearly communicate that intent in the next iteration of the design.

DOE Reply 3:

Verbiage will be clarified to state that rock size along slopes of the disposal cell shall be modified. The size and depth of rock at the base of slopes will not change. The side slope angles will not change. The following table (Table 3) is provided to show the proposed rock size/depth changes on the disposal cell side slopes.

Table 3. Proposed Rock Size Changes

	Revised values		Original Values	
	D50	RipRap thickness	D50	RipRap thickness
North Slope	3.0	6.0	4.0	8.0
South Slope	3.0	6.0	6.0	12.0
West Slope	2.0	4.0	4.0	8.0
East Slope	2.0	4.0	4.0	8.0

Comments Related to Radon Attenuation

NRC Comment:

The NRC staff has reviewed the radon attenuation aspects of the ET cover design, but has not updated its confirmatory analysis for radon attenuation at this time. Staff plans to update those calculations at the next iteration of the design. Staff will consider the long-term moisture content of the radon barrier as well as freeze-thaw impacts to the radon barrier at that time.

DOE Reply:

The design report included a sensitivity analysis of long-term moisture content based on the borrow soil investigation performed on the site and previously accepted by the NRC. This sensitivity analyses was performed in response to a request made by the NRC in the 60% design review. The design analyses also included a sensitivity

analysis of changes due to freeze/thaw conditions. The analysis confirmed that a 4-ft thick clay radon barrier is required in the cover profile. The 60% design included a radon barrier that was only 3ft thick. This 4ft thick radon barrier included in this proposed ET Cover matches the thickness of the radon barrier in the approved UMTRA cover profile. The placement conditions (moisture and density) match those from the 4ft radon barrier in the UMTRA cover profile that had previous NRC approval.

Comments Related to Biointrusion

NRC Comment 1:

1. Discuss the potential for biointrusion at the site by documenting the types of burrowing animals or insects that have been observed in the site vicinity or could potentially inhabit the site in the future. For instance, a burrowing example (assumed to be at the site), is shown on page 6 of Attachment 2 of the Post Construction Monitoring Plan report. This discussion should include information on deepest depths and volumes of burrows they might be expected to excavate, and maximum rock sizes that have been shown to deter such burrowing by these animals at other sites (if available). The impact of deep-rooted plants (i.e., invasive species or proposed ET cover species) over the service life of the cover should also be considered in this discussion; as shown in Table 1, several of the plant species proposed for the ET cover have maximum rooting depths that could damage the radon barrier and potentially exceed the depth to the tailings, which are located at a depth of ~7-feet.

Table 1. Proposed Seed Mix (from Section 2.01, Bullet E of the Technical Specifications) and Potential Maximum Rooting Depths.

Common Name	Maximum Rooting Depth
Tall Wheatgrass	2.46 ft (Nie et al., 2008) 4.33 ft (Nie et al., 2008)
Basin Wildrye	>6.56 ft (Reynolds and Fraley, 1989)
Russian Wildrye	6-8 ft (nrcs.usda.gov) 8-10 ft (fs.fed.gov) 4.26 ft (Table 5.4 of Hauser, 2009)
Alkaligrass	0.997 – 1.93 ft (mean rooting depth, umces.edu)
Inland Saltgrass	9.02 ft (Young, 2015)
Alkali Sacaton	1.33 ft (minimum, usda.gov)
Galleta Grass	0.98 ft (Peace et al., 2004)
Four-wing saltbush	39.37 ft (Stromberg, 2013) 6.66 ft (Lee and Laurenroth) 1.97 ft (Wallace et al., 1980) 12.86 ft (average; Foxx et al., 1985)

DOE Reply 1:

None of the pictures in the post-construction monitoring plan are from the Crescent Junction site. They are from other sites in other parts of the country. They were

included as examples only. We have improved the conditions against biointrusion compared to the previous design. There was no design criterion for biointrusion in the original design. The rock in the biointrusion layer of the UMTRA cover profile is D50 2-inch diameter and 6-inches thick. The rock in the ET Cover surface admixture layer is D50 2.3-inch diameter (15% larger) and volume is 33% greater (thickness of 8-inches compared to 6-inches). Thus, the ability of the proposed cover design is better able to resist burrowing than the currently approved UMTRA cover profile. Additionally, part of the biointrusion design is not to prevent burrowing, but to discourage it. At similar sites where the rock/soil admixture was installed; burrowing takes placed around the cover but is limited on the cover because burrowing is much easier in adjacent areas without the rock in the soil compared to the cover that contains rock. A Biological Assessment was conducted for both Moab and Crescent Junction as part of the Environmental Impact Statement; however, it is an assessment of threatened and endangered species only. There is no available assessment of other mammals, including burrowing mammals. Therefore, we have only observational evidence which indicates that badgers and prairie dogs are in the area of the Crescent Junction Cell. Badgers are found in the vicinity of prairie dog colonies because that is their primary food source. We have not observed prairie dogs on the top of the cell or the top of the adjacent wedge.

NRC Comment 2:

2. Based on the information regarding the potential for biointrusion at the site, as requested above, justify the removal of the biointrusion rock layer at a depth of 3.5-foot as shown in Figure 1 of Section 1, “Existing Final Cover System." Furthermore, discuss the protective measures (e.g., rock material, adequate soil thickness) that will be incorporated in the cover design to minimize cover degradation from the anticipated burrowing and root penetration. Section 11, “Biointrusion,” states that the “rock/soil admixture layer of 2.3-inch-diameter D50 rock, which composes 30 percent of the volume of this surface layer, will discourage burrowing of small mammals.” However, Albright et al., 2010, referencing Cline et al., 1981, note that prairie dogs and ground squirrels have burrowed more than 200 millimeters into crushed rock layers with a D50 of 60 millimeters or less. They further note that “larger rock would be needed to stop larger animals such as prairie dogs and badgers.”

DOE Reply 2:

The Final Remediation Action Plan states that the biointrusion layer was included to (a) provide positive drainage of any seepage at this depth; (b) provide a capillary barrier to reduce infiltration; (c) prevent burrowing animals; and (d) discourage root intrusion. Each of these objectives are discussed below:

a. The intent of the cover is to prevent percolation into the underlying waste and thus remain as dry as possible and remain in an unsaturated state. Consequently, if saturated seepage occurs, the performance objective has not been satisfied. Therefore, the inclusion of this biointrusion layer to laterally route saturated flow to the perimeter of the cover makes no sense and should never occur.
b. The rock layer was installed with no filter medium above or below it. Thus, the fine-grained soils above the rock layer are free to migrate into the voids in the rock layer. By filling these voids, the effectiveness of a capillary barrier is reduced or

even eliminated. Furthermore, the surface rock armor allows 100% of precipitation to infiltrate into the frost protection soils until the storage capacity of that soil is exceeded and moisture will continue downward into the biointrusion layer whether a capillary barrier exists or not. Moisture will then continue down through this rock layer into the underlying radon barrier soil, and eventually, the waste. This is confirmed via current monitoring practice at the site with the vertical stand pipe placed where saturated conditions deep in the cover have been identified. This is created by the layering that encourages infiltration and prevents water removal via ET. Consequently, the current cover design is flawed and requires correction which the proposed ET Cover does.

c. There are no specific biointrusion design criteria cited for the disposal cell. The type of burrowing animal that the layer will prevent from burrowing was not cited. There were no design calculations associated with the biointrusion layer. It appears that the biointrusion layer may have been included because it was part of a typical prescriptive cover profile for UMTRA sites rather than a specific need.
d. As previously stated, the biointrusion rock layer has no filter layer above it and thus the fine-grained upper soil is free to move into the pore spaces of the rock layer. Thus, the layer is not likely to prevent root intrusion from passing through it. Furthermore, the existence of this layer creates a capillary barrier with the underlying finer-grained radon barrier. Because the surface layer is allowing 100% infiltration of precipitation, this moisture is migrating down into underlying layers. This moisture has likely passed through the capillary barrier formed by the biointrusion layer over the radon barrier. The moisture cannot move back up as the profile dries due to the reverse effect of the capillary barrier. Thus, the moisture content in the radon barrier is increasing with time. This increased moisture content will attract deep rooted vegetation intrusion when vegetation is established on the cover. The rock armor may have wind-blown sediment deposited in it over time and allow for the establishment of some vegetation. The vegetation will likely be deep, woody rooted plants.
e. Albright et al (2010) states that the inclusion of a compacted clay layer such as the radon barrier is an effective biointrusion layer.
f. The surface rock armor layer and the biointrusion layer are repetitive. That is, they are both 6-inches deep composed of the same size rock. The proposed surface admixture layer that includes an 8-inch-thick layer of rock (D50 2.3") mixed into the surface cover soil has 15% larger rock and 33% more rock volume than the 6-inch rock layer. Furthermore, Abt et al 1988 (NUREG/CR-4651) stated that results of rock mixed with soil are more stable than riprap only.

NRC Comment 3:

3. Discuss the impact of a potentially degraded cover (i.e., resulting from biointrusion) on the performance of the cover including the including the impacts on the radon flux calculations provided in Section 5. “Radon Attenuation.” In addition to unearthing buried waste, burrowing animals and invertebrates can alter physical and hydraulic soil properties that influence erosion and the soil water balance of covers (Albright et al., 2010). Williams et al., (2022) observed that radon fluxes were higher in regions where woody vegetation or aggressive insects had established on select UMTRCA covers. They attributed these higher fluxes to soil structure induced by root activity and insect

burrowing in the radon barrier, as well as higher radon diffusion coefficients associated with lower water saturation in areas influenced by root water update.

DOE Reply 3:

The radon barrier layer was adjusted to a 4-ft thick layer identical to that approved in the original UMTRA cover profile for the site compared to the 3-ft thick radon barrier proposed in the 60% design. Thus, the revised cover profile contains a 4-ft thick radon barrier composed of compacted Mancos shale soil. Albright et al., 2010 states that a rock/soil surface admixture will mitigate erosion. We believe the proposed surface rock/soil admixture provides a better biointrusion layer that the 6-inch layer of rock previously proposed. Refer to the response to comments 7, 8 and 9. We believe that the proposed ET Cover will better encourage shallow, thin-rooted vegetation such as native grasses than the currently approved UMTRA cover profile. Because of layering of the UMTRA cover profile, we believe that the UMTRA cover profile will attract more woody, deep-rooted vegetation than an ET Cover. Mr. Dwyer served as a technical reviewer for the NUREG/CR-7288 "Evaluation of In-Service Radon Barriers over Uranium Mill Tailings Disposal Facilities – Vol. 1 and 2." This document evaluated potential changes in installed radon barriers. Part of the conclusion was that the changes you discuss resulted in hydraulic property changes that were taken into account in the water balance modeling and less so in changes that affect radon flux. The study showed that although there might be isolated changes that affect performance, the overall performance of the radon barrier remains effective with no overall degradation over the full area of the disposal cell cover system.

Comments Related to ET Cover Vegetation

NRC Comment 1:

1. Discuss the ecological basis (e.g., a reference or analog site) for the proposed ET cover seed mix that is shown in the table in Part 2, Section 2.01, Bullet E, of the Technical Specification Report. One of main objectives of cover revegetation is to create a soil environment that is similar to nearby undisturbed areas (i.e., reference areas or analog sites) and establish plant communities that are well adapted to that environment (Albright et al., 2010). The reference area or analog site can also be used to assess the revegetation success of the ET cover. As such, this discussion should include detailed information regarding the native vegetation and soils in nearby undisturbed areas.

DOE Reply 1:

The seed mix was provided by a vegetation expert upon review of native vegetation in the area. Vegetation was shown to be relatively insensitive to the water balance results. Vegetation is not considered in the calculations associated with design of the rock/soil admixture. Thus, there is no critical success criteria for the establishment of vegetation. However, the rock/soil surface admixture has successfully encouraged a healthy stand of native vegetation. Comparisons have shown the admixture produces a better stand of vegetation than undisturbed analog sites in the vicinity of the cover systems. Also refer to reply to *ET Cover Vegetation NRC Comment #2* below.

NRC Comment 2:

2. Provide the following information related to the establishment of cover vegetation:
   a. The revegetation success criteria as well as the ecological basis for the selection of the revegetation criteria.
   b. The time frames for the revegetation target values.
   c. Details regarding how the proposed revegetation success criteria will compare to the reference area of analog site.

DOE Reply 2:

Vegetation is not critical to the design of the cover for either erosion or water balance. Thus, no success criteria have been established. Refer to the graph showing that the annual flux rate estimated for the ET Cover profile without any vegetation is zero (Figure 5). Also refer to the comparison of the PET (demand for water) for the site compared to the precipitation (supply of water) whereby the demand for water is about 6 times greater than the actual supply of water (Figure 6). Thus, a well-designed ET Cover without ponding should produce no percolation with or without vegetation. A graph summarizing modeling results for the modified cover profile with a thinner (16inch) surface admixture is also showed here for information - results show that the PODR is also satisfied within the cover profile depth (Figure 7).

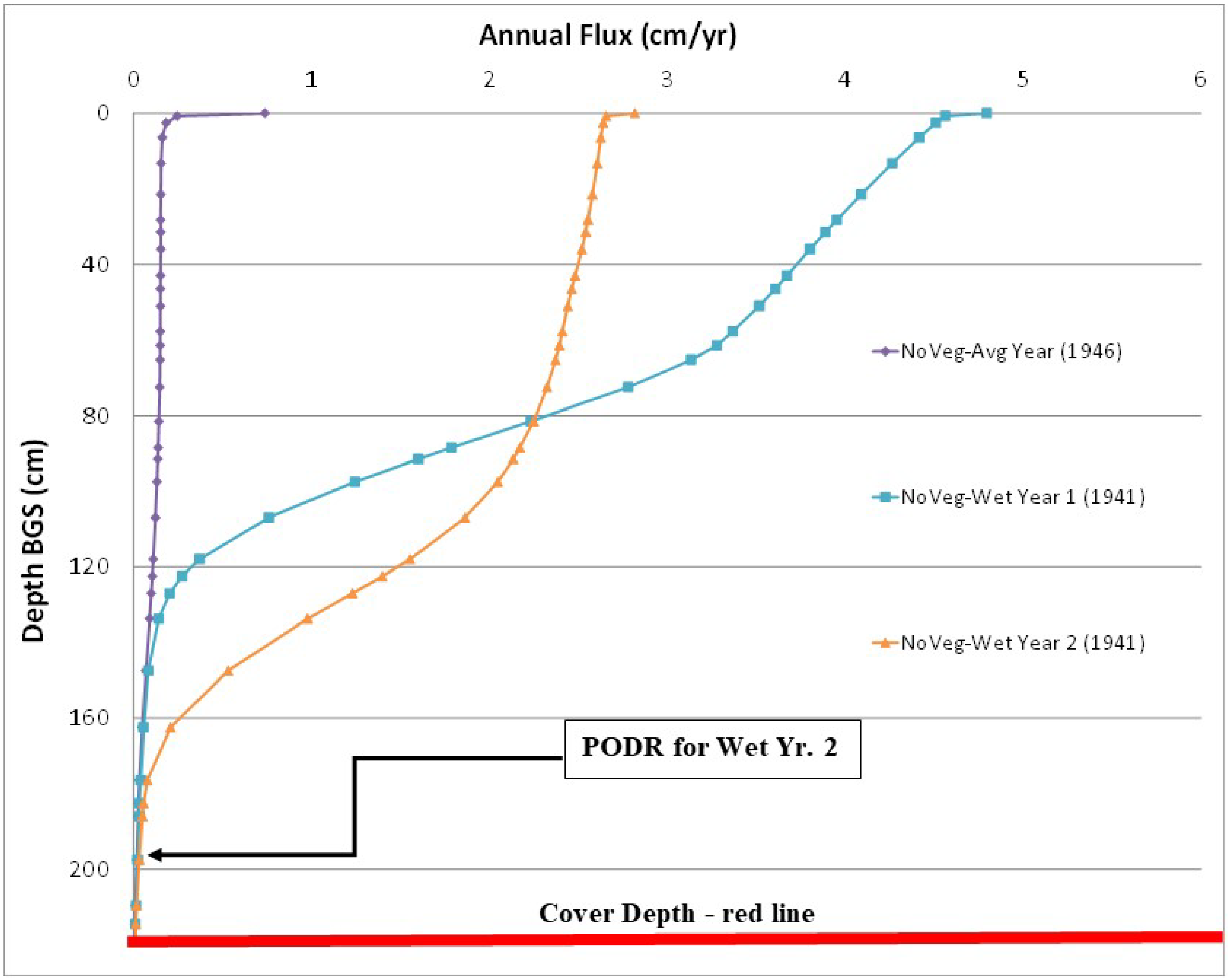

Figure 5. PODR for Profile with 2ft Thick Surface Admixture Layer

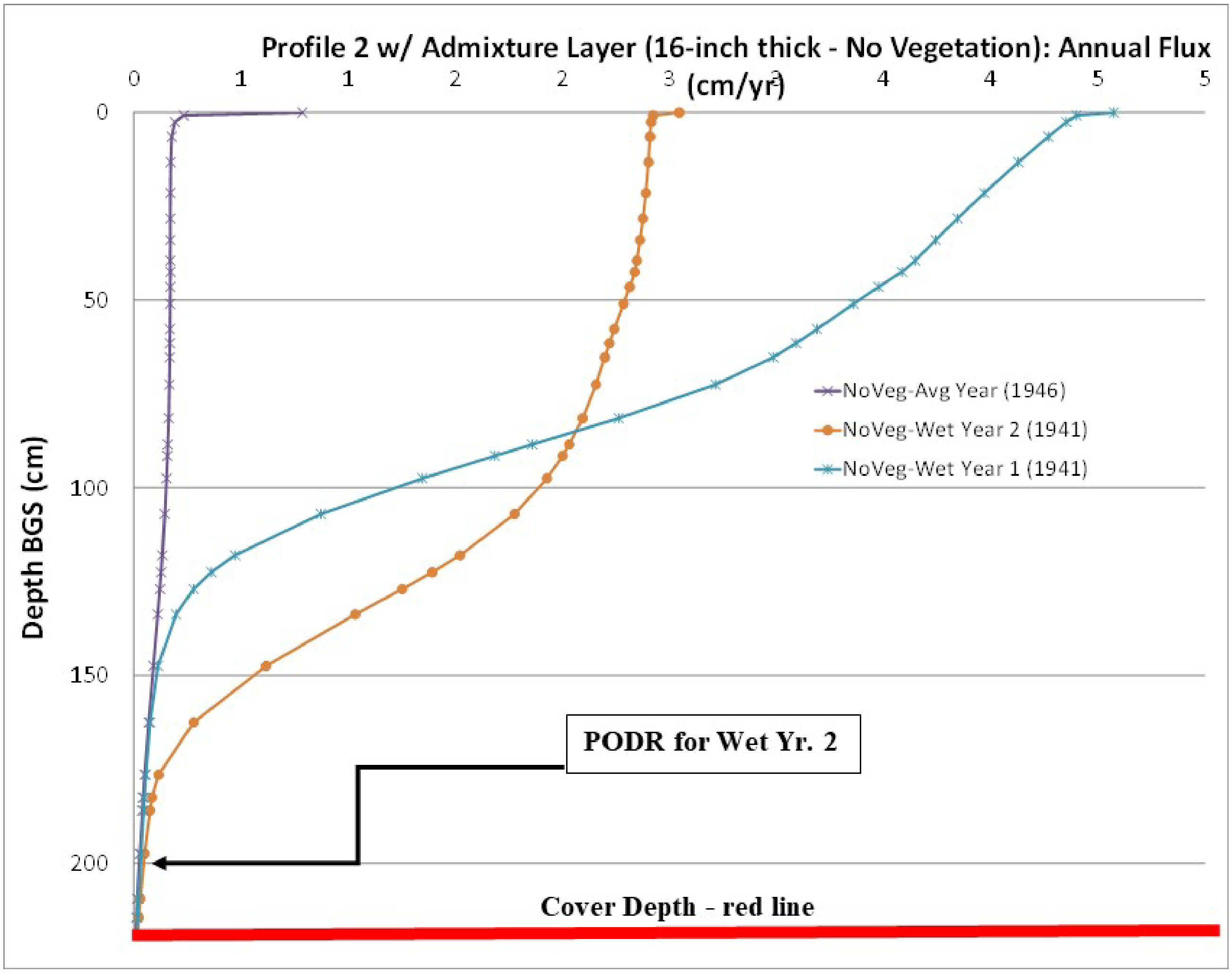

Figure 6. PODR for Profile with 16" Thick Surface Admixture Layer

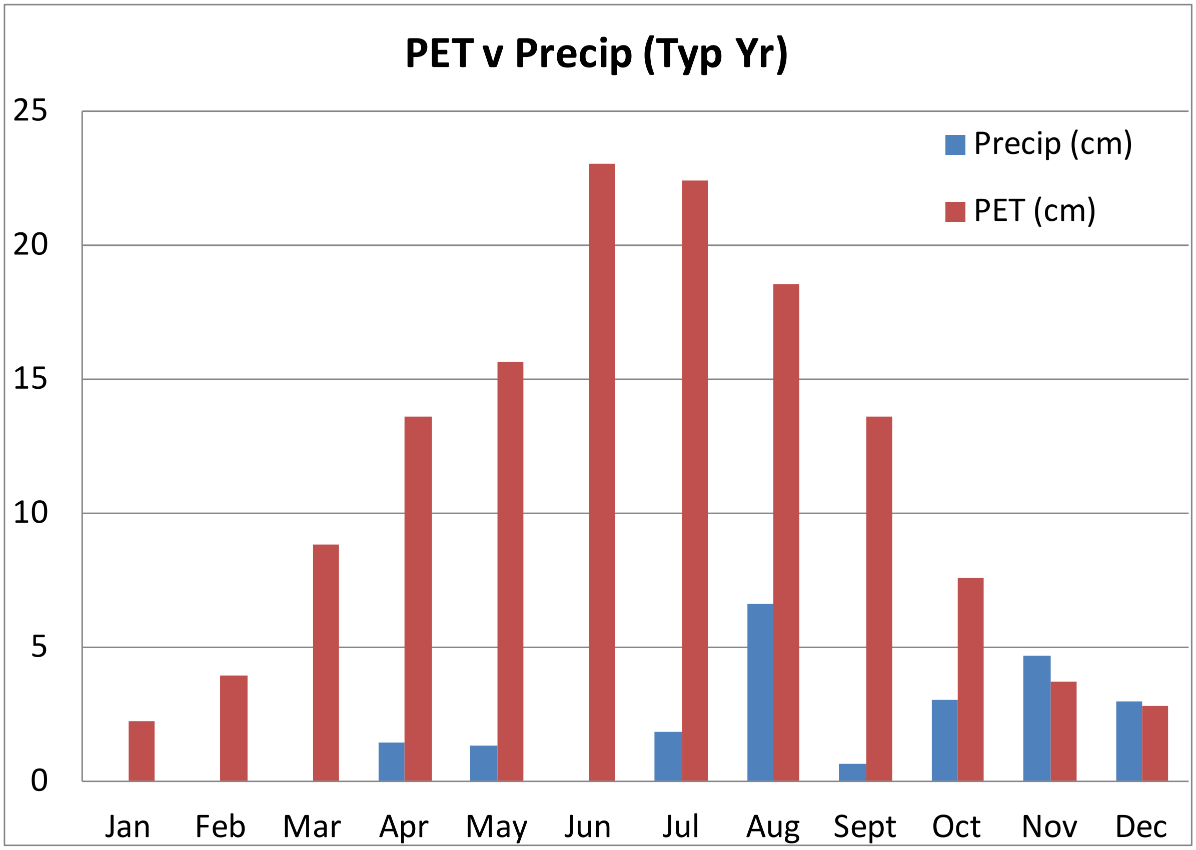

Figure 7. Climate Demand for Water (PET) v. Climate Supply of Water (Precipitation)

Comments Related to Soil Properties

NRC Comment 1:

1. Section 6, "Unsaturated Modeling of Cover System," and Section B.1.2, "UNSAT-H Input Parameters," state that the "input parameters utilized in the computer simulations for the ET cover were developed based on values reported in the Final Remedial Action Plan (FRAP), (DOE, 2008), various literature cited, laboratory analyses (Development Bank of Southern Africa ((DBSA), 2020), and experience." This report should be provided to support the NRC's review of the proposed ET cover soil properties (i.e., DBSA, 2020, Laboratory Report for Dwyer Engineering LLC, Project: Crescent Junction, performed by Daniel B Stephens & Assoc, September 9, 2020).

DOE Reply 1:

Report provided as part of this submittal (Reference, DBS&A Northwind Portage (Crescent Junction) Laboratory Report, 9-9-20).

NRC Comment 2:

2. Section B.1.7, "Soil Properties," states that because varied soil properties were reported in the FRAP (2008), the computer simulations attempted to bound the reported soils. This report is referred in several places in Appendix B. For example,

Table B-3, “Soil Samples Hydraulic Properties,” refers to the FRAP, Attachment 5, Volume 1, Appendix K, Table 1). According to the FRAP, Volumes I and II of the Field and Laboratory Results are provided in Attachment 5 of the Draft RAP and were not submitted with the FRAP. This information should be provided for NRC to review in the context of the proposed ET cover.

DOE Reply 2:

The FRAP Attachment 5 PDF files are too large to email, but they are available at the following online site: https://www.energy.gov/em/moab/crescent-junction-disposal-site

NRC Comment 3:

3. Table B-3, “Soil Samples Hydraulic Properties” refers to alluvium and shales samples from the DOE report “Cover Performance Enhancement Tests at the Grand Junction, Colorado Disposal site: Construction Documentation Material Testing, and Instrument Calibration,” report number LMS/GRJ/SO7112 dated February 2013. Since the hydraulic properties of these samples were used in the water balance modeling sensitivity analyses, this report should be provided for NRC staff to review.

DOE Reply 3:

Report provided -- "Cover Performance Enhancement Tests at the Grand Junction, Colorado, Disposal Site: Construction Documentation, Material Testing, and Instrument Calibration February 2013" in PDF format (Reference, LMS/GRJ/S07112).

NRC Comment 4:

4. As stated in the Section B.1.7, “Soil Properties,” the computer simulations attempted to bound the reported soils due to their variability. Section 2.4 of the Technical Specifications states that: “cover soil to be used with this surface admixture layer shall be tested prior to placement for agronomic properties to determine whether nutrient and/or organic material amendment is required and to what extent.” However, the target soil properties, the appropriate ranges, and the specific borrow source(s) for the ET cover soils should be clearly defined (i.e., in Section 6 and/or Appendix B as well as in the Technical Specifications). Sufficient volumes of available material should also be identified. The specified target properties should include the following: soil pH; organic content, CaCO3 content; nitrogen, potassium, and phosphorous content; electrical conductivity; salt content; cation exchange capacity; clay content (and type); soil texture (U.S. Department of Agriculture (USDA)); particle size distributions and limits; porosity; Atterberg limits; bulk density; moisture content. A reference or analog site1 may be used to help determine the target bulk densities and any necessary soil amendments for the borrow source (Waugh et al., 1994).

DOE Reply 4:

The soil properties required as input parameters for the design of the ET Cover profile specifically for the water balance modeling, erosion, and radon attenuation were provided in the applicable sections. The area the disposal cell is being constructed at serves as the borrow source for the cover soils. There is more than enough available cover soil reinforced by the fact that some of the excavated soil utilized in the diversion wedge located just north of the disposal cell has more soil piled on it than originally

planned due to the excess cut excavations. Agronomic properties of the soil to be used in the cover's surface rock/soil admixture layer will be tested by the contractor for applicable agronomic properties to best determine what amendments the soil will require (if any) to maximize vegetation establishment.

NRC Comment 5:

5. Justify the selection of an alluvial soil with 30 percent rock and a D50 of 2.3-inches for the entire layer thickness of the water storage layer, rather than just the upper portion (i.e., as a gravel mulch layer). Typically, loamy soils are recommended for ET covers and soils containing gravel and rock (i.e., particles larger than 2 mm) may be unsuitable for use in ET cover soil as they can reduce the water holding capacity and dilute the nutrient-supplying capacity of the soil (Hauser, 2009). ET cover guidance developed by the State of Colorado (Colorado Department of Public Health and Environment (CDPHE), 2013) recommends that the soil used for the cover contain less than or equal to 15 percent gravel (i.e., greater than 2 mm, retained on the No. 10 sieve) in addition to limiting the maximum particle size to less than 2-inches in the longest dimension. One of main objectives of cover revegetation is to create a soil environment that is similar to nearby undisturbed areas (reference areas or analog sites) and establish plant communities that are well adapted to that environment (Albright et al., 2010). As such, an appropriate reference area or analog site can also be used to assess the suitability of the proposed ET cover soils.

DOE Reply 5:

The soil comes from on-site excavations. The cover soils are loam soils: generally classified as silt loam, sandy loam, or silty clay loam. The cover design was based on the measured values of these local soils. The provided design analyses demonstrated that the local soils meet the applicable criteria. The CDPHE guidance document recommends an ET Cover profile 2.5ft thick for the region adjacent to the Crescent Junction site. The Crescent Junction proposed ET cover is almost 3 times that thick. Without exception, every deployment of a cover system utilizing the rock/soil admixture surface layer has produced a better stand of native vegetation than undisturbed areas in the vicinity or its natural analog counterpart. Albright et al., 2010 states that a surface rock/soil admixture is effective at reducing erosion.

NRC Comment 6:

6. Provide the basis for the porosity values in listed in Table 4, “Radon Flux Calculations Summary,” in Section 5, “Radon Attenuation,” and discuss these values with respect to the saturated water contents provided in Table B-3. In Table 4, the porosity of the top layer (Admixture) is 0.27, while the porosity of Mancos Shale soil layer is 0.31. In Table B-3, “Soil Samples Hydraulic Properties,” the saturated water contents listed for the top layer and radon barrier are higher than the porosities shown in Table 4. For example, the saturated water contents of the existing radon barrier samples 5 and 6 are 0.4171 and 0.4203, respectively, while the reported values for shale from TP154 and the Grand Junction site are 0.4803 and 0.38, respectively. The saturated water content of alluvium samples range from 0.3584 to 0.42. The saturated water content should not be larger than the porosity since water can only fill the pore space. Furthermore, discuss how using higher porosity values would impact the

calculated exit radon fluxes that are provided in Table 4.

DOE Reply 6:

The radon barrier layer is the same thickness as that of the previously approved cover profile. The potential change in properties in the upper portion due to freeze/thaw conditions was included in the design calculations and shown to be adequate to meet the applicable regulation and performance criterion. The soil properties used were from the previously approved borrow source investigation.

NRC Comment 7:

7. Section 3.07 (C) of the Technical Specifications states that, for the surface admixture cover soil, the compacted soil density is to be 90 percent of the maximum dry density as determined by American Society for Testing and Materials (ASTM) D698 and that the tolerance for this placement density is plus or minus 5 pcf. However, CDPHE (2013) notes that “for most soil textures, the growth-limiting bulk density is in the range of about 83 to 88 percent of the maximum standard Proctor density (ASTM, D698).” Justification for specifying a compacted soil density at the upper end of the recommended range should be provided. Details regarding the placement specifications of this layer to prevent over-compaction should also be provided. For instance, CDPHE, 2013 and Interstate Technology Regulatory Council, 2003 recommend placing cover soil in relatively thick lifts (i.e., 18-inches to 2-foot) to control compaction along with the use of low-ground-pressure equipment during soil placement.

DOE Reply 7:

The surface admixture layer will have a demonstration plot to determine lift thickness and placement techniques. Placement of surface admixtures at a relative density of 90% of maximum dry density (MDD) has been shown to be successful at similar projects in similar climates. The 90% of MDD is within the recommended cover soil density range for an ET Cover per the CDPHE (2013). The growth-limiting bulk densities are from USDA publications and are directed toward agriculture crops, not native species intended for deployment on cover systems such as grasses. Furthermore, the natural or in situ bulk density of soils tends to be about 90% of the MDD (ASTM D698). Thus, this is a natural density for the establishment of the intended vegetation on the cover surface.

Comments Related to Water Balance Modeling

NRC Comment 1:

1. Provide a detailed discussion of the performance objectives of the ET cover. This discussion should specify the ET cover design percolation rate (i.e., percolation from the base of the cover), the basis for the selection of this rate, and how the ET cover will be monitored in the short-term to ensure that it performs as designed. The NRC staff recognizes Crescent Junction is a relatively dry site, but understanding the design percolation rate may help inform any monitoring needs.

DOE Reply 1:

See response to *NRC Comment on Geotechnical Stability #1* and *NRC Comment on ET Cover Vegetation #2.*

NRC Comment 2:

2. Section B.1.7, “Soil Properties,” notes that the computer simulations attempted to bound the reported soils and used “worst-case” soils. What are the implications of these “worst-case” soils on the vegetation success and how vegetation is modeled in the computer simulations? In other words, can credit be taken for the selected vegetation-related parameters as described in Sections B.1.5, “Vegetation Data” and B.1.6, “Soil Properties Related to Vegetation.”

DOE Reply 2:

See response to *NRC Comment on Geotechnical Stability #1* and *NRC Comment on ET Cover Vegetation #2.*

NRC Comment 3:

3. Section B.1.5, “Vegetation Data,” states that measured vegetation parameters are not available for the Crescent Junction sites and that vegetation parameters utilized in the simulations are based on those obtained from the Northeast Church Rock, NM site (Cedar Creek, 2014). Although corrections are applied to account for the observed reduced vegetation surface coverage, justification for the reliance on the Northeast Church Rock site for vegetation parameters (including vegetation succession) should be provided since the Crescent Junction site is approximately 300 miles to the northwest of the Northeast Church Rock site. Supporting information should include a detailed comparison of the soils and native vegetation between the Church Rock Mill site and the Crescent Junction site. However, given that the distance between these two sites is substantial, vegetation parameters should ideally be obtained from a reference site that is similar to the Crescent Junction site and borrow source areas (or a similar nearby undisturbed area).

DOE Reply 3:

See response to *NRC Comment on Geotechnical Stability #1* and *NRC Comment on ET Cover Vegetation #2.*

NRC Comment 4:

4. The potential impacts of climate change on the ET cover vegetation should be considered. For example, potential drought conditions on the performance of the ET cover, associated with a significant amount of vegetation dieback, and followed by extreme precipitation events.

DOE Reply 4:

The worst-case scenario for water balance modeling, resulting in the deepest PODR, is produced by wet conditions. It was demonstrated that "beyond worst case" conditions will not produce percolation given the proposed ET Cover profile. It was demonstrated that change in vegetation did not have a significant impact on the results. If the climate gets hotter and drier, the water balance is not an issue; and the erosion deterrence included in the design will work to mitigate soil loss.

NRC Comment 5:

5. Is the monthly distribution of precipitation, shown in Figure B-2 and Figure B-3 based on data?

DOE Reply 5:

Figure B-2 is based on actual data from Thompson Springs, Utah (1946) – it states this in the figure caption.

National Environmental Policy Act

NRC Comment 1:

1. Staff appreciates understanding DOE-EM's approach to the National Environmental Policy Act (NEPA) with this revision to the RAP for Moab as it will inform the NRC's approach going forward. Staff has not made any decisions on how it plans to comply with NEPA for this action at this time.

DOE Reply 1:

DOE proposes using the DOE Categorical Exclusion (CX) List to satisfy NEPA requirements for the redesigned cell cover. The relevant CX numbers are B6.1 (e) and B6.1 (h).