



September 15, 2010
File No.: 83088.4.4-ALB10LT001

Mr. Frank Filas
Energy Fuels Resources
44 Union, Suite 600
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SUBJECT: Responses to CDPHE RFI 2 Comments of Tailing Cover Design

Dear Mr. Filas:

The following discussions and additional information are hereby submitted in response to CDPHE's Response for Additional Information #2, dated May 25, 2010 and related specifically to tailing cover design. The CDPHE comments are repeated below in italics, followed by Kleinfelder's (KLF's) response in regular font. The revised Tailing Cell Closure Design Report, 83088.5.U2-ALB08WP001 Rev. 1, is submitted with this letter, as well.

Response to comments on RADON BARRIER

As currently planned, the proposed radon barrier will consist of 4.6 to 7.0 feet of "compacted native soil". The native soil has been classified according to the Unified Soil Classification System (USCS) as predominantly silt (ML), silty sand (SM), and well-graded sand (SW) with some sandy clay (CL) and clayey sand (SC) lenses. According to Table C-4-1 (Appendix C-4, Geotechnical Investigation, Volume 4), undisturbed hydraulic conductivity testing showed values of this material ranging from 5.9×10^{-4} cm/sec to 3.4×10^{-5} cm/sec. This range of hydraulic conductivities is not conducive to forming a low permeability barrier. A low permeable barrier must have a hydraulic conductivity of 1.0×10^{-7} cm/sec or less. A low permeability barrier is required to meet one of the project's stated Design Objectives (Tailings Cell Closure Design Report, Section 3.0, page 2, 3rd bullet: "Limit infiltration of moisture into, and release of contaminated liquid from, the tailings.") as well as meet the requirements of NRC (2003)¹ guidance.

The radon barrier is not designed to be a low permeability (infiltration) barrier but rather a barrier that, in combination with the water balance or evapo-transpiration (ET) cover layers, provides attenuation of radon to achieve the limit of 20 pCi/m²/s. In the ET cover approach, the layers above the radon barrier form the infiltration barrier. The ET cover is not intended to be impermeable as presently designed but to balance infiltration rates with evapo-transpiration rates. The two primary cover components, the radon barrier and the ET cover, work together to 1) limit the flux of radon from the cover surface and 2) limit infiltration of water from ground surface to the tailings.

KLF prepared the tailing cover design assuming that the NRC, and in turn the CDPHE, would not give credit for any synthetic materials used in the cover system in estimating long-term



performance (both as an infiltration barrier and as a radon barrier), based on the precedence of UMTRA Title I/II closure designs. CDPHE has indicated that it believes, based on recent research by Stormont, Benson and others, that geosynthetics can be used. Therefore, Kleinfelder has revised the tailing cover design to reflect this; a geosynthetic liner, a geomembrane-supported geosynthetic clay liner, has been added with the radon barrier to provide an additional barrier to both radon leaving the impoundment and water infiltration into the tailings.

In the RADON model of the revised design, the geosynthetic liner was positioned between the interim cover and the radon barrier, simplifying the model by simulating the radon barrier as one layer rather than two layers separated by the geosynthetic liner. In practice, the location of the geosynthetic liner above, below or within the radon barrier has no significant impact on either radon flux from the cover surface or infiltration to the tailings. The revised design will position the geosynthetic liner 1.0 foot below the top of the radon barrier, mirroring the shape of the top surface of the tailing cell cover.

Response to comments on CAPILLARY BREAK

First, the source of the CBDL is unknown, and has been described differently in the license application. According to Section 4.3.1 of the Tailings Cell Closure Design Report (Exhibit K2, Volume 13) the CBDL will be imported from an off-site source. However, within the radon barrier thickness calculation (Appendix B of Tailings Closure Plan, item 3 under the 4th bullet on page 8), the capillary break material will be from "... recycled base course (No.2 and No.6) from reclaimed pads and roads on site (additional material may also be imported)". This is not acceptable for use as capillary break material. All material designed for use as a capillary break must have a specified gradation in order to assure that the contrast in pore sizes that are necessary to form the capillary break have been attained.

The source of granular materials (clean sand up to cobble size) has not been selected because the time for closure is years away. Local sources have been identified, but these might not be in business or able to provide the specified material at that later date. The material specifications have been prepared and included in the design, and one or more vendors will be contracted based in part on their ability to provide the volume of materials that meet the QC requirements. These requirements include gradation that will meet those needed for the capillary break layer and the filter layer. Some of this material may be reclaimed base course (previously imported from an off-site source) but would, of course, have to be uncontaminated and properly screened and sized to meet the specification before being re-used in the capillary break.

The revised cover design eliminates the "drainage layer" and places the bio-intrusion barrier immediately below the capillary break. In the unlikely (based on revised UNSAT-H modeling results) event that saturation begins to develop in the bio-intrusion/ capillary break zone, its hydraulic conductivity would be high enough to effectively drain this excess moisture to the outer edges of the tailing cell, away from the tailings.

Column tests of the selected gradations can be performed to verify that a capillary break can be created using these materials. Such tests would logically be conducted prior to the field tests; results of the column tests would be used in refining the design of the field test. The field test,



described in the original design submittal, will provide an opportunity to quantify the cover system components, including the capillary break, under actual field conditions.

Response to comments on FILTER LAYER

The stated design criteria of the filter layer is to work in combination with the CBDL and limit infiltration as well as prevent migration of soil fines into the CBDL in order to preserve the capillary break effect. Given the discussion above for the CBDL, the overall usefulness of this layer is questionable. Pending further discussion, this layer may not be required in the cover system.

The filter layer has been removed from the cover design. Instead, the capillary break sand material will be sized to meet the filter criteria to prevent fines migration out of the vegetative cover in the unlikely event of saturation. See section 4.3.1 of the Revision 1 of the cover design report.

Response to comments on BIO-INTRUSION BARRIER

The biota-intrusion barrier is currently designed to be 1-ft of native soil matrix with 3-in cobbles. It is stated that "The cobbles will be placed so that they overlap within the soil matrix". This description is confusing and no technical basis has been provided. How the 3-in cobbles will be overlapped as well as how it will be quality assured has not been discussed. A specific gradation has not been provided. It seems that if the cobbles are not adequately distributed, the material will appear similar to the native soil above and will not discourage burrowing animals. Note that at the Monticello site, the biota-intrusion barrier is described as "cobbles filled with soil", and not a soil matrix with cobbles.

The term "cobbles filled with soil" accurately describes this layer, and the text of Revision 1 of the cover design report has been revised accordingly. As described in Revision 1 of the cover design report, the bio-intrusion layer of cobbles will be overlain by the capillary break material, some of which will fill and effectively choke the voids in nominal 3-inch cobbles layers to provide not only an effective barrier to deep root penetration and burrowing animals but also an effective drainage layer for moisture that might reach that depth. The revised closure plan specifications will provide additional details for constructing the bio-intrusion barrier.

Response to comments on NATIVE SOIL

*As you know, the native soil layer must act as the "sponge" layer that stores moisture during periods when plants are dormant (e.g., winter) and then allows the plants to transpire the moisture out of the cover during active growing seasons (e.g., summer). In addition, the layer must have adequate thickness to support vegetative root growth. The native soil layer is sometimes described as the "vegetative growth layer" or "root zone layer". For the vegetative species planned for this project (assumed to be the mix shown in Attachment F to Attachment B, Kleinfelder Memorandum, page F-5), several species are described in the literature as having root depths greater than the currently planned 2-ft. For example, Reynolds and Fraley (1989)^{vii} state: "Roots of Indian ricegrass (*Oryzopsis hymenoides*) and standard crested wheatgrass were both found to depths of 150 cm (~5 -ft). Benson (2008)^{viii} points out that another species of Indian ricegrass, *Achnatherum hymenoides*, has*



*a rooting depth greater than 3-ft. Reynolds and Fraley (1989) also state that Squirreltail bottlebrush (*Elymus elymoides*) roots were found in their study to a depth of 100 cm (3.3-ft), and actually may have deeper roots. The above does not represent an all exhaustive root-depth search for the various vegetative species proposed.*

Based on past experience in Colorado with landfill caps that have used a water balance "alternative cover" approach, a nominal thickness of 4-ft for the water storage layer is the minimum thickness that should be planned, even if numerical modeling suggests that a thinner cover is capable of the required water storage capacity. This was also the approach used for design of the water balance covers at RMA and Ft. Carson. A conservative design is required for both vegetation and water storage reasons to account for uncertainties that cannot be modeled. Note that for the Monticello, UT repository, which is geographically closer to Piñon Ridge than then the Front Range sites, a water storage layer depth of 163 cm (5.3-ft) was used.

The cover design has been revised to include 4.0 feet of native soil as the vegetative cover. The rock mulch zone (rock mixed into the top 0.5 feet of the vegetative cover for erosion protection) has been retained. The seed mix will be adjusted in the revised closure specifications to species that have root penetration generally limited to the upper 3.0 feet of soil. Both Benson et al (2010) and McGuire et al (2009) indicate that vegetative covers of 3.0 feet or more had little root penetration below 3.0 feet and can be expected to limit infiltration rates to 0.4 mm/year over a 5 year period.

Specific Comments - Tailings Closure Plan

In addition to the more general concerns discussed above, we have found specific items related to the cover design analysis that need to be clarified. These are detailed below.

1. Section 4.3.1, Radon Barrier, pg 6 - The last paragraph of this section generally describes the method for radon barrier placement. There is no discussion, however, on raising the moisture content of the natural soils to the required $\pm 2\%$ optimum moisture content (OMC). According to EPA (1993)^{ix}, if the water content of a barrier layer soil is to be increased by more than 3 percentage points, at least 24 to 48 hours should be required for uniform absorption of water and hydration of soil particles. According to Table 1 of the Phase 2 Geotechnical Field and Laboratory Test Program (Volume 4), the in-place moisture content averaged about 4.5%, however, the OMC averaged about 12.2%. Therefore, the moisture content of the soils for the radon barrier will need to be raised about 7.7%. Provisions should be made for allowing adequate time for moisture conditioning as recommended by EPA. In addition, the water quantity needed for soil processing will be significant, and should be taken into account for overall planning purposes.

The specification for this earthwork requires moisture conditioning to +/- 2% of OMC, per standard practice. This will bring the soil moisture to the 12-13% range. The time required for this varies and will be addressed in the revised closure specifications.

2. Section 4.3.1, Capillary Break/Drainage Layer, pg 7 - The last paragraph of this section states that the CBDL will limit root penetration into the radon barrier because soil moisture will be concentrated in the CBDL rather than the drier radon barrier. We



disagree with this concept. As discussed above, the proposed radon barrier material OMC averaged about 12.2%. In addition, the estimated long-term gravimetric moisture content and long-term volumetric moisture content of the radon barrier material were both assumed to be 13% (Attachment B, Radon Barrier Cover Thickness Design, Section 4.2.6, page 15). When water is theoretically "draining" through this layer, the soil above in the "native soil" layer is assumed to be saturated, so the plants will obviously have adequate moisture. However, during drought or dry conditions, it is assumed that the CBDL will be dry or at least have a moisture content less than the OMC. According to standard design charts such as the U.S. Bureau of Reclamation (1987)^x, the average OMC of GW or GP material is about 11%. Therefore, we conclude that the long-term radon barrier moisture content (assumed ~ 13%) will be greater than the long-term CBDL moisture content, and the soil moisture will not be concentrated in the CBDL.

The intention of this paragraph was to state that moisture reaching the CBDL would be rapidly drained away and would not remain there to be available to roots. The confusion of meaning apparently comes from the wording "by concentrating available soil moisture". The revised UNSAT-H modeling indicates that moisture content in the vegetative cover will not reach saturation and, therefore will not cause the head to exceed the air-entry pressure for this layer as might be expected if saturated conditions in the vegetative cover were to occur. The drainage layer has been eliminated from the cover design, and the report text has been revised to clarify the function of the capillary break under both normal and unlikely extreme conditions.

3. Section 4.3.1, Erosion Barrier/Vegetative Cover, pg 8 -The fifth paragraph discusses vegetation mix. This is a different mix than that shown in Attachment F to Attachment B, Kleinfelder Memorandum, page F-S. The proposed seeding should be clarified and made consistent between this section and the Kleinfelder memo. The percentages as well as the actual species name (in addition to common name) should be provided to eliminate confusion. For example, it is not known which of the two species of Indian ricegrass (as discussed in the Native Soil general comment above) is planned for use.

A table of seed mixes recommended by the NRCS and the Colorado Division of Wildlife will be included in the revised closure specifications.

4. Section 4.3.2, Modeling Results, pg 12 - The climate set used for the modeling, as described in this section, was the data for the years between 1999 and 2007. Although this is recent chronologic data, it is not necessarily a conservative assumption, because it is unknown whether this time period was a wet, dry, or average time period. In lieu of using the entire record, Benson (2008) suggests that the climate set for water balance cover modeling consist of one of the following: 1) wettest year on record repeated sequentially to simulate a prolonged wet period; 2) wettest 10 year period; or 3) year with highest precipitation/potential evapotranspiration (P/PET) ratio. Alternative 3 was used for modeling the covers at RMA, with the year 1983 selected because it had an unusually high potential for deep percolation.



The 46-year meteorological record at the Uravan station used by Golder in their water balance for tailing cell design lacked some parameters needed for the original UNSAT-H infiltration modeling. Therefore, Kleinfelder ran the revised UNSAT-H model assuming very conservative (high) estimates of infiltration over five consecutive years, in an attempt to simulate Benson's (2008) #1 scenario. The modeling is described in Attachment D of the revised cover design report.

5. Section 5.3.3, ET Cover Construction, pg 19 - The last paragraph states that rock mulch will be mechanically mixed into the soil of the final lift. This procedure, as minimally described, appears to be incompatible with maintaining a low density soil layer. The low density layer is required to optimize root growth in the native soil layer. However, the use of heavy equipment to "mechanically mix" the rock mulch will clearly increase the soil density above the stated placement specification (according to pg 8, maximum 85% standard Proctor density). Once the native soil mass has been placed and graded, no traffic, particularly wheeled equipment (e.g., haul truck, pickup truck, scraper, loader, etc.) should be allowed on the cover. The mixing of gravels into the native soil should be planned as an operation outside of the cover footprint and placed with low ground pressure equipment.

The amount and size of rock in the top lift is driven by the resistance to erosion from runoff, as described in Attachment C of the design report. Mixing the rock with soil off-site can be done, but size separation can occur during transport. 85% density is relatively light and usually occurs with tracking by dozer. Light scarification could also be used to loosen the surface prior to seeding. Mixing and placement of the rock mulch will be addressed in more detail in the revised closure specification.

6. Section 6.1 .2, Field Test of Cover Design, pg 22 - a) The second paragraph discusses the establishment of a test cover with vegetation but using soil amendments that would not be used on the full-scale cover. This would be used to assess the effects of vegetation on the cover. It is our understanding that the use of amendments could change the nature of the vegetation compared to non-amended areas (e.g., rate, type, quantity, etc.). The test cover should emulate the full-scale cover to the maximum extent possible; therefore, the use of amendments on the test cover only should not be done if the results are to be applied to the full-scale cover.

b) The third paragraph discusses the use of ceramic cup lysimeters. The Division recommends the use of Alternative Cover Assessment Project (ACAP)-style pan lysimeters instead. Additional references and information concerning this type of lysimeter can be provided upon request.

Soil amendments were intended only to accelerate the field test and reduce the time needed to assess soil hydrologic parameters. No amendments were expected to be necessary for the actual cover. Amendments will be eliminated from the field test of the cover design. ACAP-style pan lysimeters or equivalent will be used instead of ceramic cup lysimeters.



Attachment B - Radon Barrier Cover Thickness Design

*7. Section 2.3, Assumptions, page 8, 4th bullet, number 5 - This item states that the erosion/vegetative cover will be placed in 6 to 8-in lifts and compacted to 85% standard Proctor dry density. Based on past experience, the Division recommends that, for water balance covers, a full-thickness mass of soil be placed rather than several thinner lifts for this layer. The primary concern with constructing water balance covers with respect to density typically involves compacting the vegetative growth soil **greater** than their Growth Limiting Bulk Density (GLBD), thereby limiting root growth, as described by Goldsmith and others (2001)^{xi}. From a geotechnical engineering perspective, a simple solution to limit compaction density is to increase the lift thickness and require the specified moisture content to be less than the soil's optimum moisture content. A full-thickness soil lift technique was used successfully at RMA with minimal failing density tests during construction.*

Lower density and moisture content of the vegetative cover would reduce its role in radon attenuation, causing an increase in the radon barrier layer thickness; however, this concern is lessened by the addition of the geosynthetic liner to the cover system. One or more lifts placed without deliberate compaction or moisture control can be evaluated in the field test of the cover. A full-thickness mass of soil placement will be included in the revised closure specifications.

8. Section 4.2.6, page 15, Estimated Long-term Gravimetric Moisture Content of Radon Barrier - This parameter is stated to be 13% and discussed in Section 2.3. Section 2.3 states that this parameter was based on the Kleinfelder Memo in Attachment F. The Kleinfelder Memo in Attachment F is based on a literature search, and not on actual sampling and testing of soils proposed for use. Specifically, the water content (at 15 bar) for the Kleinfelder Memo was based on a USDA Soil Survey of the area, using the Mikim Loam generic description for the input parameter. The Division recommends that actual soil data be used to determine this parameter. In particular, three soil samples were tested for hydraulic characteristics and soil water characteristic curves (SWCC) were generated (Phase 2 Geotechnical Investigation, Appendix C-7). From these curves, the 15-bar volumetric water content can be directly determined, then converted to the required gravimetric water content. Another technique is to directly read (or calculate) the wilting point on the SWCC, using the curve's inflection point as the wilting point indicator. At any rate, site-specific data is always preferred relative to data gathered from large-scale sources such as USDA reports.

The SWCC values for the native soil have been incorporated into the revised RADON model (Attachment C of the design report, Revision 1) for the moisture content in the radon barrier.

Response to comments on Attachment D - Cover Infiltration Analysis

9. Leaf Area Index (LAI) - The memo in this attachment states that the LAI was based on the Kleinfelder memo of August 2008. The Kleinfelder memo of August 2008 is assumed to be the one contained in Attachment F to Attachment B to the Tailings Cell Closure Design Report. As discussed above, the Kleinfelder memo in Attachment F to Attachment B is based on a literature search, and not on an actual field investigation. The LAI values are significantly overstated, and do not represent a conservative assumption. In particular, a LAI of 3 is not feasible given the climate and expected



vegetative conditions. In contrast, cover modeling at RMA used a maximum LAI of 0.45. At the Monticello site, measured LAI after cover construction and vegetation establishment ranged up to 0.85 maximum. The model for this cover should be rerun using a more realistic LAI for input. It may also be helpful to run a "sensitivity analysis" using a range of LA I inputs.

The LAI values shown on page F-10 of the referenced attachment were not used in the cover design calculations. The table was included, for information only, to show that LAI values vary seasonally. We concur that the LAI for the vegetation cover is lower than the listed maximum value of 3 (see page F-6), and likely has an effective year-long LAI of <0.5. For modeling of infiltration, Kleinfelder assumed a value of 0.35.

10. Table 1, van Genuchten Parameter α - The value used for " α " for the capillary break layer is shown as 2.41, which, the Division understands, is physically impossible. By definition, α must [be] less than one. Typical values of α ranged from about 0.0005 to 0.005 for compacted clays to about 0.01 to <1 for clean sand with little fines. The values for α should be checked and changed where appropriate.

The UNSAT-H calculation in Attachment D provides reference for the α values. Alpha values of greater than 2.0 for coarse grained soils are supported by research, including that of John Stormont, to whom we spoke directly on this question. Professor John Stormont teaches and conducts research at the University of New Mexico in geo-environmental engineering and is a recognized expert in the application of geotechnical and hydrologic engineering to environmental problems. He specializes in waste containment facilities for landfills and mine waste dumps and the use of geosynthetics for stabilization and drainage of soil.

Please contact me with any questions.

Respectfully submitted,

KLEINFELDER WEST, INC.

A handwritten signature in black ink, appearing to read "Alan K. Kuhn". The signature is fluid and cursive.

Alan K. Kuhn
Senior Principal Consultant