UTAH DIVISION OF RADIATION CONTROL
DENISON MINES (USA) CORP.
WHITE MESA MILL; BLANDING, UTAH;
CELL 4A LINING SYSTEM

INTERROGATORIES – ROUND 7

TABLE OF CONTENTS

Acronyms and Abbreviations

BAT	Best Available Technology
CFR	Code of Federal Regulations
CQA	Construction Quality Assurance
DR	Design Report
DRC	Division of Radiation Control (Utah)
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
TDS	Total Dissolved Solids

Summary of Requested Items

Please refer to the interrogatories for the context of the item requests.

1. The Division still awaits receipt of a Radiation Survey Report to demonstrate that the existing subgrade for Cell 4A has radiation and contamination levels that are acceptable.
2. Minor revisions and clarifications to the technical specifications and CQA Plan to address minimum thickness of soil subgrade under the cell liner, soil compaction lift thickness, and soil material testing requirements.
3. The proposed GCL field hydration plan shall include the requirement that the GCL testing continue until hydration levels is 140% or greater. As an alternative to the demonstration that the GCL will reach the desired hydration levels, 2-feet of compacted clay can be placed and compacted in the bottom and on the side slopes of the cell (in place of the GCL). In addition, there are a few clarifications on the revised field hydration plan that need to be addressed.
4. Cell 4A slimes drain design needs to include a drainage layer over the strip drains that will have the ability to drain the tailings solution in a timely manner. The use of a drainage layer over the strip drains needs to be included in the demonstration of the effectiveness of the slimes drainage system. In addition there are a few clarifications on the demonstration provided that need to be addressed.

INTERROGATORY DMC R313-24-4-01/05: RADIATION SURVEY AND RELATED DEMONSTRATIONS

PRELIMINARY FINDING:

Refer to R313-24-1(3), R313-24-4, R313-15-501, R313-15-406, and 10 CFR 40 Appendix A, Criterion 5A(1); DRC rules require that a radiation survey be performed to demonstrate that the requirements of R313-15 are met, including the magnitude and extent of radiation levels and concentrations or quantities of radioactive material (see R313-15-501). DRC rules also require DMC to describe "… how facility design and procedures for operation will minimize, to the extent practicable, contamination of the facility and the environment,…" (see R313-15-406). R313-24-4 and 10 CFR 40 Appendix A, Criterion 5A(1) require that for uranium tailings impoundments where wastes have migrated into the liner during the active life of the facility, that closure of said impoundment must include "…removal or decontamination of all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate."

Refer to R317-6-6.3(Q); "Unless otherwise determined by the Executive Secretary, the application for a permit to discharge wastes or pollutants to ground water shall include the following complete information:… Q. Other information required by the Executive Secretary."

Also refer to R317-6-6.4(A); DMC must provide information that allows the Executive Secretary to determine:…"3. the applicant is using best available technology to minimize the discharge of any pollutant;…".

INTERROGATORY STATEMENT:

This interrogatory is now being addressed under a separate cover.

BASIS FOR INTERROGATORY:

DMC provided to the DRC a report from SENES Consulting (via a transmittal letter dated September 1, 2006) that addressed the radiation levels in Cell 4A subgrade. DRC comments to this report were provided to DMC in an email from Mr. John Hultquist dated 9/15/06. In addition, DMC has communicated that the confirmation sampling of the clean up effort on Cell 4A is complete, and the results and analysis will be submitted to the DRC.

This issue is now being addressed under a separate cover. However, prior to the start of Cell 4A liner installation a final report must be submitted to, and approved by, the DRC that includes data and a demonstration that the existing cell liner subgrade has radiation and contamination levels that are acceptable.

REFERENCES:

Letter from DMC to UDRC dated May 8, 2006; Re: Cell 4A Lining System Design Report, Response to URS Completeness Review,

October 18, 2005 DRC letter to DMC (request for additional information).

Letter from DMC to DRC dated June 22, 2006; Re: Cell 4A Lining System Design Report, Round 2 Interrogator Response.

Letter from DMC to DRC dated June 30, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 2 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC dated December 8, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 5 Interrogatory, Cell 4A Design.

INTERROGATORY DMC R313-24-4-02/05: DOUBLE LINER SYSTEM

PRELIMINARY FINDING:

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(1): Surface impoundments must have a liner that is designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, ground water, or surface water at any time during the active life (including the closure period) of the impoundment. The liner may be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil, ground water, or surface water) during the active life of the facility, provided that impoundment closure includes removal or decontamination of all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate. For impoundments that will be closed with the liner material left in place, the liner must be constructed of materials that can prevent wastes from migrating into the liner during the active life of the facility.

Refer to R317-3-1(1.7). 1.7. Construction Supervision. The applicant must demonstrate that adequate and competent inspection will be provided during construction. It is the responsibility of the applicant to provide frequent and comprehensive inspection of the project.

Refer to R317-3-10(4)(E). E. Construction Quality Control and Assurance. A construction quality control and assurance plan showing frequency and type of testing for materials used in construction shall be submitted with the design for review and approval. Results of such testing, gradation, compaction, field permeability, etc., shall be submitted to the executive secretary.

INTERROGATORY STATEMENT:

Please state in Section 02220 (3.02) of the Technical Specifications that the subgrade soil shall be a minimum of 12-inches thick. Also include in this section that an acceptable maximum loose lift thickness before compaction of the subgrade soil is 8-inches.

Please revise the use of the term "in general conformance" (with a specific test procedure) to state "in conformance". This revision should be made throughout the Technical Specifications and CQA Plan.

Please revise Table 1B in the Revised Construction Quality Assurance Plan to state that at a minimum, one test per soil type will be performed for ASTM D 422 and ASTM D 1557.

BASIS FOR INTERROGATORY:

In response to this interrogatory in Round 6, DMC stated:

"Technical Specifications Section 02220, Subgrade Preparation, has been revised to include requirements for subgrade compaction, moisture content, and proof-rolling. The Construction Quality Assurance Plan has been revised to include testing requirements for compaction and moisture content."

Review of Section 02220 confirms that these requirements have been included in the technical specifications. However, a minimum thickness of subgrade soil under the cell liner needs to be included. This minimum thickness of soil needs to be no less than 12-inches. Also, a maximum lift thickness for soil that is placed and compacted needs to be stated. Acceptable maximum loose lift thickness for the placement of subgrade soil is 8-inches.

Table 1B has a frequency of one test per source (of soil borrow) for ASTM D 422 and D 1557. This should state at a minimum, one test per soil type. Please note that one source could have different soil types, with different maximum densities and optimum moisture content.

Review of the CQA Plan confirms that these requirements have also been included. However, the use of the term "in general conformance" with a specific test procedure is not acceptable. It should state "in conformance". This applies to the use of this phrase throughout the technical specifications and CQA Plan.

REFERENCES:

"Cell 4A Lining System Design Report for the White Mesa Mill, Blanding, Utah," by GeoSyntec Consultants, January 2006. Prepared for International Uranium (USA) Corporation.

Letter from DMC to DRC dated June 22, 2006; Re: Cell 4A Lining System Design Report, Round 2 Interrogator Response.

Letter from DMC to DRC dated June 30, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 2 Interrogatory, Cell 4A Design.

Letter from DMC to DRC dated August 28, 2006; Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 4 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC dated December 8, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 5 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC March 28, 2007; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 6 Interrogatory, Cell 4A Design.

INTERROGATORY DMC R313-24-4-03/05: LINER STRENGTH & COMPATIBILITY

PRELIMINARY FINDING:

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(2)(a): The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;

INTERROGATORY STATEMENT:

The proposed GCL field hydration plan shall include the requirement that the GCL testing continue until hydration levels (mass of water to mass of solids as determined by ASTM D 2216) is 140% or greater.

As an alternative to the demonstration that the GCL will reach the desired hydration levels, 2-feet of compacted clay can be placed and compacted in the bottom and on the side slopes of the cell (in place of the GCL).

The location of the proposed test pad shall be away from the toe of the slope, in an area away from any surface water flow path, and protected from surface water run on.

In addition, the statement is not acceptable "Based on the anticipated favorable results from this field demonstration, DMC has removed the post installation hydration requirement from the technical specifications section 02772". In order to remove this requirement, DMC must first demonstration the optimum moisture content (level of hydration) can be achieved.

BASIS FOR INTERROGATORY:

Round 6 requested additional information in support of the proposed GCL field hydration test plan. This included:

1. *Please provide detailed information on the justification for the 100% optimum moisture content (providing for low permeability) of the GCL in consideration of liquids with pH in the 1 to 2 range. Is CETCO stating that 100% is the optimum moisture content that will provide for the optimum (low) permeability under the acidic conditions? If so, what is their basis?*

DMC responded:

"CETCO recommends the hydration of GCLs to 100% moisture content when the GCL is to be permeated by liquids other than water. The basis for this recommendation is for hydrocarbon permeation through GCLs as demonstrated by Daniel, et al (Daniel et al, 1993). The permeant in this case will be liquids with low pH. However, as discussed in our response to Interrogatory #1, the number of pore volumes anticipated to permeate the

GCL is very low. Therefore, the GCL will serve to provide an effective hydraulic barrier."

As discussed in previous interrogatories, the compatibility and effectiveness of GCL under acidic conditions is of concern. Available studies (cited in past interrogatories) indicate that GCLs may not be effective in a low pH environment. The studies also indicate that if the GCL is pre-hydrated to a specific level it can be effective (maintain permeability) against low pH liquids (i.e, tailings solution). In addition, The concern is not the ***estimated*** *number of pore volumes of the tailings solution the GCL will be exposed too, but the compatibility of the GCL with the tailing solution and its ability to be an effective barrier layer.*

Since the available information suggests that at specific hydration levels the CGL could be an effective barrier for an acidic solution, the DRC agreed that if DMC could demonstrate what the respective level is, and that the GCL will reach the needed hydration level in a reasonable amount of time after installation (and before cell use), then that information would serve to demonstrate GCL/tailings solution compatibility, and effectiveness of the GCL.

However, the level of GCL hydration that is needed to be effective against acidic solutions (in the pH range of the tailings solutions) has not been demonstrated by DMC. As stated in past interrogatories, available literature (Ruhl and Daniel, 1997) identifies pre-hydration levels of 144% that result in laboratory measured permeability's greater than 10^{-7} *cm/sec (in the* 10^{-9} *cm/sec range). Whereas GCLs that are not pre-hydrated have measured permeability's in the* 10^{-6} *cm/sec or less range, and are susceptible to degradation and an increase in permeability with time from exposure to the acidic liquid.*

2. *Please modify the work plan to state that samples will be taken until optimum hydration is reached, or a maximum level reached. This may require more samples through time than is currently planned.*

In response, DMC stated that hydration would be reached within 15 days. However, the time required for hydration is dependent on the level of moisture in the subgrade soil and the rate in which the GCL will absorb the water, which is not yet known (this is the primary reason for performing the test). Available literature (Daniel, Shan, and Anderson, 1993) includes a demonstration that sandy soils with less than 10% moisture content will not hydrate GCL to the 140% level. At the 10% moisture content level it took over 35 days to reach a level in the 140% range. The test needs to be conducted until the desired hydration level is reached to demonstrate it can be reached, and in what time frame. This is of particular concern when considering the aired climate at the site.

REFERENCES:

"Cell 4A Lining System Design Report for the White Mesa Mill, Blanding, Utah," by GeoSyntec Consultants, January 2006. Prepared for International Uranium (USA) Corporation.

Daniel, Shan, and Anderson. 1993. Effects of Partial Wetting on the Performance of the Bentonite Component of a Geosynthetic Clay Liner. International Fabrics Association International, Vol. 3, pp 1483-1496.

DMC, March 7, 2005 Request to Amend Radioactive Material License, White Mesa Mill and Environmental Report.

DMC May 1999, Groundwater Information Report for White Mesa Uranium Mill.

Letter from DMC to DRC dated June 22, 2006; Re: Cell 4A Lining System Design Report, Round 2 Interrogator Response.

Letter from DMC to DRC dated June 30, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 2 Interrogatory, Cell 4A Design.

Letter from DMC to DRC dated August 28, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 4 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC dated December 8, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 5 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC dated January 5, 2006; Re: Response to technical review of DMC proposed Geosynthetic Clay Liner Hydration Demonstration Work Plan to be used in the liner for Cell 4A.

Ruhl, J., and Daniel, D. 1997. "Geosynthetic Clay Liners Permeated with Chemical Solutions and Leachates", Journal of Geotechnical and Geoenvironmental Engineering, Vol. 123, No. 4, pp. 369-381.

State of Utah Ground Water Discharge Permit No. UGW370004.

Smith R.D.1987, U.S. Nuclear Regulatory Commission, Sampling of Uranium Mill Tailings Impoundments for Hazardous Constituents, Memorandum, Februarey9, 1987, Division of Waste Management.

U.S. Nuclear Regulatory Commission, Standard Review Plan for Review of DOE Plans for Achieving Regulatory Compliance at Sites With Contaminated Ground Water Under Title I of the Uranium Mill Tailings Radiation Control Act, Draft Report for Comment, NUREG-1724, June 2000.

Letter from Denison Mines (USA) Corp. (DMC) to DRC March 28, 2007; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 6 Interrogatory, Cell 4A Design.

INTERROGATORY DMC R313-24-4-06/05: BEST AVAILABLE TECHNOLOGY

PRELIMINARY FINDING:

Refer to R313-24-4, R317-6-1.13: ***Best Available Technology*** *means the application of design, equipment, work practice, operation standard or combination thereof at a facility to effect the maximum reduction of a pollutant achievable by available processes and methods taking into account energy, public health, environmental and economic impacts and other costs.*

Refer to R313-24-4, R317-6-6.4(A)(3/112): The Executive Secretary may issue a ground water discharge permit for a new facility if the Executive Secretary determines, after reviewing the information provided under R317-6-6.3, that: 1.the applicant demonstrates that the applicable class TDS limits, ground water quality standards protection levels, and permit limits established under R317-6-6.4E will be met; 2. the monitoring plan, sampling and reporting requirements are adequate to determine compliance with applicable requirements;3. the applicant is using ***best available technology*** *to minimize the discharge of any pollutant; and 4. There is no impairment of present and future beneficial uses of the ground water.*

INTERROGATORY STATEMENT:

Please include in the Cell 4A liner design a slimes drainage layer over the strip drains that will have the ability to drain the tailings solution in a timely manner (i.e., in the range of 1.7 years). This drainage layer will have a minimum permeability of 10^{-2} *cm/sec and address the potential for clogging from the tailings.*

Please address the following concerns identified in the calculation entitled "Analysis of Slimes Drain":

- *Account for the use of a sufficiently sized drainage layer over the cell bottom and drain pipes. This includes permeability and thickness.*
- *Clarify the use of gravel around the PVC pipe (assumption #6).*
- *Provide further justification of the use of* $1x10^{-5}$ *cm/sec as a conservative value for hydraulic conductivity of the tailings, when the tailings are estimated to have hydraulic conductivity as low as* $1x10^{-7}$ *cm/sec (assumption #7).*

BASIS FOR INTERROGATORY:

For waste cell liner systems as proposed for Cell 4A, the State of Utah considers BAT to be a double liner with leachate collection/detection systems. For Cell 4A, this was defined in Round 1 Interrogatory and continued to be a concern in Round 2, 4, 5, and 6 Interrogatories. All interrogatories provided to DMC to date on the subject of the slimes drain design have requested a demonstration that the slimes drain system will remove the tailings solution remaining in the cell (after the cell has become full) in a timely manner.

DMCs response to the interrogatories prior to Round 6 were descriptive in nature and did not include an actual demonstration that the slimes drain would be effective in removing the tailings solution in a timely manner. DMC did commit to using a cyclone to separate out the courser fraction of the tailings for placement over the bottom of the cell and the slimes drain piping. DMCs recent response to Interrogatory 6 included a revised slimes drain design that included strip drains placed throughout the bottom of the cell on top of the liner. Also included in this response is a proposed demonstration of the effectiveness of the slimes drain to remove the tailings solution in the cell in an effective and timely manner. This demonstration included an acceptable estimated time frame for removal of the tailing solution (i.e., 1.7 years). However, there are concerns that the demonstration did not include a slimes drain design that could support the estimated 1.7 year time frame. Primarily, there is no mention of a granular slime drain layer over the strip drains (such as could be created through the use of the cyclone). There were also several additional concerns with some of the assumptions as well as with some of the calculations. These concerns are detailed in a technical memorandum prepared by URS and provided as Attachment A. The concerns include:

- *A drainage layer over the slimes drains needs to be included in the design. This layer needs to be a sufficient permeability to allow the tailings solution to drain freely to the strip drains. It also needs to consider the potential for clogging due to the fines in the slimes.*
- *Account for the use of a sufficiently sized drainage layer over the cell bottom and drain pipes. This includes permeability and thickness.*
- *Clarify the use of gravel around the PVC pipe (assumption #6).*
- *Provide further justification of the use of $1x10^{-5}$ cm/sec for a conservative value for hydraulic conductivity of the tailings when the tailings are estimated to have hydraulic conductivity as low as $1x10^{-7}$ cm/sec (assumption #7).*

These concerns are detailed in the technical memorandum prepared by URS included as Attachment A.

In summary, the estimated time frame for removing the tailings solution is acceptable. However, the design needs to support this estimated time by including a drainage layer over the strip drains that has the capacity to accommodate the flow of solution from the tailings.

REFERENCES:

"Cell 4A Lining System Design Report for the White Mesa Mill, Blanding, Utah," by GeoSyntec Consultants, January 2006. Prepared for International Uranium (USA) Corporation.

GSE. Technical Note: "Installation of Geosynthetic Drainage Products". Undated. Available at:

http://www.gseworld.com/Literature/TechnicalNotes/PDF/TN025installationgeo.pdf

Koerner, R.M. 1997. Designing with Geosynthetics, Fourth Edition.

Letter from DMC to DRC dated June 22, 2006; Re: Cell 4A Lining System Design Report, Round 2 Interrogator Response.

Letter from DMC to DRC dated June 30, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 2 Interrogatory, Cell 4A Design.

Letter from DMC to DRC dated August 28, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 4 Interrogatory, Cell 4A Design.

Letter from Denison Mines (USA) Corp. (DMC) to DRC dated December 8, 2006; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 5 Interrogatory, Cell 4A Design.

Richardson, G.N., and Zhao, A. 1999. Design Manual for Lateral Drainage Systems for Landfills

Thiel, R., Criley, K., and Bryk 2005. "Practical Guidelines for Specifying GCL Overlaps", Geotechnical Fabrics Report, October/November 2005. St. Paul, MN.

40 CFR 264.301.

Letter from Denison Mines (USA) Corp. (DMC) to DRC March 28, 2007; Re: Cell 4A Lining System Design Report, Response to DRC Request for Additional Information – Round 6 Interrogatory, Cell 4A Design.

ATTACHMENT A

TECHNICAL MEMORANDUM

REVIEW FINDINGS; “ANALYSIS OF SLIMES DRAIN” PREPARED BY GEOSYNTEC CONSULTANTS

TECHNICAL MEMORANDUM

To: Loren Morton, URRC File: 39400166.10300

From: Kevin Sullivan, Britt Quinby, and Robert Baird

Date: May 1, 2007

Re: Review Findings; “Analysis of Slimes Drain” by Geosyntec Consultants

Documents Reviewed:

URS has reviewed and evaluated the following document in connection with the Utah Division of Radiation Control (the Division), Cell 4A Lining System, Denison Mines (USA) Corp. (DMC), White Mesa Mill, Blanding Utah - Round 6 Interrogatories.

“Analysis of Slimes Drain,” Geosyntec Consultants, Meghan Lithgow, SC0349, March 26, 2007.

Summary Evaluation

DMC has submitted a design of the proposed Cell 4A Lining System to the Division. URS has reviewed certain submissions pertaining to the slimes drainage design. URS and the Division have pursued unresolved matters through issuance of six rounds of interrogatories, to which IUC has responded, submitting information beyond that initially provided. URS concludes at this point that the current submission is deficient in completely addressing the slimes drain issues contained in previous round of interrogatories.

General Description

All interrogatories provided to IUC to date on the subject of the slimes drain design have requested a demonstration that the slimes drain system will remove the tailings solution in the cell (after the cell has become full) in a timely manner. In addition, the following elements were requested in the interrogatories:

- A continuous drainage layer over the strip drains needs to be included in the slimes drain design.
- Evidence must be presented to demonstrate that the drain, when in active use, will minimize the hydraulic head of solution on the upper liner.
- An estimation of the maximum solution flow rate from the tailings into the slimes drain and the predicted ability of the slimes drain to remove this solution in a timely manner must be provided.

- Consideration of the potential for clogging of the drain system through time, the slope of the drain, size and length of the drainpipes, and a means to monitor the fluid head on the liner to evaluate and ensure the effectiveness of the drain and extraction system must also be addressed.

In the latest submission, IUC has provided details on the design, capacity, materials of construction, dewatering time, and other aspects of performance of the slimes drain system that is proposed for Cell 4A. These details are provided in calculation form. The calculation followed the following general outline:

1. Purpose and Method of Analysis

2. Assumptions

3. Calculations

    a. Computation of the emptying time for the slimes drain;

    b. Evaluation of the flow capacity of the proposed strip drains;

    c. Calculation of the minimum required AOS and permitivity for the filtration geotextile;

    d. Calculation and evaluation of the header pipe flow rate, and;

    e. Discussion on effect of precipitation on drainage time.

To facilitate this review and comment process, the detailed comments (below) are provided in similar format.

Detailed Comments

1. Purpose and Method of Analysis

To be fully responsive to the interrogatory, the purpose should, in addition, contain the following elements, which are not currently addressed in the calculation:

- A drainage layer over the drain.

- Demonstration that the proposed design employs the Best Available Technology (BAT) in minimizing the hydraulic head on the upper liner.

- Demonstration of the long-term performance of the drain including consideration of the potential for clogging of the drain system over time.

2. Assumptions

Assumption #6: It is unclear what is meant by the assumption that "a PVC pipe and *gravel* header will be installed". DMC should state whether the gravel portion of this construction item is necessary for structural strength of the pipe or integral to performance and whether the PVC pipe is perforated.

Assumption #7: The assumption states that the range of hydraulic conductivities of the slimes material is 0.1 cm/sec to $1x10^{-7}$ cm/sec and the average saturated hydraulic conductivity is $1x10^{-5}$ cm/s. Then, in the last sentence of the assumption, a *conservative* hydraulic conductivity of $1x10^{-5}$ cm/s is selected for the tailings. URS does not agree that the *average* in this case can justifiably also be considered a *conservative* estimate. DMC must provide a basis for the use of these hydraulic conductivities in the calculation (i.e., physical testing of representative samples of the slimes material). In the absence of real data on the slimes, URS judges that a better representation of a conservative estimate would be the scenario where a large amount of $1x10^{-7}$ cm/s material is deposited directly on one of the strip drains. Under this scenario, the conservative estimate for hydraulic conductivity would be $1x10^{-7}$ cm/s. DMC needs to address this.

3. Calculations

a. Calculation of the Flow Velocity and Empting Time

The sketch on page 2 illustrates the flow path of the most remote particle as directly toward the drain, not downward as would be expected if a continuous, underlying, high permeability drainage layer were present. Based on this sketch, URS understands that DMC does not intend to install such a drainage layer. DMC should confirm whether this understanding is correct.

The calculation of "emptying time" ending at the bottom of page 3/11 is performed using Darcy's Law and assuming that a particle of water furthest from the drain moves toward the drain at a constant velocity (Darcy seepage velocity). Darcy's law is a one-dimensional means of estimating fluid (particle) velocity at any point in time in an aquifer that does not confine this flow. The velocity is directly dependent on the hydraulic conductivity of the media, the gradient, and the effective porosity of the media. The resultant velocity of 7.31×10^{-7} ft/sec is applied to the distance of 39.8 feet to get a time of 1.7 years. Again, this assumes that the fluid is allowed to freely drain though the media and is not confined (there is no back pressure). However, Cell 4A is a closed or confined system (by design), and requires a drain system that has the capacity to remove the fluid so as not to confine or impede its flow through the tailings. Therefore, the slimes drainage system must have the capacity to remove the tailings solution at a rate greater than the rate the solution flows through the tailings.

b. Evaluation of the flow capacity of the proposed strip drains

The calculation beginning at the middle of page 4/11 provides an estimation of the flow to be expected in the strip drains. The equation used, Darcy's equation, is as follows:

Q = kiA Where:

Q = flow rate through the cross-section

k = aquifer permeability

i = hydraulic gradient

A = cross-sectional area of flow

The calculation presented considers flow into the strip drain as the unknown parameter, but then uses the cross sectional area of the entire (tributary) area for the cross-sectional area of flow (i.e., 50ft x 600ft = 3,000 ft^2). However, this is not the area of flow from the tailings into the strip drain. The equation should consider the cross-sectional area of the drain itself, A = 1ft x 600 ft = 600 ft^2, since this is the only outlet for the water. Based on this revision, the flow rate through the cross-section (the strip drain) is actually 0.07 gpm or 1/50th of the flow calculated. There is no discussion on the design of a drainage layer and the assumption that such a layer is present is inconsistent with the sketch on p.2. This calculation would apply if the drainage layer were present and properly designed (and the gradient was changed to 1.0)

DMC should revise the calculation to reflect the characteristics of a drainage layer.

c. Calculation of the minimum required AOS and permittivity for the filtration geotextile

The fabric Apparent Opening Size (AOS) of the geotextile selection assumes that the material is non-dispersive (Double-Hydrometer Ratio [DHR] less than 0.5). Without this necessary information, a conservative design would assume dispersive soils necessitating the installation of a sand filter layer between the geotextile and the slimes material. DMC should clarify this matter.

d. Calculation and evaluation of the header pipe flow rate

Refer to b. above. This calculation should be revised based on the changes required under b.

Summary of Comments

In reviewing the subject calculation, it becomes evident that the calculation presents a conceptual plan whereby there are 1-foot-wide drains located at 50-foot intervals across the base of the cell. This concept inherently allows significant groundwater mounding between drains and, based on URS' comments provided above, would require a significantly long time for dewatering of the slimes. Neither the mounding condition that is anticipated nor the significantly long dewatering time meets the Division's intent of utilizing BATs in the slimes drainage design.

Recommendations

The problem that is being considered in the calculation is a complicated issue that is best solved using groundwater flow modeling software. This solution will provide a more accurate estimate of the dewatering time for the slimes, but our feeling is that the dewatering time will still be excessive. It is not the lack of modeling that appears to be the issue, but the drainage system design concept itself.

Design of a continuous "drainage layer" beneath the slimes will provide many benefits to the project. The potential for clogging of the manufactured drains will be significantly reduced. Properly designed, the drainage medium will act as a filter between the slimes and the filter fabric on the drains. In addition, the groundwater flow problem becomes a linear flow problem (downward flow) and can be easily estimated using the Darcy equations. Under linear downward flow, the hydraulic gradient becomes 1, and assuming a 1ft^2 area of flow, the flowrate through the slimes is (using the assumptions presented in the calculation):

$Q = kiA$ where $k = 3.28\text{x}10^{-7}$ ft/sec

$Q = 3.28\text{x}10^{-7}$ ft/sec x 1 x 1 ft^2 = 3.28x10-7 ft^3/sec (per ft^2).

And based on that flow rate, the dewatering time (T) becomes dependent on volume (V-per ft^2) as:

$T = V / Q$ = Vol Tot (ft^3) / Q (ft^3/sec), or T = Vol Tot (ft^3) / 3.28x10-7 ft^3/sec, converting to days:

T = Vol Tot (ft^3) / (3.28x10^{-7} ft^3/sec x 60 s/m x 60 m/hr x 24 hr/day), then

T = Vol Tot (ft^3) / (0.0283 ft^3/day)
(Eq. 1)

Now the time for dewatering can be calculated based on the volume of fluid in the slimes (for a 1ft^2 vertical column that is 31 ft in height as:

Vol = 1 ft^2 x 31 ft x porosity (0.35) = 10.85 ft^3,

and accounting for rainfall [13.4 in/yr converts to 3.06x10^{-3} ft^3/day (per ft^2)] the total volume becomes (per ft^2 area):

Vol Tot = 10.85 ft^3 + 3.06x10^{-3} ft^3/day x T (time in days)
(Eq. 2)

Then using Eq. 1 and Eq. 2 to solve for T and Vol Tot, we can find:

Vol Tot = 10.85 ft^3 + 3.06x10^{-3} ft^3/day x Vol Tot (ft^3) / 0.0283 ft^3/day, and

Vol Tot = 10.85 ft^3 + 0.108 x Vol Tot (ft^3), solving for the unknown we find:

Vol Tot = 12.17 ft^3 (per ft^2 of cell area)

and now we can solve for T using EQ 1:

T = Vol Tot (ft^3) / (0.0283 ft^3/day) = 12.17 ft^3 / 0.0283 ft^3/day

T = 430 days (dewatering time) = 1.18 years

This example demonstrates the effect of installing a continuous bottom drain that is designed so as not to clog. If no drainage layer is placed over the strip drains (as is indicated in the calculation provided), then the flow is limited to 1/50th of this flow and the resulting time to dewater is 50 times greater (59 years). This would be greater when consideration is made for clogging of the drains.

The drainage layer (thickness) can be designed to accommodate the flows developed from the Darcy equation. A sample calculation demonstrating design of the drainage layer is as follows:

Find the minimum drainage layer thickness by solving for t_{max}, the maximum thickness of water in the drainage layer. The solution utilizes "*Giroud, Zornberg, &Zhao – Hydraulic Design of Geosynthetic and Granular Liquid Drainage Layers*", Giroud's Equation based on Simplified Assumptions:

$$t_{max} = j[(\mathrm{sqrt}\ (\tan^2\beta + 4q_h/k) - \tan\beta) / (2\cos\beta)]\ L_s$$

Assuming that k_{slimes} is limit for q_h, $q_h = k_{slimes}$ (as a conservative case), we find that:

$$t_{max} = j[(\mathrm{sqrt}\ (\tan^2\beta + 4\ k_{slimes}/k) - \tan\beta) / (2\cos\beta)]\ L_s \qquad \text{(Eq.3)}$$

Drainage Layer Thickness, using k_{slimes} of 1×10^{-5} cm/s

S = slope of drainage layer (%) = 1%

Ls = length of slope = 50 ft

H = height of slope = 0.5 ft

β = slope angle = 0.6 degrees

k_{slimes} = permeability of slimes soil = 3.3×10^{-7} ft/s

k = permeability of drainage layer = 3.3×10^{-4} ft/s

j = modifying factor (default of 1) = 1.00

t_{max} = max liquid thickness in drainage layer = 1.35 ft

This solution suggests that, assuming a slimes permeability (k_{slimes}) of 1×10^{-5} cm/s (3.3×10^{-7} ft/s), a drainage layer of 1.35 ft in thickness with a permeability of 1×10^{-2} cm/s (3.3×10^{-4} ft/s) would be necessary to provide adequate drainage. Based on this solution and additional iterative solutions, it appears that with a drainage layer thickness of 16" (1.35 ft), the drainage material permeability must be 3 orders of magnitude greater than the slimes permeability. Lower permeability drainage material would similarly be required in greater depths. Note that consideration for clogging has not been included, and would need to be considered. This may be a geotextile, or added thickness to the drainage layer.

An additional consideration for drainage layer material is a geosynthetic drainage composite (geonet). Designs for these engineered materials are available in the manufacturer's literature. However, due to the use of Cell 4A as a holding area for solution and slurry, a geonet as a drainage layer in this application would need special consideration (e.g., the design would need to account for ballasting, clogging, folding, and damage during operations, etc.).