24 June 2011

Project No. 7420143000

Mr. Frank Filas
Director of Environmental and Regulatory Affairs
Energy Fuels Resources Corporation
44 Union Blvd., Suite 600
Lakewood, Colorado 80228

Re: Response to EPA Comments on Tailings Cell Seepage and Stability
Piñon Ridge Project, Montrose County, Colorado

Dear Frank:

AMEC Earth & Environmental (AMEC) has prepared this letter report to present the results of additional stability analyses performed for the proposed Tailings Cells at the Piñon Ridge Project located in Montrose County, Colorado, in response to verbal comments received from Mr. Robert Duraski of the U.S. Environmental Protection Agency (EPA) during a meeting held on the 16th of June, 2011.

1.0 Background

The EPA is currently reviewing the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) permit application submitted by Energy Fuels Resources Corporation (EFRC) for their proposed uranium/vanadium mill, termed the Piñon Ridge Project. The project received a radioactive materials license from the Colorado Department of Public Health and Environment (CDPHE) on 7 March 2011, a Special Use Permit from Montrose County on 30 September 2010, and various other permits, as required.

During its review of EFRC's NESHAPs permit application, the EPA has performed a review of the tailings cell design, and in particular the Golder Associates (Golder, 2008a) report titled "*Tailings Cell Design Report, Piñon Ridge Project, Montrose County, Colorado*." EPA's review of the tailings cell design has been in general accordance with the U.S. Nuclear Regulatory Commission's (NRC) Regulatory Guide 3.11 (Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities). This guidance document provides reference to EPA regulations dictating design of uranium tailings impoundments (40 CFR 264.221; 40 CFR 192.32) as well as 10 CFR Part 40 (Domestic Licensing of Source Material), and specifically Appendix A to 10 CFR Part 40 (Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content).

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Paragraph 5A(5) of Appendix A to 10 CFR Part 40 states that "*when dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient integrity to prevent massive failure of the dikes. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment*." This statement implies that seepage analyses of the proposed tailings cell shall be performed in support of the stability evaluation for design. As the tailings cells are designed with a double composite liner system to limit seepage to negligible amounts, Golder's design analyses did not consider seepage in the stability evaluation. However, for completeness, this letter has been prepared to present the results of seepage analyses for the tailings cells.

Regulatory Guide 3.11 indicates that stability analyses should be performed to assess the structural stability of the tailings cells under the following scenarios:

- Case 1 - End of construction;
- Case 2 - Partial pool with steady seepage;
- Case 3 - Maximum storage pool with steady seepage; and
- Case 4 - Earthquake loading.

Golder's stability evaluation included Cases 1, 3 and 4, but not intermediate filling of the tailings cell (i.e., Case 2). As such, the EPA has requested that EFRC perform additional stability analyses to evaluate intermediate filling.

Though this letter is submitted by AMEC, design continuity for the project is provided by the project manager (Kimberly Morrison), who is the Engineer of Record for the tailings cell design work.

2.0 Seepage Analyses

AMEC performed seepage analyses of the proposed tailings cells to consider intermediate filling of the facility with a partial pool, and ultimate filling of the facility with a maximum pool. For the seepage analyses, a cross-section was developed through the maximum height section of the proposed tailings cell.

2.1 Material Parameters for Seepage Analyses

Material parameters for input into the seepage evaluation were developed as follows:

- Foundation Soils – Permeability of the foundation soils is assumed to be an average value of 3.0×10^{-4} centimeters per second (cm/sec) based on the results of flexible-wall permeability testing performed on undisturbed samples of the foundation soils, which range from 3.4×10^{-5} to 5.9×10^{-4} cm/sec (Golder 2008b).
- Structural Fill – Locally-available soils are anticipated to be used as fill for embankment construction. The permeability of the structural fill is assumed to be an average value of 5.0×10^{-5} cm/sec based on the results of flexible-wall permeability

testing performed on site soils remolded to approximately 95 percent of the standard Proctor maximum dry density (per the construction specifications), which produced permeability values ranging from 1.3×10^{-4} to 4.9×10^{-6} cm/sec (Golder 2008b).

- Tailings – As actual tailings were not available for testing, the permeability of the tailings materials is assumed to be 1.0×10^{-5} cm/sec, which is considered representative of the majority of the tailings mass (coarser-grained material) and is based on the anticipated average tailings gradation presented in Golder (2008a).
- Composite Liner System – Estimation of an equivalent permeability for the double composite liner system designed for the tailings cells was developed as follows:
  - Golder (2008a) used the method proposed by Giroud & Bonaparte (1989) to calculate potential seepage through the secondary composite liner system, assuming good contact between the geomembrane and the underlying geosynthetic clay liner (GCL) component of the composite liner. In this evaluation, they assumed one defect in the geomembrane per acre of coverage, with an average defect diameter of 0.06 inches (0.0015 m), equivalent to thickness of the proposed 60 mil geomembrane liner;
  - Under the maximum solution level and given the presence of an overlying primary geomembrane liner and leak collection and recovery system (LCRS), Golder (2008a) calculated the head on the secondary composite liner system as 0.017 ft (0.005 m);
  - The GCL thickness is approximately 0.4 inches (0.01 m) with a reported hydraulic conductivity of 5×10^{-9} cm/sec, per CETCO specifications for the proposed standard Bentomat ST. However, compatibility testing of the proposed GCL with anticipated tailings leachate solution indicated a nominally higher hydraulic conductivity of 1.1×10^{-8} cm/sec (1.1×10^{-10} m/sec) (TRI, 2008);
  - Given the above information, AMEC calculated the rate of liquid migration (*Q*) through the secondary composite liner system using the following equation presented in Giroud (1997):

$$Q = 0.976 C_{qo} \left[1 + 0.1 (h/t_s)^{0.95} \right] d^{0.2} h^{0.9} k_s^{0.74} \text{ (SI units)}$$

where C_{qo} is the contact quality factor (assumed as 0.21), h is the liquid head (0.005 m), t_s is the thickness of the low-permeability liner (0.01 m), d is the defect diameter (0.0015 m), and k_s is the hydraulic conductivity of the low-permeability liner (1.1×10^{-10} m/sec). The discharge, Q, is calculated as approximately 2.1×10^{-11} m^3/sec. Then, equivalent permeability is calculated as:

$$k = Q/A$$

Where A is the area over which the discharge was calculated (i.e., one acre or 4,046 square meters). Hence, the equivalent permeability is calculated as 5.2×10^{-15} m/sec (5.2×10^{-13} cm/sec).

Table 1 summarizes the hydraulic conductivity parameters assumed in the seepage analyses.

Table 1: Summary of Seepage Analysis Input Parameters

Material Type	Hydraulic Conductivity* (cm/sec)	Hydraulic Conductivity* (ft/sec)
Foundation Soils	3.0×10^{-4}	9.8×10^{-6}
Structural Fill	5.0×10^{-5}	1.6×10^{-6}
Tailings	1.0×10^{-5}	3.3×10^{-7}
Composite Liner System	5.2×10^{-13}	1.7×10^{-14}

*An anisotropy factor of one was assumed (i.e., $k_h = k_v$).

2.2 Seepage Analysis Method

Seepage analyses were conducted using the groundwater module in *SLIDE 6.0*, a two-dimensional computer program developed by RocScience (2010). The program employs a finite element method to model groundwater flow using Laplace's equation. Analyses were performed using a mesh of approximately 1,500 three-noded triangular elements. The tailings mass was assumed to be saturated and modelled under steady-state conditions. Boundary conditions were assumed in the seepage analyses as follows:

- Lateral boundaries were placed far enough upstream and downstream so as to not materially affect the analyses;
- A total head boundary was assumed at the tailings surface for the intermediate filling and end of filling stages; and
- The remainder of the model boundary was reviewed by the finite element program to evaluate the phreatic surface within the embankment and underlying materials.

2.3 Seepage Results

The seepage analyses were used to evaluate the phreatic levels for both an intermediate and the ultimate filling stages of the tailings cell. Due to the extremely low permeability of the secondary composite liner system, no phreatic surface is shown to develop within the perimeter tailings embankment or underlying foundation for either scenario, as demonstrated in Figure 1 and Figure 2. The phreatic conditions developed via the seepage models were used in the updated slope stability analyses, discussed in Section 3.0 .

3.0 Stability Analyses

The stability of the proposed tailings cell was evaluated under static and earthquake loading conditions using *SLIDE 6.0* (RocScience 2010) to estimate the least stable failure surface via

a critical surface search routine for each failure mode. *SLIDE* iterates through a variety of failure surfaces to determine the surface with the minimum safety factor (i.e., critical surface). For failures mechanisms considered in the analyses, slope stability was evaluated using limit equilibrium methods based on Spencer's method of analysis for the intermediate and ultimate filling stages. As no phreatic surface was developed outside the limits of the tailings cell in the aforementioned seepage evaluation for either filling scenario, the analyses presented in Golder (2008a) remain valid and unchanged for the ultimate filling scenario. Further, AMEC has not re-evaluated the stability for the end of construction scenario presented in Golder (2008a) as no water is present from which to model seepage conditions.

3.1 Material Parameters for Stability Evaluation

The stability analyses were performed using the results from the seepage evaluation. The material strength parameters presented in Golder (2008a) were assumed for the analyses, presented in Table 2. Both peak and residual strength values for the composite liner system were analyzed, with the minimum resulting factors of safety presented in Section 3.3 .

Table 2: Summary of Stability Analysis Input Parameters (from Golder, 2008a)

Material Type	Unit Weight (lb/ft^3)	Friction Angle (degrees)	Cohesion (lb/ft^2)
Foundation Soils	107	33.7	0
Structural Fill	120	30.3	0
Tailings Slurry	120	20	0
Composite Liner System (Peak Strength)	110	21.2	0
Composite Liner System (Residual Strength)	110	14.8	0

3.2 Loading Conditions

The stability analyses considered both static and earthquake-induced (pseudo-static) stress conditions. Static loading considers only the stress of the tailings and embankment materials placed at the design slopes. For the tailings cell design, Regulatory Guide 3.11 provides the minimum factor of safety recommendations presented in Table 3.

Table 3: Minimum Safety Factors for Design (NRC, 2008)

Loading Condition	Minimum Factor of Safety
End of construction	1.3
Partial pool with steady seepage	1.5
Maximum pool with steady seepage	1.5
Earthquake (in combination with the above conditions)	1.0

Earthquake (seismic) loading conditions were simulated using a pseudo-static approach. The pseudo-static analysis incorporated a horizontal load coefficient of half the peak ground acceleration, or 0.05g, as discussed in Golder (2008a).

3.3 Stability Results

The limit equilibrium stability analyses yielded the minimum factors of safety summarized in Table 4 for static and pseudo-static loading conditions for the intermediate and ultimate filling stages of the proposed tailings cell. For completeness, the end of construction factors of safety from Golder (2008a) are also included in Table 4.

Table 4: Stability Analysis Summary

Scenario	Minimum Static Factor of Safety	Minimum Pseudo-Static Factor of Safety
End of Construction	2.0	1.7
Intermediate Filling Stage	2.0	1.7
Ultimate Filling Stage	3.0*	2.4*

*Same condition modelled by Golder (2008a) without seepage model produced identical stability values.

The locations and results of the most critical (i.e., least stable) failure surface for the intermediate filling and the ultimate filling stages are presented in Figure 3 through Figure 6 for static and pseudo-static conditions.

4.0 Conclusions

To meet the requirements of Paragraph 5A(5) of Appendix A to 10 CFR Part 40 and in line with the guidance provided in Regulatory Guide 3.11, AMEC developed a seepage model to evaluate the steady-state seepage conditions anticipated within the proposed tailings cell and surrounding embankment and foundation materials under intermediate and ultimate filling scenarios. Due to the extremely low equivalent permeability of the secondary composite geomembrane liner system (5.2×10^{-13} cm/sec), no phreatic surface develops under steady-state conditions outside of the tailings cell, which confirms the assumptions made by Golder (2008a) as part of the original stability evaluation.

As requested by the EPA, AMEC performed stability analyses to assess an intermediate filling stage for the tailings cell, as well as confirm the previous stability analyses performed by Golder (2008a) for the ultimate filling condition. The stability analyses were performed using the results from the seepage evaluation.

The minimum static and pseudo-static factors of safety for the proposed tailings cell under intermediate filling stages is 2.0 and 1.7, respectively, exceeding the minimum factor of safety requirements outlined in Regulatory Guide 3.11. The minimum static and pseudo-static factors of safety for the proposed tailings cell under ultimate filling conditions remains the same as that presented in Golder (2008a) at 3.0 and 2.4, respectively, which also exceeds the minimum factor of safety requirements outlined in Regulatory Guide 3.11.

5.0 Closing

We appreciate the opportunity to provide engineering support services to EFRC for the Piñon Ridge Project. If you have questions or concerns about the contents of this letter, please contact the undersigned via phone at 303-742-5303, or via e-mail at kimberly.morrison@amec.com.

Sincerely,

AMEC Earth and Environmental

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Senior Engineer

Reviewed by

Kimberly Finke Morrison, P.E., R.G.
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JH/KFM

References

Code of Federal Regulations, 10 CFR Part 40, Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content."

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Golder Associates Inc. (Golder). 2008a. “Tailings Cell Design Report, Piñon Ridge Project, Montrose County, Colorado.” Prepared for Energy Fuels Resources Corporation. October.

Golder Associates Inc. (Golder). 2008b. “Phase 2 Geotechnical Field and Laboratory Test Program, Piñon Ridge Project, Montrose County, Colorado.” Prepared for Energy Fuels Resources Corporation. September.

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TRI/Environmental Inc. (TRI). 2008. “Results for permeability of the Bentomat ST GCL for the Piñon Ridge Uranium Mill Tailings Pond, (TRI Log #: E2308-20-10).” Letter to Chris Athanassopoulos, CETCO. 29 September 2008.

U.S. Nuclear Regulatory Commission (NRC). 2008. Regulatory Guide 3.11, “Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities.” Revision 3. November.

FIGURES

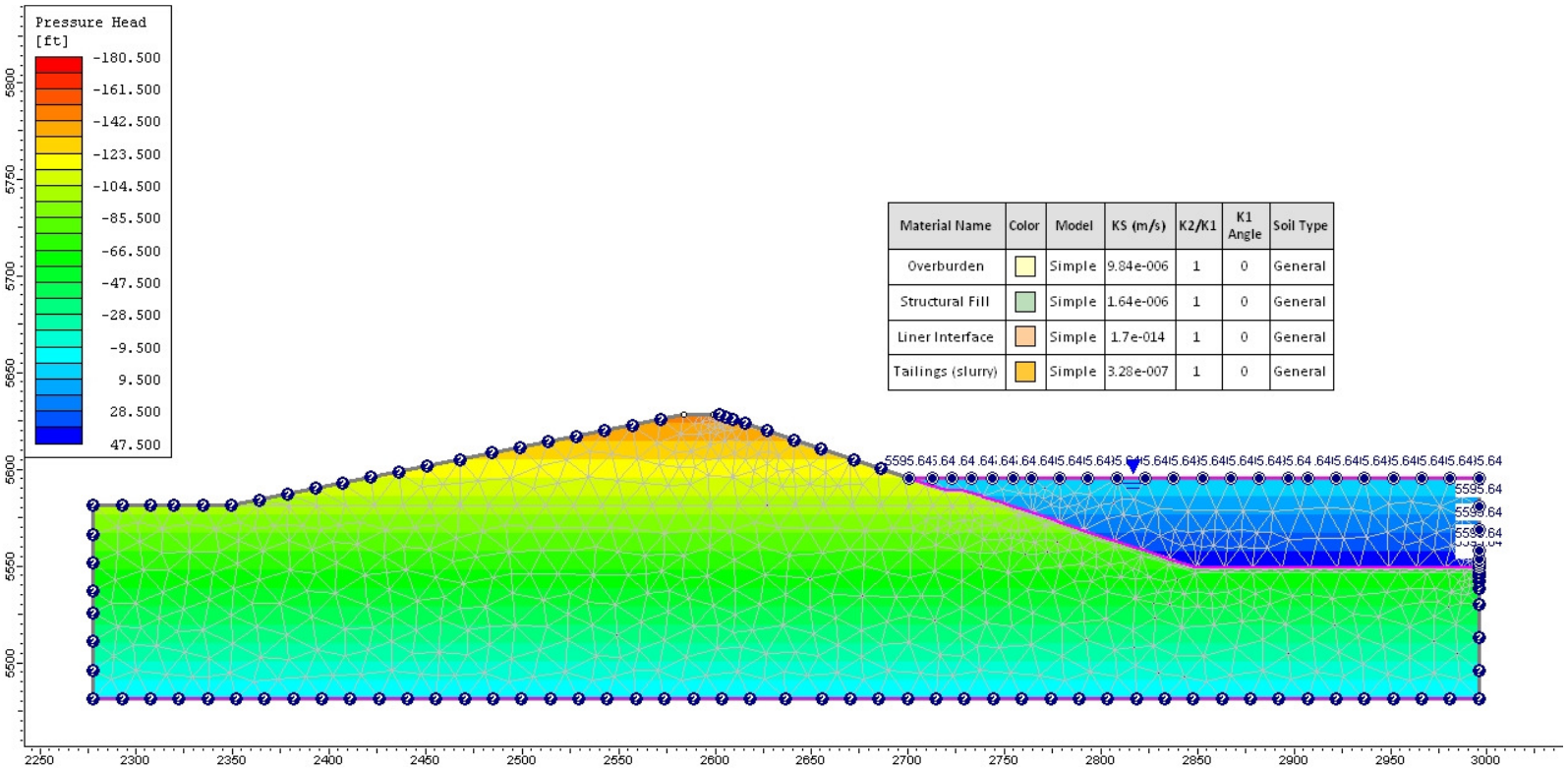
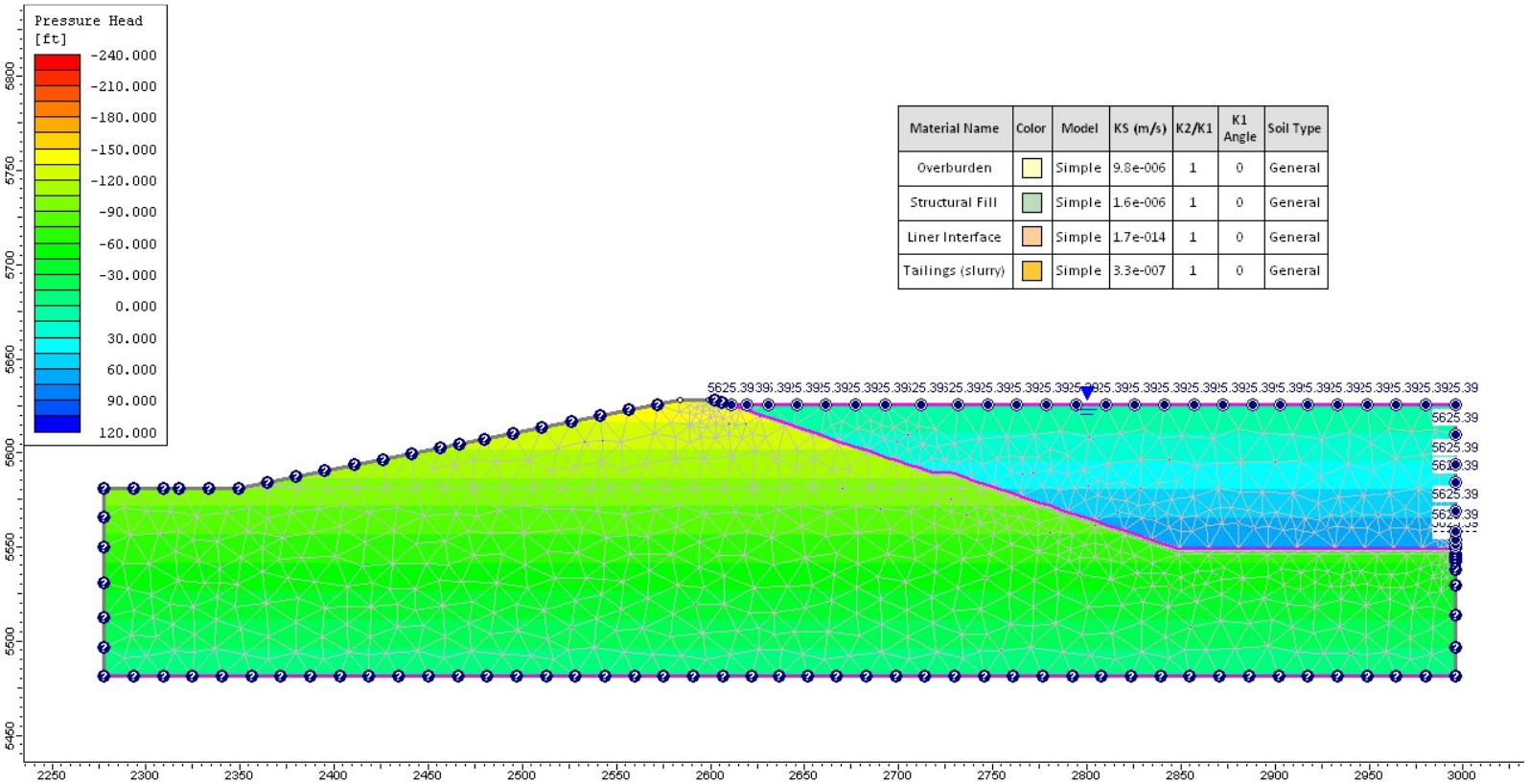
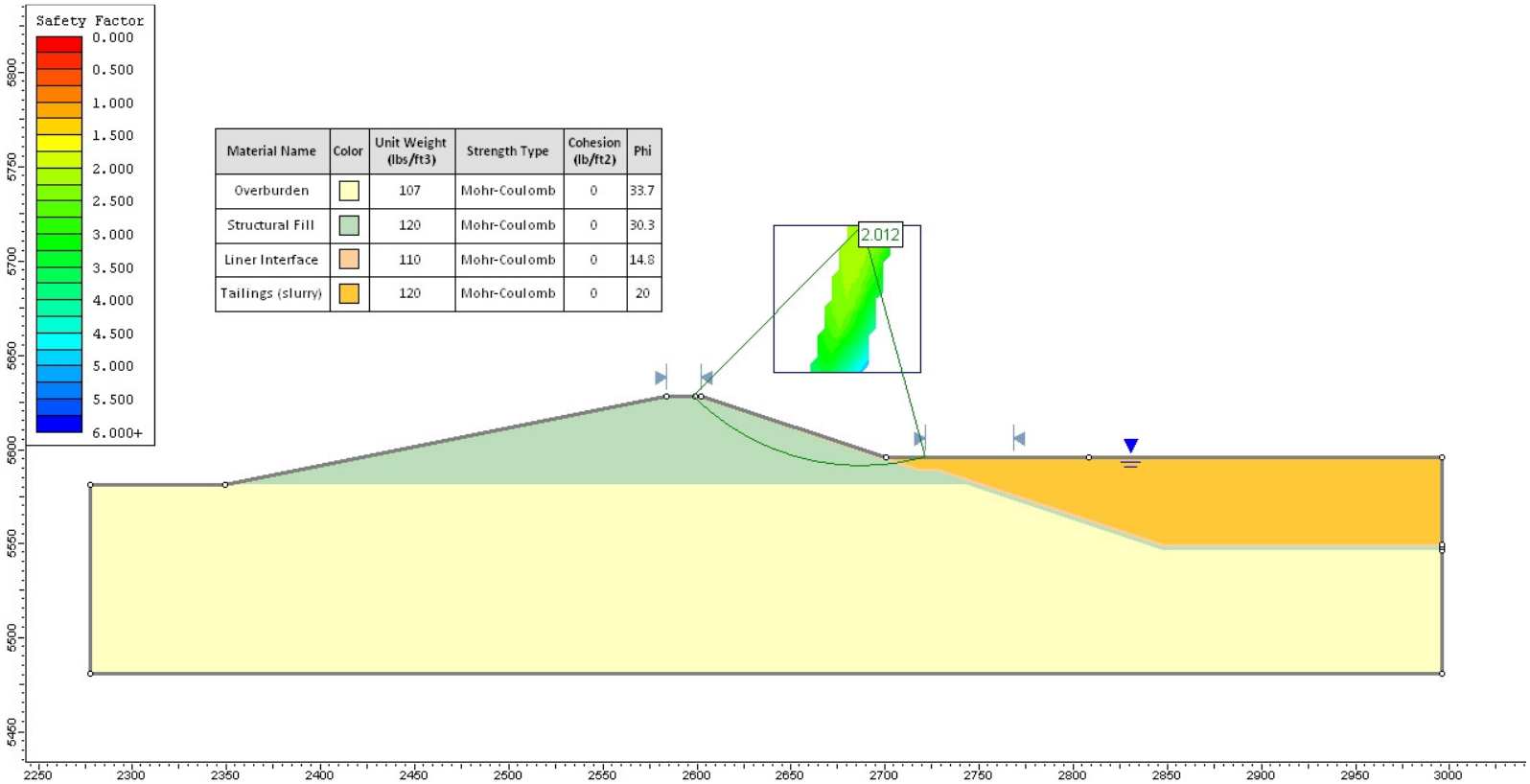


Figure 1: Seepage Results, Intermediate Filling Stage.



Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle	Soil Type
Overburden		Simple	9.8e-006	1	0	General
Structural Fill		Simple	1.6e-006	1	0	General
Liner Interface		Simple	1.7e-014	1	0	General
Tailings (slurry)		Simple	3.3e-007	1	0	General

Figure 2: Seepage Results, Ultimate Filling Stage.



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi
Overburden		107	Mohr-Coulomb	0	33.7
Structural Fill		120	Mohr-Coulomb	0	30.3
Liner Interface		110	Mohr-Coulomb	0	14.8
Tailings (slurry)		120	Mohr-Coulomb	0	20

Figure 3: Critical Failure Surface (Static Conditions), Intermediate Filling Stage.

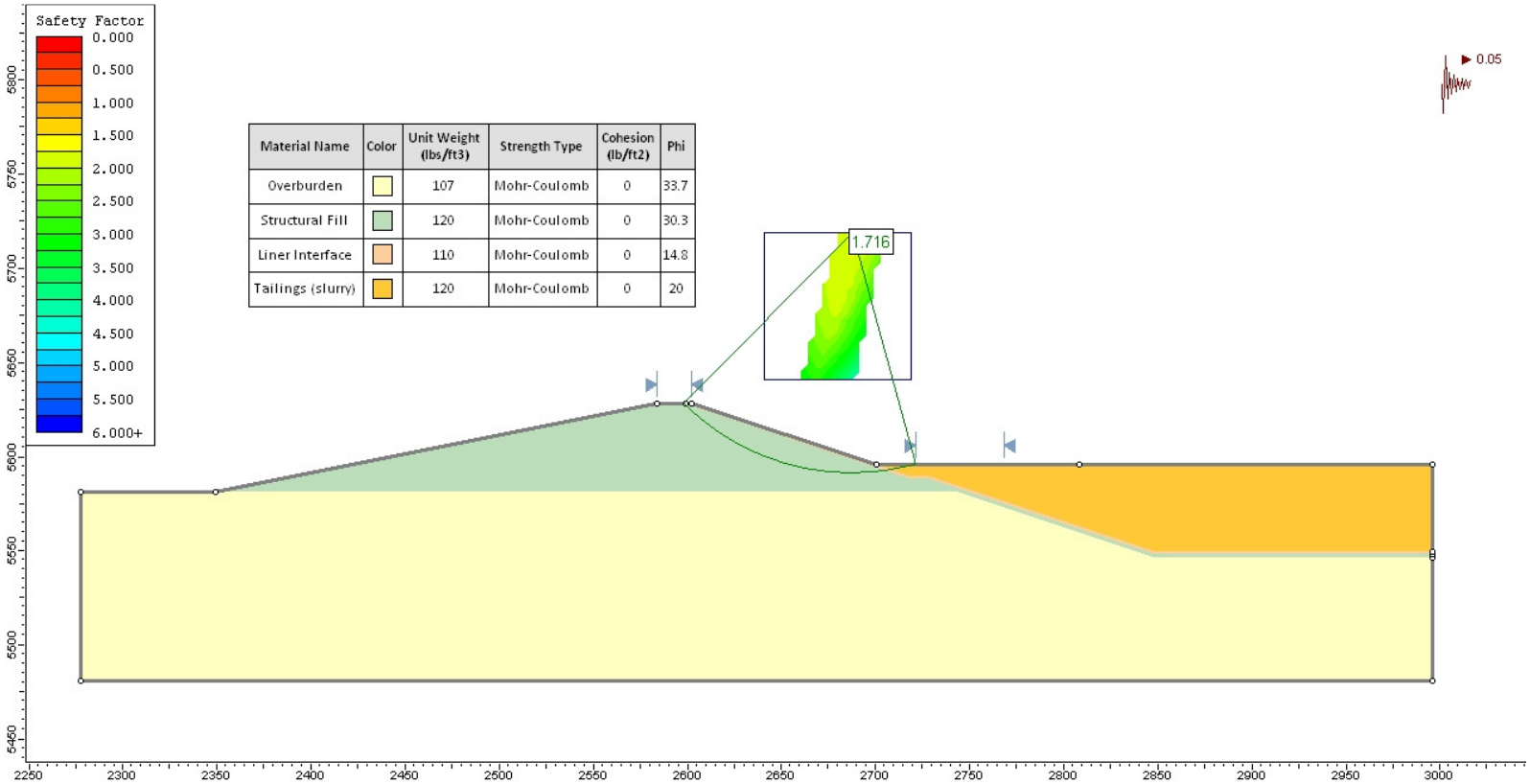
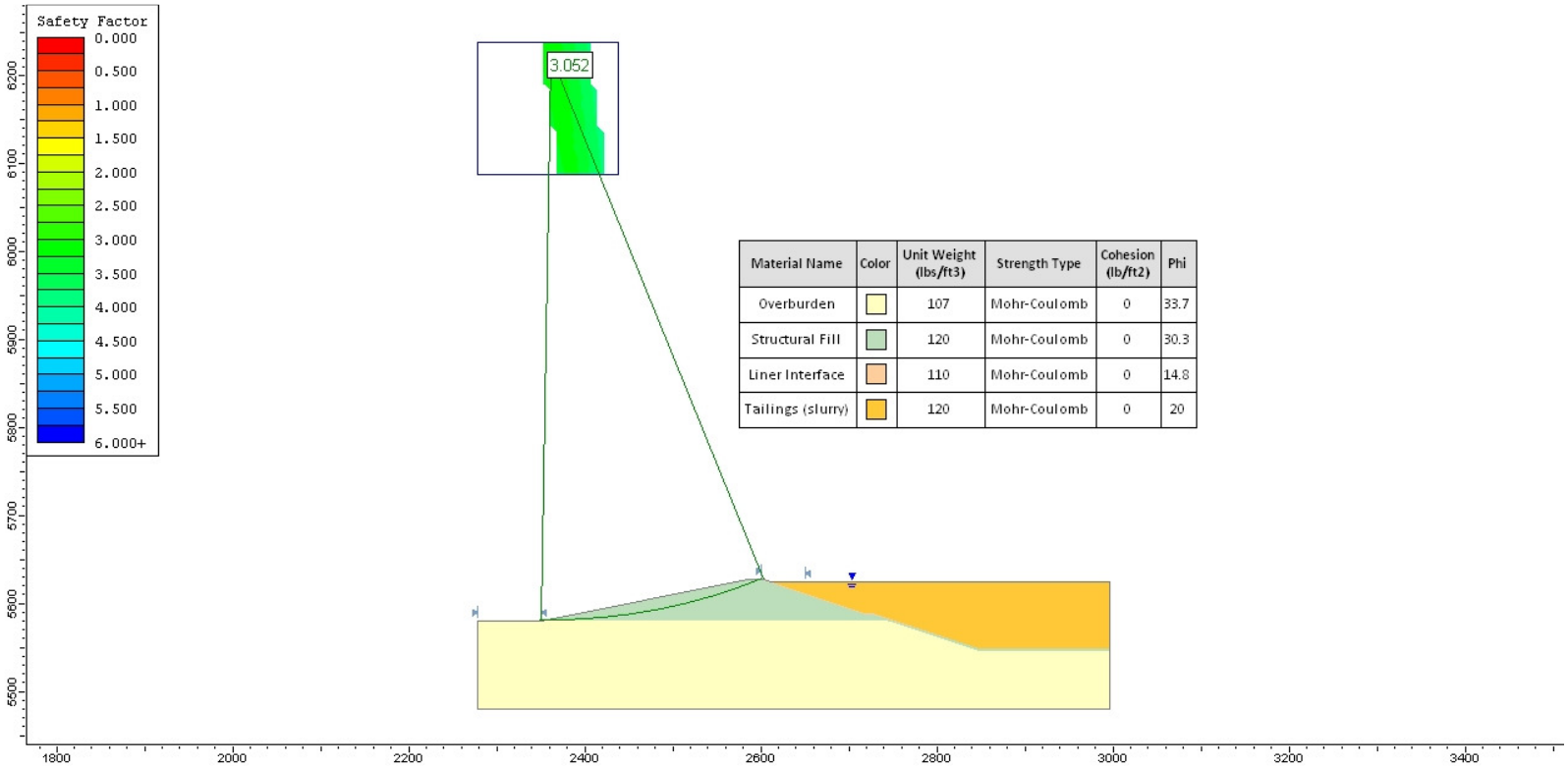


Figure 4: Critical Failure Surface (Seismic Conditions), Intermediate Filling Stage.



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi
Overburden		107	Mohr-Coulomb	0	33.7
Structural Fill		120	Mohr-Coulomb	0	30.3
Liner Interface		110	Mohr-Coulomb	0	14.8
Tailings (slurry)		120	Mohr-Coulomb	0	20

Figure 5: Critical Failure Surface (Static Conditions), Ultimate Filling Stage.

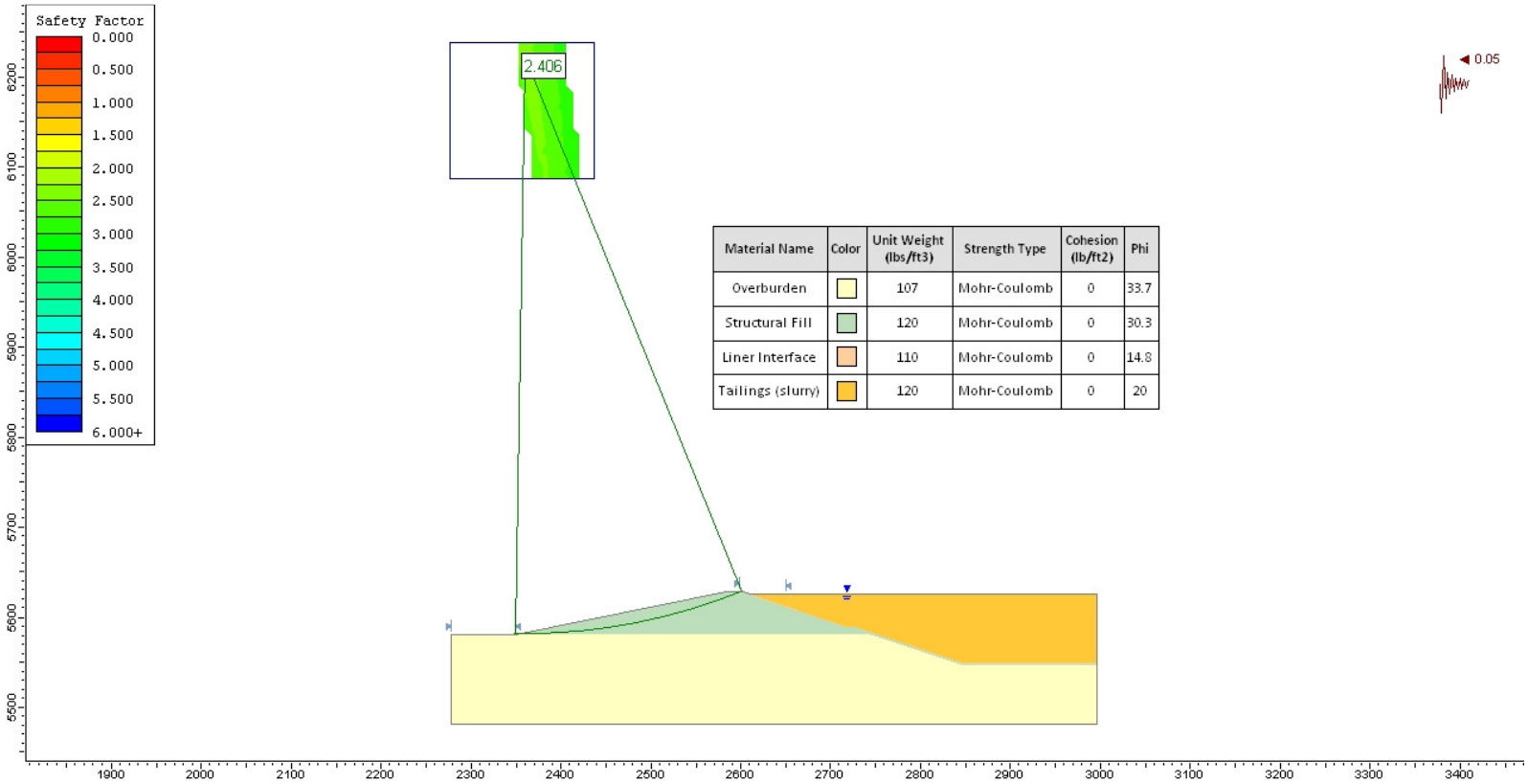


Figure 6: Critical Failure Surface (Seismic Conditions), Ultimate Filling Stage.