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Geotechnical Report for Appalachian Community Health and Disaster Readiness: Interprofessional Practice

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INTRODUCTION

The Appalachian Community Health and Disaster Readiness: Interprofessional Practice is a collaboration between the University of Tennessee's College of Nursing, Architecture, and Engineering. Each college is currently working on a variety of projects to improve overall quality of life for the rural residents of the Appalachian region of the United States and bolster local authorities' ability to respond to extreme and unexpected natural disasters. Currently, the project is primarily focused on Clay County, Kentucky. Clay County is the second poorest county in Kentucky and is plagued with poverty and poor public services and resources available to locals. The Department of Civil and Environmental Engineering is looking to create an alternative water source for the city of Manchester. There are currently around 2500 households that do not have access to clean drinking water or proper sanitation. The county has a 700 acre-foot reservoir that has reached its functional capacity to provide water; therefore, the Hydraulic Solutions Team from the Department of Civil and Environmental Engineering Senior Design class is tasked with designing a new reservoir to service unreached areas and possibly serve as a recreational attraction. The design will be converted into a cost estimate for Clay County that can be presented first to local government officials, and ultimately Congress representatives, for funding.

Hydraulic Solutions consists of several sub-teams. The environmental/waters group investigated the environmental impacts of creating a reservoir as well as the logistics of filling the reservoir with enough water to service the surrounding area. A geotechnical team worked on classifying the soil of the area as well as designing the geometry and designating the materials to construct the dam. The spillway team involved interdisciplinary work between geotechnical, structural, and water resources students to design the emergency spillway to relieve pressure on the dam during extreme flooding events. Another set of geotechnical, structural, and water resources students worked on the control tower, which controls the flow of water out of the reservoir to a future water treatment plant. A transportation group created an access road for the construction of the reservoir as well as a parking lot for recreational purposes upon completion. Finally, the construction group organized the cost estimate and scheduling for each of the reservoir's components. All of the components can be found as a plan view in Figure 1.

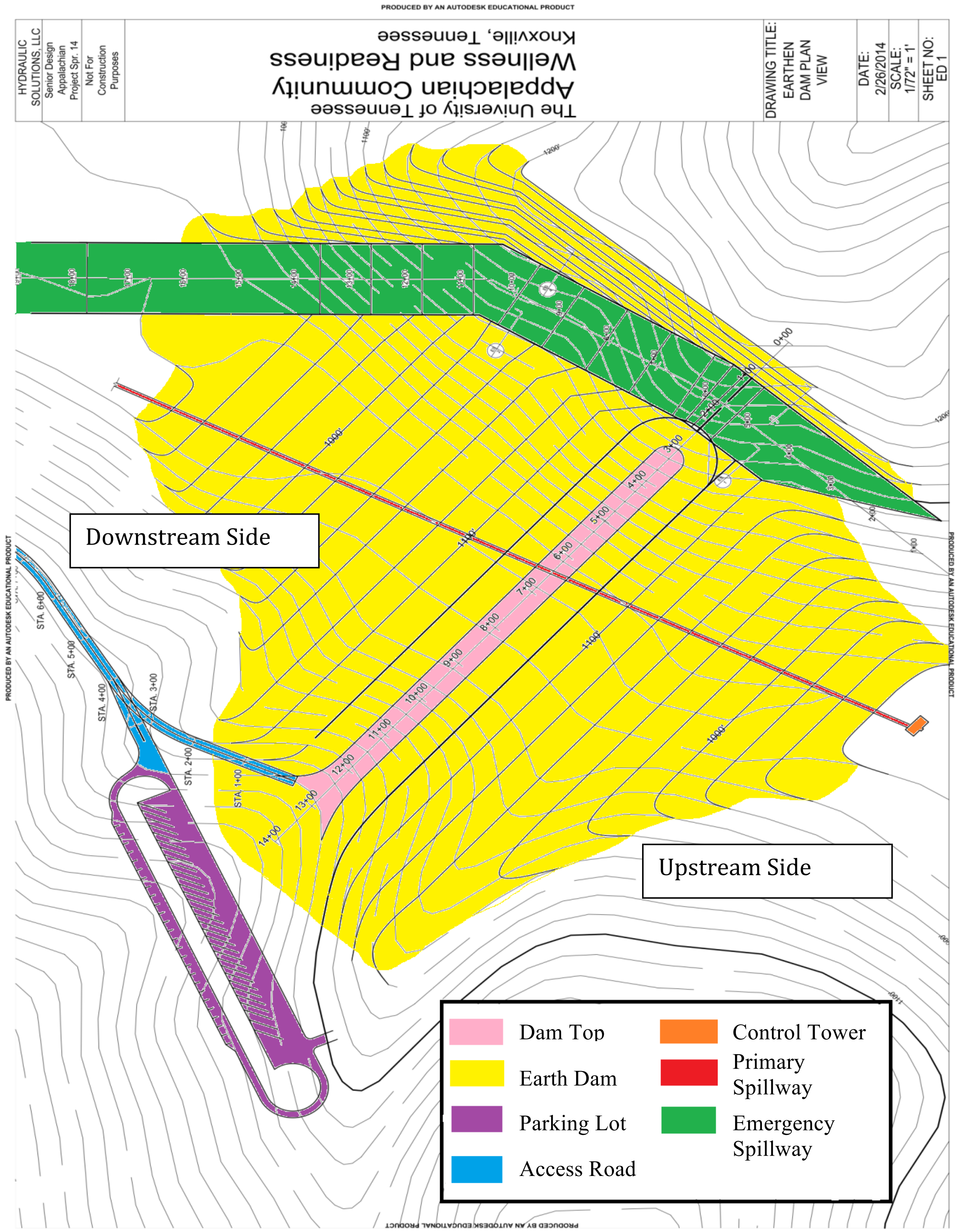

Figure 1: Plan of entire Appalachian Reservoir. Not to Scale.

EARTHEN DAM DESIGN PARAMETERS

As part of the main geotechnical team, Trey Pippen and I were responsible for designing the geometry and materials for the dam as well as analyzing the dam's slope stability under normal conditions, rapid drawdown, and after an earthquake event.

Based on Trey Pippen's soil report and USGS soil maps, the soil in the area is classified as a gravelly silt-loam. Because of the lack of clay in the region and abundant rock, the dam will be a rock-fill dam. Rock-fill dams consist of a clay core and several transitioning rock layers. The dam consists of five zones found in Figure 2. The first zone is the outermost rock layer on the upstream side of the dam. The outside slope is set to 3:1 and uses a high-quality rock from a nearby quarry. Zone 2 and Zone 4 consist of intermediate-quality rock from the areas cut soil placed at a slope of 1:1. The inner clay core should consist of 80% clay and 20% sand and gravel and should be placed at a slope of 4:15. Finally, Zone 5 should be placed at 3:1 with the best quality rock from the areas cut soils.

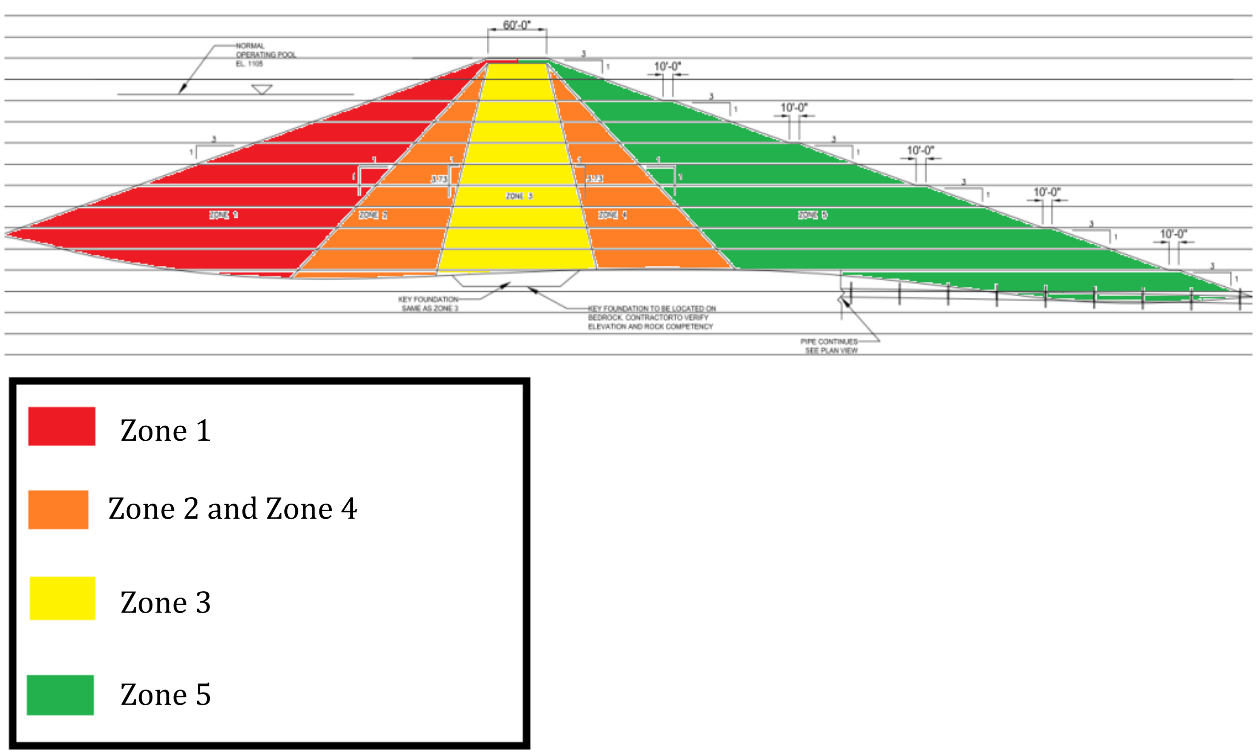

Figure 2: Material Designation Zoning for Layered Construction of Earthen Dam

SLOPE STABILITY ANALYSIS

Once the geometry and materials are assigned, the dam needs to be analyzed to verify slope stability. Originally, all analyses were to be completed with Geo-Slope International's Slope/W and Seep/W. These programs are capable of computing seepage through the soils as well as analyzing slope stability; however, due to lack of experience and restrictions of the student license, the geotechnical team opted to use Slide by rocscience. Joshua Cole, P.E., a Senior Geotechnical Engineer at S&ME Engineering, Inc., assisted the geotechnical team in using Slide. This program works through a grid and radius method. This method considers all points along the surface of the dam to be the potential start of a slip entry and exit surface. The program analyzes all of the possible radii of the slip surface. The slip surface with the lowest factor of safety is considered the critical slip plane. The critical slip plane is the weakest surface and is the plane most likely to experience failure. The factor of safety computed by the program must be greater than the respective factor of safety dictated by Kentucky Memorandum No. 5, summarized here in Table 1.

Loading Condition	Factor of Safety	Basis for Shear Strength
Rapid Drawdown	1.2	Effective Stress Analysis
Long-Term Steady Seepage	1.5	Effective Stress Analysis
Earthquake Loading	1.0	Effective Stress Analysis

Table 1: Factors of Safety required for different analyses by the state of Kentucky in Memorandum No. 5.

The first, most basic slope stability analysis performed by the design team evaluated the downstream side of the dam with consideration of the long-term steady seepage load case as prescribed by Memorandum 5. The analysis considers the seepage through the dam and the material properties of each zone. The analysis yielded a slip plane illustrated in Figure 3. The factor of safety is 1.683, which satisfies the Memorandum 5 requirement of 1.5.

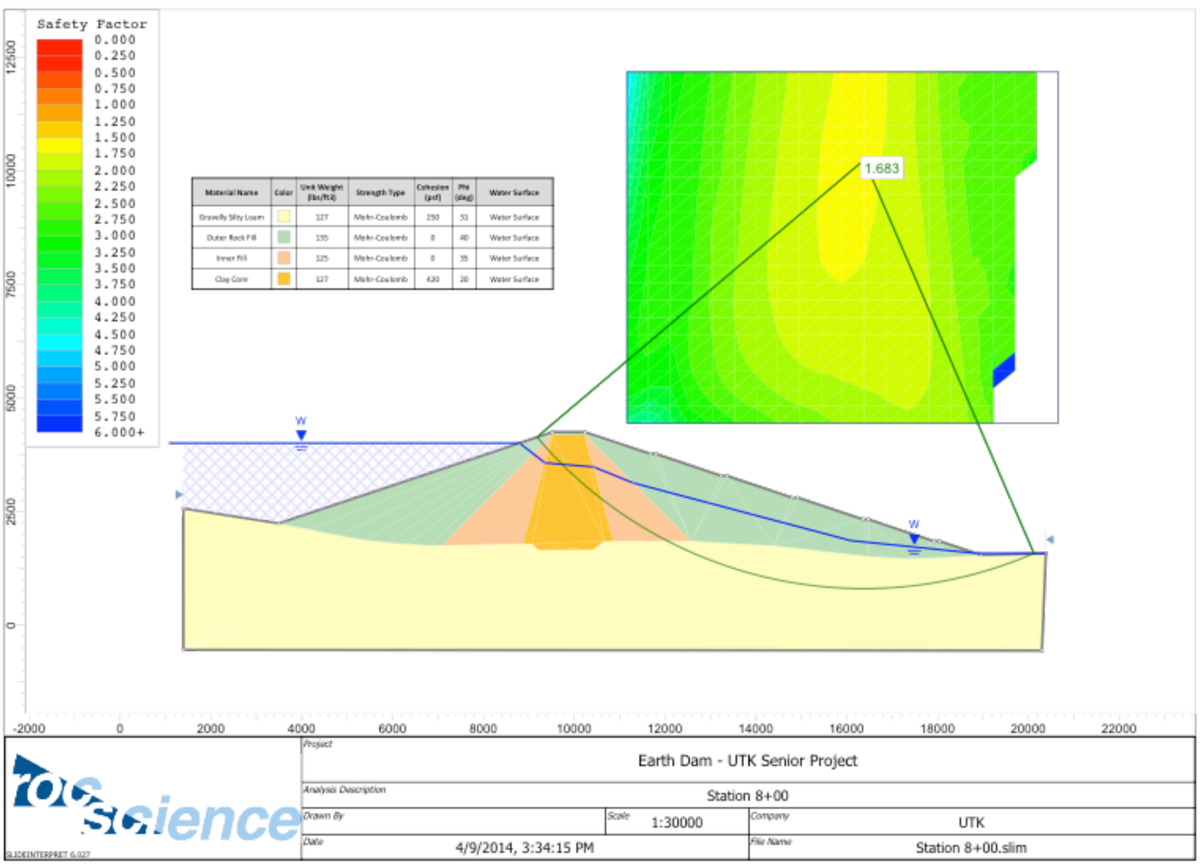

Figure 3: Downstream slope stability analysis with Factor of Safety of 1.683.

The second load condition evaluated for the slope stability of the earthen dam was the condition of rapid drawdown. Rapid drawdown occurs when the water pool adjacent to the slope is lowered faster than the bank material can drain. This analysis considers the pressure imbalance caused by the drawdown and its affect on slope stability. Originally, Zone 1 was made of the same cut soil rock as Zone 5; however, the factory of safety did not satisfy Memorandum No. 5.

To satisfy the requirement, Zone 1 was changed to a higher quality rock. After the alteration, the factory of safety of 1.253 passed the Memorandum requirements of a 1.2 factor of safety.

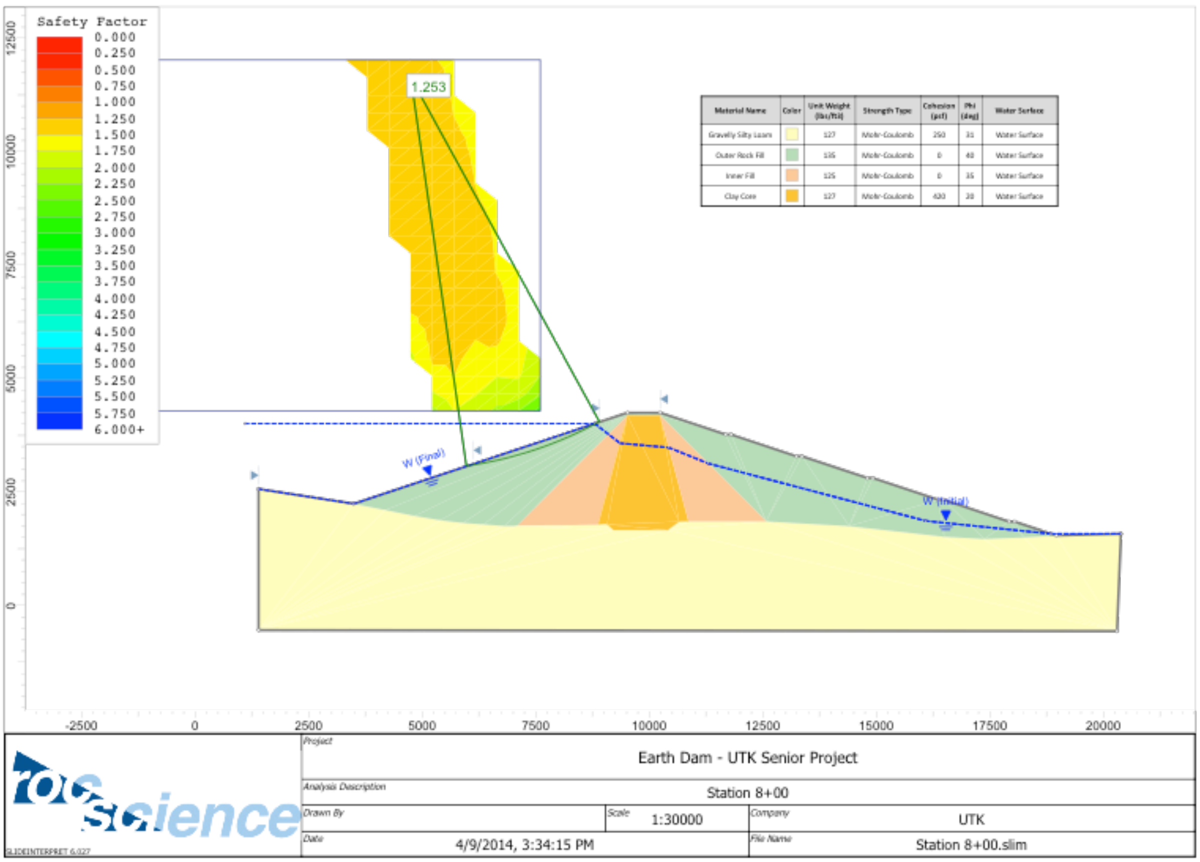

Figure 4: Rapid drawdown slope stability analysis of upstream slope with Factor of Safety of 1.253.

Lastly, slope stability analysis was required to ensure safety during a seismic event. The earthquake analysis considers the peak ground acceleration for the area. Figure 5 is a portion of a map of the United States that illustrates seismic contours. Clay County is in the peak ground acceleration range of 10% of the acceleration of gravity associated with a 1% chance of exceedance in 50 years; however, the analysis was performed at 12% of the acceleration of gravity.

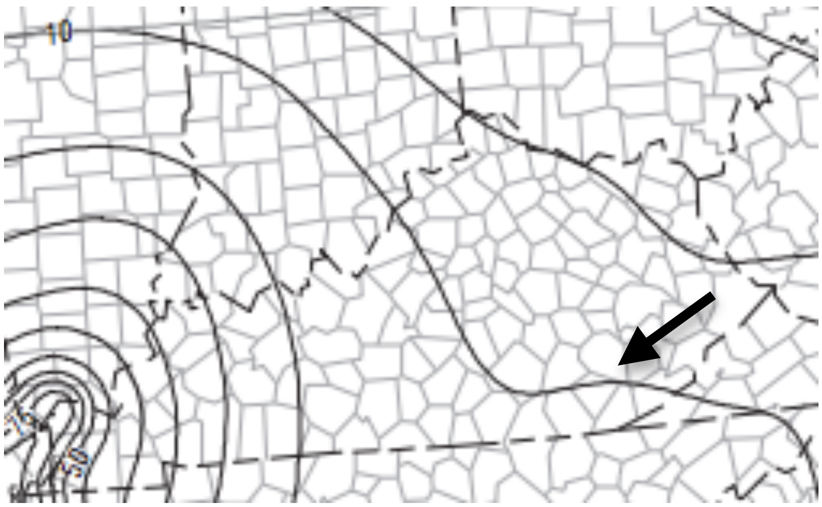

Figure 5: Seismic map indicating peak ground acceleration of Kentucky from USGS hazard design maps

Figure 6 shows the Slide analysis yields a factor of safety of 1.134, which passes the 1.0 factor of safety requirement. The actual factor of safety would be higher if the analysis had been completed at 10%, thus using a value of 12% increases the conservativeness of the design.

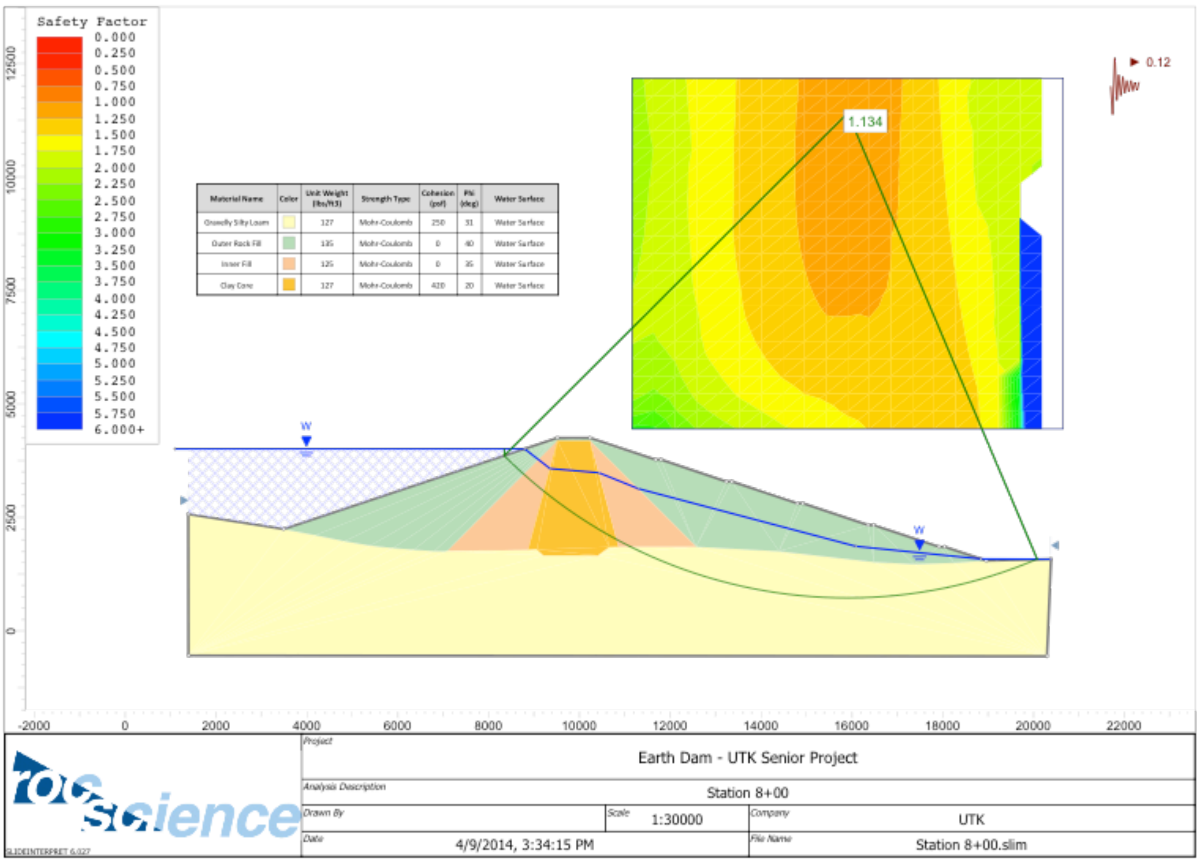

Figure 6: Earthquake slope stability analysis of downstream slope with Factor of Safety of 1.134. The earthquake peak ground acceleration (PGA) was set to 12% the force of gravity.

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