Twin Pines Minerals, LLC

LABORATORY TESTING DATA AT TWIN PINES MINE

Prepared For:

TWIN PINES MINERALS, LLC
PROPOSED HEAVY MINERALS MINE
ST. GEORGE, CHARLTON COUNTY, GEORGIA

Prepared By:

Robert M. Holt
Professor of Geology and Geological Engineering
The University of Mississippi
Department of Geology and Geological Engineering

J. Mark Tanner, PG
James R. Smith, P.G.
Austin C. Patton,
Zachary B. Lepchitz

TTL, Inc.
3516 Greensboro Avenue
Tuscaloosa, Alabama 35401
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TTL

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INTRODUCTION

On July 3, 2019, Twin Pines Minerals (TPM) submitted an individual permit application to the U.S. Army Corps of Engineers for impacts to water of the United States to develop a heavy mineral sand mine along Trail Ridge in Charlton County, Georgia (Figure 1). The proposed mine is located 3.2 miles west of St. George, Georgia, along Georgia State Highway Route 94. Trail Ridge is a 0.6 to 1.2 mile wide and 99 mile long topographic ridge that separates the Okefenokee Basin and Swamp from the coastal plain of Georgia (Force and Rich, 1979). It represents the crest of a former beach complex and was formed as inland sand dunes near the proposed Twin Pines Mine (e.g., Pirkle et al. 1993). The ridge is underlain by a shallow aquifer, locally known as the surficial aquifer, which forms a hydrologic divide between the Okefenokee swamplands to the west and the Saint Mary's River to the east. At the proposed mine site, the water table is very shallow with water depths of only a few feet. The surficial aquifer is perched on the clays of the upper Hawthorn Group, which is considered to be the upper confining unit to the Floridian Aquifer in the region (e.g., Williams and Kuniansky, 2016).

The proposed permit area is approximately 2,414-acres, located southeast of the Okefenokee National Wildlife Refuge (ONWR) boundary; however, TPM will only mine an approximate 1,268-acre area located about 2.7 miles from the ONWR boundary (Figure 2). The portion of the proposed permit area extending from the western mining boundary to the edge of the permit boundary will be avoided and will provide a buffer to the ONWR.

The project study area consists of approximately 12,000-acres of land located near St. George, Charlton County, Georgia. This area is comprised of five (5) tracts identified as Loncala, Dallas Police & Fire, Keystone, TIAA, and Adirondack. To evaluate local groundwater, surface water, and precipitation, field activities were performed both within the proposed mining area and on adjacent properties outside of the proposed mining area footprint. Reference to "project study area" in this report refers to activities conducted within the proposed mining area and adjacent tracts.

The purpose of this report is to compile and discuss results of laboratory testing data of soil/sediments collected from project study area. This data compiled from the tests performed on surface and subsurface soil/sediments will assist in modeling efforts to evaluate the proposed mining activities.

SOIL/SEDIMENT SAMPLING AND ANALYSIS

Vertical Hydraulic Conductivity

Undisturbed Borings (UD)

Fourteen soil borings (designated UD-10, UD-25, UD-34, UD-43, UD-51, UD-65, UD-67, UD-93, UD-126, UD-128, UD-179, UD-231, UD-238, and UD-338) were drilled throughout the project study area for the collection of undisturbed soil samples (Figure 3). Each UD boring was advanced utilizing TTL's CME-550 all-terrain vehicle (ATV) drill rig. Due to the presence of unconsolidated sands and a high groundwater table, a mud rotary drilling technique was used to counter saturated heaving sands within each boring. Additionally, since undisturbed samples of unconsolidated sands could not be collected using standard Shelby tube sampling methods, a Denison Sampler was used to collect undisturbed samples of unconsolidated soils. A general summary of the mud rotary drilling technique and operation of the Denison Sampler is included below.

The mud rotary drilling technique used AWJ rods with an approximate 6-inch diameter wing bit to drill down to the target sampling interval in each UD boring. A bentonite slurry (i.e. drilling mud) was circulated the entire length of the borehole to counter saturated heaving sands. Once the target sampling interval was reached the AWJ rods and wing bit were removed from the borehole and the Denison Sampler was inserted. The Denison Sampler was equipped with a sample tube designed to extend ahead of the outer rotating barrel. To obtain a sample, the Denison Sampler and outer barrel were inserted through the drilling mud and set on the bottom of the borehole. The outer barrel of the sampler was slowly rotated while, at the same time, pushing downward at a steady rate. As the sampler was pushed downward, the undisturbed soil sample was collected into a thin-wall sample tube. As the soil sample was pushed upward into the thin-wall sample tube, the drilling mud was vented to the low-pressure area on the outside of the core barrel through a disc valve. This pressure differential is what allowed the Denison Sampler to collect and retain an undisturbed unconsolidated soil sample.

Three undisturbed soil samples were collected from each of the 14 UD borings. Undisturbed samples were collected from two-foot intervals within the following general depth ranges [13 to 19 feet below ground surface (bgs), 28 to 32 feet bgs, and 43 to 50 feet bgs]. Each undisturbed sample was collected in a thin-walled sample tube that measured approximately 3-inches in diameter by 24-inches in length. Upon sample retrieval, the ends of each undisturbed sample tube were sealed, capped, and labeled. The samples were placed upright in a soil sample storage rack that was specially designed to prevent disturbance during transport. A total of 42 soil samples were transported by TTL personnel to Bowser-Morner's laboratory in Dayton, Ohio for analysis. Vertical hydraulic conductivity (Kv) analysis was performed on 41 of the 42 above-referenced undisturbed soil samples collected from select UD borings. One sample, UD-65 (43-45 feet bgs), was remolded for vertical hydraulic conductivity analysis. A summary of the Kv samples collected from the UD borings is included in Table 1. A copy of the laboratory report is included in Appendix A.

Results

Review of the laboratory report indicates that 15 of 42 UD samples were collected from semi-consolidated to consolidate sands and clayey sands. The Kv values for these samples ranged from 1.70E-08 to 6.30E-02 centimeters per second (cm/sec). A total of 27 of the 42 UD samples collected and submitted to Bowser-Morner generally classified as unconsolidated sand (SP, SM, or SP-SM classification). The results of the laboratory analyses for these unconsolidated sands indicated Kv values ranging from 2.00E-07 to 3.90E-04 cm/sec. The distribution of these Kv ranges are listed below.

Range of Kv Values (in cm/sec)	Number of Measurements	Minimum Kv Value (In cm/sec)	Maximum Kv value (in cm/sec)	Average Kv value (in cm/sec)
10^{-2}	0	---	---	---
10^{-3}	0	---	---	---
10^{-4}	8	1.00E-04	3.90E-04	2.05E-04
10^{-5}	9	1.00E-05	9.20E-05	4.07E-05
10^{-6}	8	1.40E-06	7.60E-06	4.35E-06
10^{-7}	2	2.00E-07	7.80E-07	4.90E-07

These Kv values appear to be about one to four orders of magnitude lower than typical Kv values for unconsolidated sand (which generally range from 10^{-2} to 10^{-3} cm/sec); therefore, sample collection methodology and laboratory analysis audits were performed by TTL and Bowser-Morner. Based on the audits, it was concluded that the drilling mud used to counter saturated heaving sands most likely migrated down the open borehole, through the porous sands, and into the two-foot undisturbed target sample interval, resulting in artificially lower Kv values. Therefore, field activities were initiated for the collection of additional undisturbed samples of unconsolidated soil/sediments for Kv analysis. Collection of these additional samples was performed using alternative drilling techniques that did not use drilling mud.

For the collection of these additional undisturbed samples of unconsolidated sand, four new borings were drilled within the proposed permit area, and adjacent to existing UD borings UD25, UD43, UD2338 and UD338. A CME-550 ATV mounted drill rig equipped with hollow-stem augers was used to drill each boring. Six undisturbed samples of unconsolidated sand were collected using standard

3-inch diameter by 36-inch long steel Shelby tubes. One undisturbed soil sample was collected, using the Denison sampler, in a thin-walled sample tube that measured approximately 3-inches in diameter by 24-inches in length. No drilling mud was used during the collection of these additional samples. The undisturbed soil sample identifiers, sample intervals and collection methods are listed below:

Sample Identifier	Sample Interval (in feet below ground surface)	Collection Method
UD25R	3-5 feet	Denison Sampler
	10-12 feet	Standard Steel Shelby Tube
UD43R	5-7 feet	Standard Steel Shelby Tube
	10-12 feet	Standard Steel Shelby Tube
UD238R	6-8 feet	Standard Steel Shelby Tube
	10-12 feet	Standard Steel Shelby Tube
UD338R	9-11 feet	Standard Steel Shelby Tube

Upon sample retrieval, the ends of each undisturbed sample tube were sealed, capped, and labeled. The samples were placed upright in a soil sample storage rack that was specially designed to prevent disturbance during transport. The samples were submitted to TTL's soil laboratory in Tuscaloosa, Alabama for Kv analysis in general accordance with either ASTM D 5084 "Measurement of Hydraulic Conductivity". The laboratory also performed testing to determine grain-sized distribution and the Unified Soil Classification System (USCS) classification of each sample.

Results of the laboratory analysis indicated that the Kv values for these seven additional samples ranged from 2.30E-04 to 8.50E-04 cm/sec. Six of the samples classified as a poorly graded sand (SP) and one samples classified as poorly graded sand-silty sand (SP-SM).

The Kv laboratory results of the undisturbed unconsolidated sand samples collected from borings where drilling mud was utilized (i.e. Bowser-Morner laboratory data) were compared to samples collected from borings where drilling mud was not used (TTL laboratory data). The sets of sample data were further sorted by USCS classifications. Next, the geometric means of the sorted Kv values were calculated. The geometric means of the two data sets are shown below, and the samples collected from borings where no drilling mud have a geometric mean about one order of magnitude higher than those collected from borings where drilling mud was used, indicating that drilling mud had affected the Kv values measured by Bowser-Morner .

USCS Classification = SP			
Sample Data Set	Drilling Mud Used in Borehole?	Number of Samples	Geometric Mean of Kv (cm/sec)
Bowser-Morner Laboratory Data	Yes	17	2.65E-05
TTL Laboratory Data	No	6	4.33E-04

USCS Classification = SP-SM			
Sample Data Set	Drilling Mud Used in Borehole?	Number of Samples	Geometric Mean of Kv (cm/sec)
Bowser-Morner Laboratory Data	Yes	17	1.30E-05
TTL Laboratory Data	No	1	3.20E-04

Exploratory Borings (EB)

Exploratory borings were drilled using either a Geoprobe 8150LS Rotary Sonic Rig or Terra-Sonic Rig. Undisturbed samples of the Hawthorn Group sediments were collected from exploratory borings EB03, EB06, and EB08. Locations of each of the 16 exploratory borings are shown on Figure 4. The undisturbed soil samples from each exploratory boring were collected by direct-push of a 3-inch diameter by 30-inch long steel thin-walled Shelby tube into the top of the Hawthorn Group sediments. Immediately upon retrieval of the undisturbed sample from each boring, the ends of each Shelby tube were sealed with wax, capped and labeled. The tubes were transported to TTL's soil laboratory in Albany, Georgia for measurement of hydraulic conductivity using a flexible wall permeameter (ASTM D5084 Method C). Select samples of "disturbed" black sands were collected directly from the sonic dill rig core samples extracted from exploratory boring EB16 at various depth intervals. A disturbed sample of Hawthorn Group sediments (fat clay) was also collected from boring EB16 (86 to 90 ft bgs). These samples were submitted to TTL's soil laboratory in Tuscaloosa, Alabama for Kv analysis in general accordance with either ASTM D 5084 "Measurement of Hydraulic Conductivity" or ASTM D 2434 "Measurement of Hydraulic Conductivity". A summary of the Kv samples collected from the exploratory borings is listed in Table 2. Results of the Kv analyses are included in Table 3. A copy of the laboratory report is included in Appendix A.

Results

Review of Table 3 indicates that the laboratory results for Kv values of the three undisturbed soil/sediment samples collected from the top of Hawthorn Group were:

- EB03 (92.5-94 feet bgs) = 1.61E-09 cm/sec;
- EB06 (120-122 feet bgs) = 1.29E-05 cm/sec; and
- EB08 (130-133 feet bgs) = 9.29E-09 cm/sec

The laboratory results for Kv values of the "disturbed" black sand samples collected from exploratory boring EB16 ranged from 1.90E-02 to 1.80E-04 cm/sec. The Kv value of the Hawthorn Group sediments (fat clay) collected from EB16 was 1.30E-08 cm/sec.

Piezometer Borings (PZ)

Two undisturbed samples of black humate-cemented consolidated sand were collected from the boring for piezometer PZ57D using thin-walled steel Shelby tubes. Locations of piezometers are shown on Figure 5. These two undisturbed samples were submitted to TTL's soil laboratory in Tuscaloosa, Alabama for Kv analysis. A summary of the Kv samples collected from the boring for PZ57D is listed in Table 2. Results of the Kv analyses are included in Table 3. A copy of the laboratory report is included in Appendix A.

Results

Review of Table 3 indicates that the laboratory results for Kv values of the two undisturbed samples of the black humate-cemented consolidated sand collected from the boring for PZ59D were:

- PZ59D (20-22 feet bgs) = 2.70E-08 cm/sec; and
- PZ57D (25-27 feet bgs) = 3.47E-07 cm/sec

Porosity

Porosity analysis was also performed on the above-referenced 42 soil samples collected from select UD borings within the project area. These samples were submitted to Bowser-Morner, Inc. for porosity analysis. Analysis for porosity was performed in general accordance with ASTM D 854 "Specific Gravity of Soils Solids by Water Pycnometer". Results of the porosity analyses are included in Table 4. A copy of the laboratory report is included in Appendix A.

Results

The table below summarizes the ranges of porosity values of the 42 soil/sediment samples undisturbed soil samples.

Range of Porosity Values (percent)	Number of Measurements	Minimum Porosity Values (percent)	Maximum Porosity Values (percent)	Average Porosity Values (percent)
30-35%	15	30.1%	34.6%	32.8%
35-40%	22	35.0%	39.8%	37.3%
40-45%	5	40.0%	43.7%	41.6%

Grain-Size Distribution

During the installation of piezometers at the site, a total 90 soil/sediment samples were collected from select boreholes and submitted to TTL's soil laboratory in Albany, Georgia and Tuscaloosa, Alabama for grain-size distribution analysis. Grain-size distribution analysis was also performed on 42 undisturbed soil samples collected using thin-walled Shelby tubes. These 42 samples were collected from select undisturbed (UD) borings within the project area and were submitted to Bowser-Morner, Inc. for grain-size distribution analysis. Grain-size distribution analysis for the 132 samples was performed in general accordance with ASTM D 422 "Particle-Size Analysis of Soils". Results of the grain-size distribution analysis are included in Table 5. A copy of the laboratory report is included in Appendix B.

Results

The table below summarizes the range of sand-size particles in the 125 soil/sediment samples collected for laboratory analyses of grain-size distribution.

Range of Sand-Size Particles (percent)	Number of Measurements
90-99%	93
80-89%	7
70-79%	4
60-69%	1
50-59%	5
40-49%	22

As noted in the above-referenced table, the majority of the soil samples classified as predominantly sand with very little silts or clays.

Soil-Moisture Retention Curves

Three undisturbed soil samples (SS-ADK-01, SS-KEY-01, and SS-TIA-01) were collected from the surface at three locations within the proposed permit area for soil moisture retention curve analysis (Figure 6). In addition, a full one-gallon Ziploc bag of loose material was collected from each location for remolded sample testing. The undisturbed soil samples were collected from near surface depths (within 0.5 to 1-foot bgs interval) using 3-inch by 3-inch stainless steel thin-walled Shelby tubes. The soils for the remolded sample testing were collected from the same near surface depths as the undisturbed samples. The samples were submitted to Daniel B. Stephens & Associates, Inc (DB Stephens) in Albuquerque, New Mexico for the following laboratory analyses.

Sample ID	Matrix	Number of Samples	Summary of Test Performed
SS-ADK-01	Soil	1	Gravimetric Moisture Content Volume Measurement Method Constant Head Rigid Wall Hanging Column Pressure Plate Dew Point Potentiometer Relative Humidity Box Calculated Unsaturated Hydraulic Conductivity
SS-KEY-01	Soil	1	
SS-TIA-01	Soil	1	

A listing of methods used in performance of the above-referenced tests are listed below:

Tests	Methods
Dry Bulk Density	ASTM D 7263
Moisture Content	ASTM D 7263, ASTM D 2216
Calculated Porosity	ASTM D 7263
Saturated Hydraulic Conductivity:	ASTM D 5856 (modified apparatus)
Hanging Column Method	ASTM D 6836 (modified apparatus)
Pressure Plate Method	ASTM D 6836 (modified apparatus)
Water Potential Method	ASTM D 6836
Relative Humidity Box	Campbell, G. and G. Gee. 1986. Water Potential: Miscellaneous Methods. Chp. 25, pp. 631-632, in A. Klute (ed.), Methods of Soil Analysis. Part 1. American Society of Agronomy, Madison, WI; Karathanasis & Hajek. 1982. Quantitative Evaluation of Water Adsorption on Soil Clays. SSA Journal 46:1321-1325.
Moisture Retention Characteristics & Calculated Unsaturated Hydraulic Conductivity	ASTM D6836; van Genuchten, M.T. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. SSSAJ 44:892-898; van Genuchten, M.T., F.J. Leij, and S.R. Yates. 1991. The RETC code for quantifying the hydraulic functions of unsaturated soils. Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Ada, Oklahoma. EPA/600/2091/065. December 1991.

Results of the soil moisture retention curve analyses are included in the DB Stephens, Inc. report included in Appendix C.

Results

The porosity in the soil samples ranged from 38.5% to 44.8%, and the saturated hydraulic conductivity varied from 2.0E-03 cm/s to 1.6E-02 cm/s in the undisturbed samples and 3.2E-04 to 1.1E-02 cm/s in the remolded samples. The van Genuchten (1980) parameters α and n are consistent with those of well-sorted to poorly-sorted sands.

Sample ID	Porosity (-)	Ks (cm/s)	α (cm^{-1})	n (-)
SS-ADK-01 (Undisturbed)	44.8	1.6E-02	0.0305	3.6589
SS-ADK-01 (Remolded)	39.8	1.1E-02	0.0370	2.9456
SS-KEY-01 (Undisturbed)	38.5	2.0E-03	0.0357	1.4480
SS-KEY-01 (Remolded)	39.9	1.9E-03	0.0188	1.6228
SS-T1A-01 (Undisturbed)	42.0	2.4E-03	0.0450	1.3213
SS-T1A-01 (Remolded)	40.1	3.2E-04	0.0236	1.4332

Undisturbed (UD) Drum Sample Permeability Results

Blending of Bentonite with Processed Material from Proposed Mine Site

TTL considered that the permeability of sands returned to the mine pit during reclamation/restoration may need to be reduced to ensure that groundwater levels are appropriate for maintaining wetlands. Bench-scale studies were conducted to evaluate methods for decreasing the permeability of sands returned to the mining pit. TTL drilled 14 soil borings across the study area and collected bulk sand samples from ground surface to 50 feet below ground surface (bgs), which represents the proposed average mining impact depth. The bulk sand samples collected from 0 to 50 feet bgs were drummed by individual boring location and transported to Minerals Technologies, Inc. (MT) in Stark, Florida in order to process the material in a similar manner as the proposed mining extraction process (i.e. extraction of the humate, clays (or slime), and heavy minerals). Processing was performed on April 9, 2019. Selected photographs of the processing are included in Appendix D.

The post-processed sands, minus humate, clays (referred to by MT as slimes), and heavy minerals, were drummed and then transported to TTL's office in Tuscaloosa, Alabama for hydraulic conductivity (permeability) testing. Once at TTL's office the drums were paired as indicted on Figure 7 and the paired drums were combined to ensure that sufficient material was available for testing. The drums of paired post-processed sand were identified by the following boring identifiers: UD338/25, UD238/43, UD65/51, UD67/34, UD128/126, UD93/10, and UD231 (The drum for UD179 was not received at TTL's office). Upon opening the drums, TTL personnel noted that some liquid was present. The liquid was very dark brown in color and appeared to represent residual humate. The sand samples were placed in a steel chamber that allowed for application of a load equal to approximately 4,500 pounds over 24-hours. Prior to the addition of bentonite, three simulated in-situ samples (UD 338/25 A, B, and C) were collected from the steel chamber using drive tubes for dry bulk density, moisture content, permeability testing. This process was repeated for the permeability testing of sand samples mixed with percentages of bentonite equal to 0.35% and 1.42%, respectively. Additionally, individual samples of sand were collected directly from the UD338/25 drum and mixed with the following percentages of bentonite 5%, 7.5%, 10%, 12.5%, 15%, and 30%. After mixing each sample was remolded and tested for permeability. Bentonite used for testing was a Wyoming bentonite, high yield, high viscosity bentonite produced by Halliburton, Baroid Industrial Drilling Products. Permeability test results are provided in Table 6. A copy of the laboratory report is included in Appendix E.

Results

TTL also performed permeability tests on two undisturbed samples of black humate-cemented consolidated sand collected from the borehole for PZ57D. Results of the tests performed on the black consolidated sand samples are also listed in Table 6. Results of this bench-scale study indicated that a mixture of approximately 10% to 12.5% bentonite would be required to achieve a relative permeability similar to the results calculated for the black humate-cemented consolidated sand in the two samples from PZ57D.

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