

ISSUED FOR USE

To:	Aaron Marsh, P.E. – Tailings Manager	Date:	August 17, 2024
c:		Memo No.:	2024-02
From:	Morgan Dumkee, Ian MacIntyre P.Eng.	File:	704-ENG.WARC04415-09
Subject:	Tailings Placement and Compaction Field Trial Summary and Recommendations Keno Hill Mine DSTF, YT		

This 'Issued for Review' document is provided solely for the purpose of client review and presents our interim findings and recommendations to date. Our usable findings and recommendations are provided only through an 'Issued for Use' document, which will be issued subsequent to this review. Final design should not be undertaken based on the interim recommendations made herein. Once our report is issued for use, the 'Issued for Review' document should be either returned to Tetra Tech Canada Inc. (Tetra Tech) or destroyed.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) has been retained by Alexco Keno Hill Mining Corp. (AKHM) doing business as Hecla Yukon, to assist in developing a Standard Operating Procedure (SOP) for the placement and compaction of tailings on their Dry Stack Tailings Facility (DSTF) at the Keno Hill Mine, located near Keno City, YT.

This work was authorized under the Engineering Services Agreement between AKHM and NELPCo of which Tetra Tech is the primary service provider.

2.0 BACKGROUND

Tailings stored in the DSTF must be placed and compacted in such a manner as to promote runoff, limit erosion, avoid excessive settlement over time, and maintain the stability and performance of the facility.

Compaction testing would typically be carried out using a nuclear densometer to measure the wet density and moisture contents of the compacted soil and comparing the in-situ density to the Standard Proctor Maximum Dry Density (SPMDD) determined in a laboratory. However, the metals content of the mine tailings precludes the use of any nuclear testing methods. Density testing can only be reliably measured directly using volumetric methods (e.g., with the use of the sand cone method or balloon method), or indirectly using penetration/ resistance methods.

The goal of the work completed, and recommendations outlined below is to assist AKHM in developing a standard procedure for placement and compaction of tailings and confirm the methods and minimum requirements for Hecla and the Engineer of Record to verify adherence to this procedure and confirm design and performance requirements are achieved.

To aid in this, Tetra Tech implemented a field trial to collect the following data/samples:

- Using the sand cone method in combination with oven drying samples to determine the in-situ wet and dry density of the tailings. (ASTM D1556);
- Using a dynamic cone penetrometer (DCP) to approximate the soils modulus using empirical correlations. (ASTM D6951); and,
- Using a drive sampler to collect 100 mm long sample tubes for density and moisture determination. (ASTM D2937).

It is anticipated that most of the compaction on the dry stack will be achieved by trackpacking with the dozer while it works to spread the tailings. This field trial was intended to determine the minimum number of passes the dozer must complete to achieve compaction. It is expected that a vibratory smooth roller will be used to seal the final surface of each lift.

The proposed field trial procedure was documented and submitted to Hecla in a Technical Memorandum dated July 15, 2024 (Tailings Placement and Compaction Field Trial Procedure, 704-ENG.WARC04415-09).

3.0 FIELD TRIAL SUMMARY

The field trial was completed on July 17, 2024, by Morgan Dumkee, Geotechnical Technician, based out of Tetra Tech's Whitehorse office. The test pad was placed on top of the Phase 1 dry stack facility. The general area, at the time of the field trial, was noted to have some surficial rutting from recent rain and haul truck traffic, and some localized water was observed on the surface. Based on visual observations it was determined that additional moisture conditioning of tailings was not required for compaction. Moisture contents obtained by laboratory testing confirm that the fresh tails were within 2-4% of optimal moisture.

A test area consisting of a pad roughly 10 m by 10 m and 0.5 m thick was spread using a Caterpillar D6 dozer under the supervision of Tetra Tech's technician. After spreading this pad, the dozer track-packed it in two passes. For the purposes of this report and the recommendations herein, one "pass" is defined as the tracks passing over the same strip of material forwards and backwards.

The technician performed three sand cones and three DCP tests, distributed evenly across the pad. Sand cones were performed after removing roughly 150 mm of material from the surface of the pad, to allow testing of the material approximately 150 mm – 350 mm in depth (i.e., to represent approximately the middle of the lift). DCP tests were performed to a depth of roughly 1.2 m.

Collection of drive samples was attempted; however, it was difficult and impractical to obtain a clean sample with the two uniform faces necessary to obtain accurate volume measurements with confidence.

Once this first round of testing was complete, the dozer performed another four track passes of the pad, bringing the total to six passes. The technician repeated the testing above, Testing was repeated after the dozer track-packed it with four more passes, for a total of ten passes.

Finally, the pad was sealed with two passes of a Caterpillar CS-563E smooth drum vibratory compactor. Testing was repeated after this final effort.

4.0 RESULTS AND DISCUSSION

Results of the field trial are summarized and discussed in the following sections.

4.1 Sand Cone Results

A summary of the compiled results from sand cone testing is shown in Table 1 below

Table 1 – Sand Cone Test Results, July 17, 2024

Compaction Scenario	Sand Cone ID	Wet Density (kg/m ³)	Lab Moisture (%)	Dry Density (kg/m ³)
2 Passes with D6	SC 1-1	2202	17	1890
	SC 1-2	2124	19	1793
	SC 1-3	2178	16	1881
	Mean	2168	17	1854
	Standard Deviation	33	1	44
6 Passes with D6	SC 2-1	2032	18	1721
	SC 2-2	2394	17	2043
	SC 2-3	2349	17	2014
	Mean	2258	17	1925
	Standard Deviation	161	1	146
10 Passes with D6	SC 3-1	2248	18	1913
	SC 3-2	2388	17	2037
	SC 3-3	2290	17	1962
	Mean	2309	17	1971
	Standard Deviation	59	0	51
10 Passes with D6, 2 Passes with Roller	SC 4-1	2111	17	1799
	SC 4-2	2442	18	2071
	SC 4-3	2436	17	2075
	Mean	2330	18	1982
	Standard Deviation	155	0	129

The results in Table 1 show the standard deviation is relatively high for SC 2 and SC 4. This has been considered during the evaluation of results. Selectively removing the outliers for these data sets affects the overall values determined, but not the overall trend and recommendations herein.

Considering the complete datasets, the maximum achieved mean dry density was 1982 kg/m³ after 10 passes with the D6 and 2 passes with the vibratory roller. The tailings tested were likely 1-3% above their optimum moisture and allowing for inefficiencies during compaction/placement (i.e., effort loss to compacting underlying tailings, etc.), it was assumed that the maximum density achieved in the field was no more than 98% of the maximum achievable with standard effort. Therefore, engineering judgement was applied, and this maximum field density was divided by

0.98 to determine a field maximum dry density (MDD) of approximately 2020 kg/m³ for the tailings material and location tested.

4.2 Dynamic Cone Penetration Testing

The overall depths of DCP tests typically ranged up to approximately 1.0 m to 1.6 m. A high degree of variability was observed within the upper 30 cm of tailings. This may be attributed to surface affects from trackpacking, etc. Therefore, readings from this depth range were omitted.

To normalize the datasets for direct comparison, depth ranges of 0.3 – 1.0 m and 0.2 – 0.6 m were chosen as the ranges of interest for review.

A summary of the compiled results from DCP testing is shown in Table 2 below.

Table 2 – DCP Test Results, July 17, 2024

Compaction Scenario	DCP ID	Mean DCP Index between 0.3 m and 1.0 m in Depth (cm/blow)	Mean DCP Index between 0.2 m and 0.6 m in Depth (cm/blow)
2 Passes with D6	DCP 1-1	4.97	7.01
	DCP 1-2	3.51	7.87
	DCP 1-3	2.43	6.03
	Mean	3.64	6.97
	Standard Deviation	1.04	0.75
6 Passes with D6	DCP 2-1	3.82	7.93
	DCP 2-2	1.91	6.38
	DCP 2-3	2.73	5.68
	Mean	2.82	6.66
	Standard Deviation	0.78	0.94
10 Passes with D6	DCP 3-1	2.88	5.42
	DCP 3-2	3.10	5.83
	DCP 3-3	1.59	3.49
	Mean	2.52	4.91
	Standard Deviation	0.67	1.02
10 Passes with D6, 2 Passes with Roller	DCP 4-1	2.37	4.16
	DCP 4-2	2.50	4.94
	DCP 4-3	1.71	3.38
	Mean	2.19	4.16
	Standard Deviation	0.35	0.63

Generally, the DCP test data correlating with the MDD discussed in the previous section indicated a DCP Indices of approximately 2.2 cm/blow after 10 passes with the D6 and 2 passes with the vibratory roller for depths between 0.3 m and 1.0 m, and 4.2 cm/blow for depths between 0.2 and 0.6 m, as depicted in Figure 1 below.

This data set provides a baseline for analysis; however, additional DCP testing should be completed as noted in the recommendations below. It is important to note that the current DCP dataset is primarily applicable to the lower portion of each new lift of tailings placed and compacted, and the lift immediately below it.

4.3 Standard Proctor Maximum Dry Density

A sample was collected from the field trial test area and returned to the Whitehorse laboratory for SPMDD testing.

The resulting proctor was interpreted to be 1940 kg/m³ with an optimum moisture of 13.5%, and is included in Appendix B.

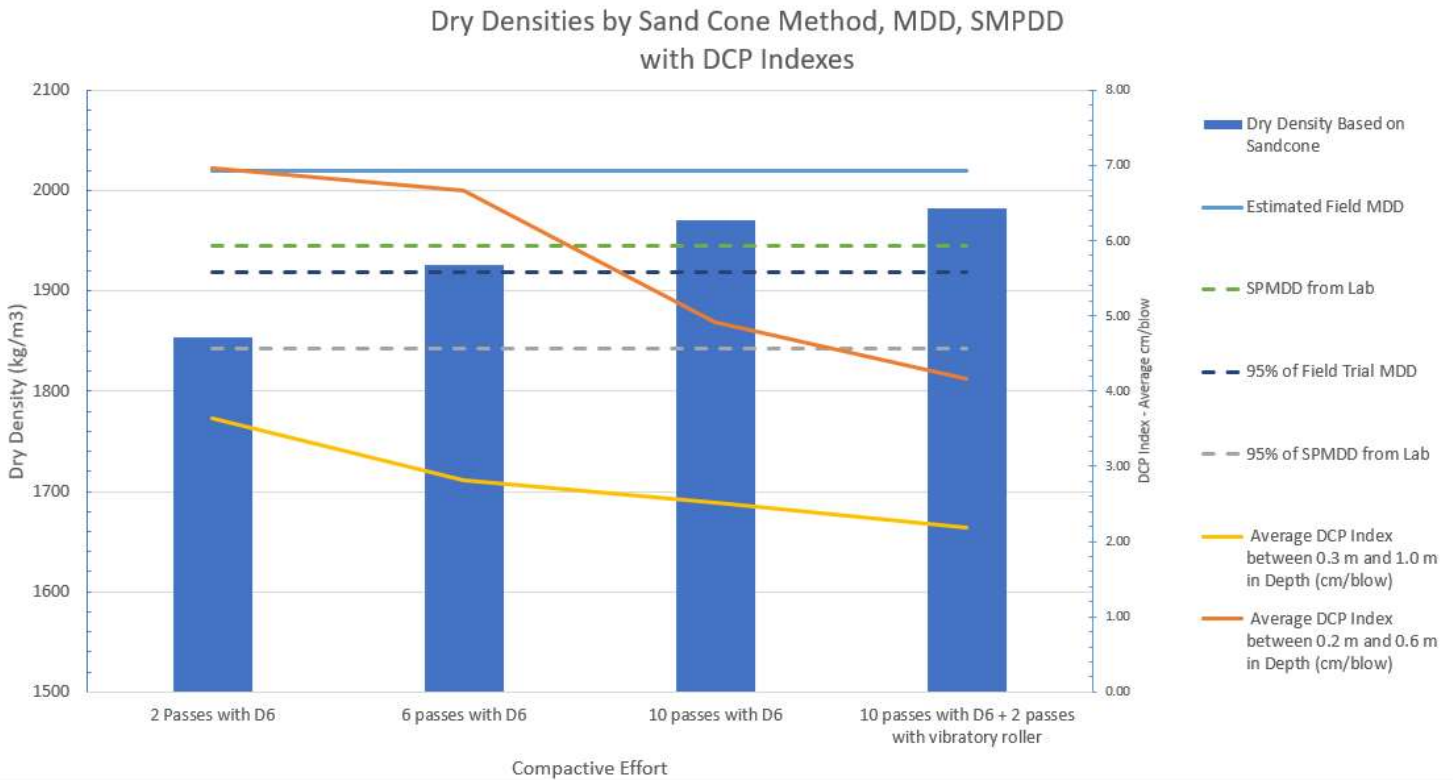
4.4 Discussion

Reviewing the data summarized above, the follow observations can be made:

- 6 passes with the D6 achieved a mean density of 1925 kg/m³.
 - Equivalent to 95.3% of the field determined MDD of 2020 kg/m³ presented in Section 4.1; and
 - Equivalent to 99.2% of the SPMDD of 1940 kg/m³ presented in Section 4.3.

The following figure presents the general findings of the sand cone testing and DCP indices interpreted under each compaction scenario, as well as estimated MDD and laboratory SPMDD.

Figure 1 – Summary of Findings



5.0 RECOMMENDATIONS

To achieve a minimum compaction of 95% SPMDD, Tetra Tech recommends that tailings be placed and compacted as follows:

- Placed and spread in a maximum loose lift thickness of 500 mm;
- Track-packed at least six times using the D6 Caterpillar dozer, or equipment with equivalent or greater ground pressure; and
- Complete at least final two passes with a large smooth drum vibratory which will also seal and promote runoff from the working front.
- Note compaction by the spreading equipment and compactor must cover the surface area of the lift in its entirety. One pass is counted as forward and backwards.

Quality Control (QC) and Quality Assurance (QA) recommendations include:

- Layout and as-built surveys should be completed as necessary to support operations staff in tailings placement and to confirm lift thicknesses do not exceed 500 mm.
- Spreading and compaction of tailings should be visually monitored by designated Hecla staff at least once weekly to confirm the placement recommendations above are being adhered to.
- Tetra Tech understands Hecla intends to purchase DCP equipment. QC DCPs should be completed weekly. An interim maximum Depth Penetration Index (DPI) of 3 cm/blow between 0.3 m and 1.0 m should be considered for initial use, however this target should be reviewed and updated with each new set of data, as necessary. DCPs should be completed to a depth of at least 1.2 m and up to 2.0 m.
- Laboratory proctors (ASTM D698-12) and specific gravities (ASTM D5550-14) should be completed on a monthly basis.
- QA DCPs should be completed by Tetra Tech on a quarterly basis.
- Sand cone testing should be repeated on an annual basis.

All other requirements documented in the DSTF Operations, Maintenance, and Surveillance (OMS) manual are to be followed.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of AKHM and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than AKHM or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

7.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.



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Enclosure: Tetra Tech's Limitations on the Use of this Document

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

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If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

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The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

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While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address or consider and has not explored, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historical environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional exploration and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX B

STANDARD PROCTOR MAXIMUM DRY DENSITY LAB RESULTS

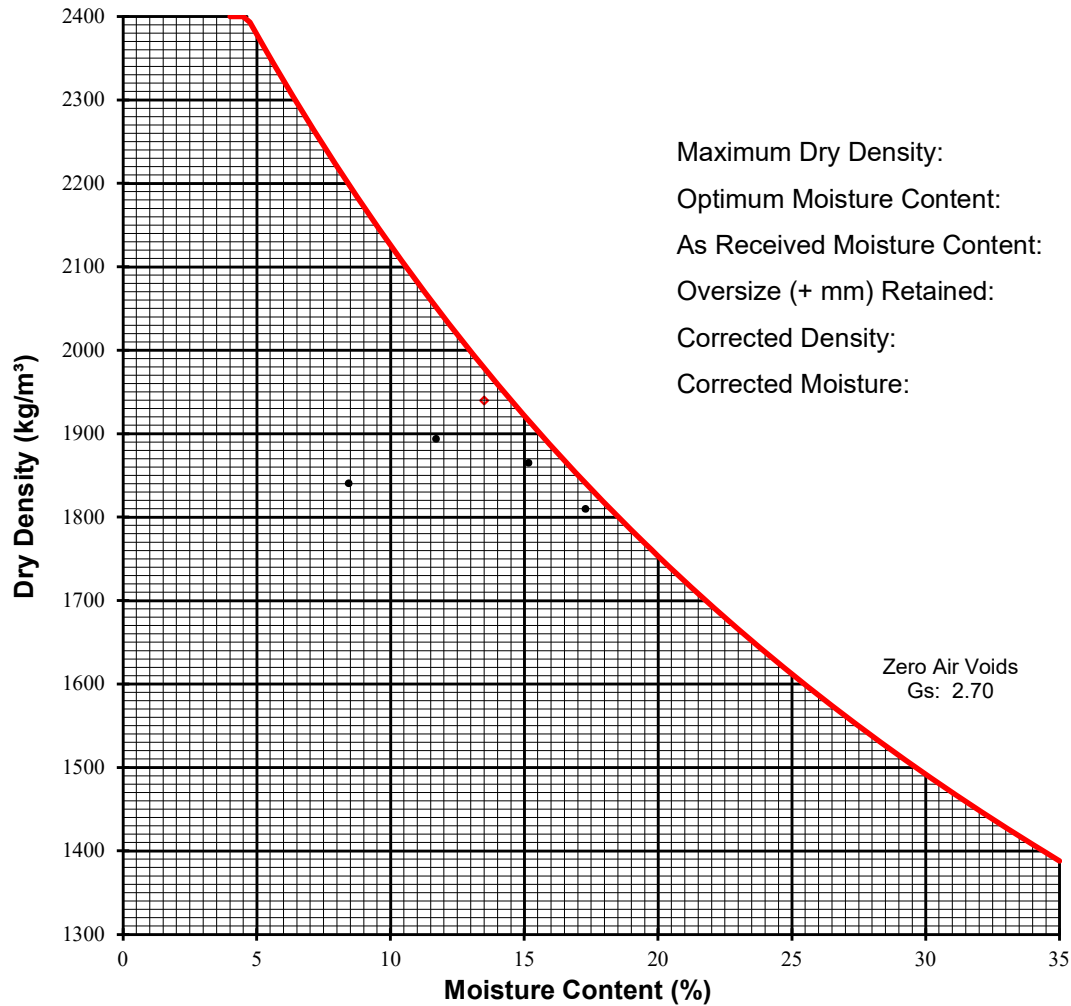
SA03 – Field Trial Sample

MOISTURE-DENSITY RELATIONSHIP (Proctor) REPORT

ASTM D698 Standard

Project: AKHM DSTF
Client: Hecla
Attention: -
Project No.: ENG.WARC04415-09
Description: Tailings
Source: Top of DSTF, fresh tailings

Sample No.: SA03
Sampled By: MD
Sample Date: -
Test Date: July 26, 2024
Preparation: Moist
Compaction: Manual



Remarks: -

Reviewed By:  P.Eng.

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