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**Date:** August 22, 2024  
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**Subject:** Instrumentation and Monitoring Plan – DSTF Phase 2 East  
Keno Hill Mine, YT

## 1.0 INTRODUCTION

This document presents the Instrumentation and Monitoring plan (IMP) for the Phase 2 East Dry Stacked Tailings Facility (DSTF P2E) at the Keno Hill Silver District Mining Operations (Keno Hill) near Keno City, Yukon. Keno Hill is an underground silver, lead, and zinc mine operated by Alexco Keno Hill Mining Corporation (AKHM), owned by Hecla Mining Company (Hecla). The site is operated under Quartz Mining License No. QML-0009.

Filtered tailings are presently being stored in the Phase 1 DSTF. Tailings are hauled from the mill to the DSTF where they are spread and compacted. The Phase 2 DSTF is located southeast of the P1 facility and comprises a lined containment facility, associated buttressing as required for stability, and is surrounded by perimeter ditching which ultimate directs contact water to the Mill Pond for water treatment. Details related to the P2 DSTF are available in the design report (revision in progress).

AKHM is planning to phase construction of the Phase 2 DSTF: the eastern portion of the Phase 2 DSTF (DSTF P2E) will be constructed in late summer/early fall 2024; the western portion (DSTF P2W) in 2025.

This IMP outlines planned instrumentation for the DSTF P2E to monitor the facility for potential failure modes as described in the Failure Modes and Effects Analysis (revision in progress). The IMP is designed for mine operations. Additional instrumentation planning will be required as part of closure.

Design updates to the P2E DSTF are presently in progress. The IMP will be updated as required to reflect design updates, and site observations during construction.

## 2.0 OBJECTIVES

The DSTF P2E instrumentation and monitoring plan is intended to:

- Confirm safe operating conditions and performance, consistent with design expectations;
- Provide advanced warning of developing instabilities and information related to instability mechanisms;
- Quantify displacement, rates, and other trends in collected data;
- Establish and maintain a record of facility performance; and
- Provide monitoring of mechanisms associated with failures modes addressed in the FMEA.

A Failure Modes and Effects Analysis workshop was completed on July 3, 2024. This workshop was attended by Tetra Tech, Hecla, and members of Hecla's Independent Tailings Review Board (ITRB). The goal of the workshop was to evaluate design and performance risks to further guide instrumentation requirements and improve design and operational components.

Potential failure modes (PFMs) were identified and categorized according to Hecla's consequence and likelihood definitions, and subsequently their Risk Classes identified using the risk matrix included in the FMEA report (under revision). PFMs were evaluated with 'no controls' in place and with 'operation or engineering controls' to manage risk. Table 2-1 summarizes the preliminary moderate, high or critical risks identified in the FMEA. It should be noted, that apart from PFM 10 (Differential Settlement) and PFM 017 (dust release), PFM risk dropped substantially with operational and engineering controls.

Instrumentation is recommended to monitor facility performance and confirm controls are functioning as intended. Generally, the instrumentation consists of:

- Ground temperature cables to monitor changes in foundation soil temperatures, indicative of changes in ground ice and permafrost conditions, which may predict ongoing or future deformation.
- Slope inclinometers to monitor trends in ground movement within the facility foundation and the P2E toe buttress.
- Survey monuments to monitor trends in surficial movement along the facility buttress and final tailings surface.
- Vibrating wire piezometers to monitor trends or changes in porewater pressures within the facility foundation (i.e., below the liner system) and within the base of the tailings (i.e., above the liner system).

In some cases instrumentation is proposed to directly monitor a specific PFM; in other, it provides operational data that used as part of subsequent design. PFM specific instrumentation is indicated in Table 2-1.

The monitoring recommendations discussed herein are to be referenced in conjunction with the DSTF Phase 2 Design and Construction Drawings (revision in progress) and incorporated into the next update of the DSTF Operations, Maintenance, and Surveillance (OMS) manual. Quantifiable performance objectives (QPO) and trigger and response plans (TARP) related to instrumentation will be included in the OMS manual.

Facility performance will also be monitored during operation using physical inspections and in situ testing methods also documented in the OMS manual.

**Table 2-1: Moderate and High Risk PFMs for Phase 2 East DSTF**

PFM ID	PFM Description	Risk Class <sup>1</sup> (No Control)	Risk Class <sup>1</sup> (With Control)	Controls	Instrumentation
PFM-001	Global slope instability - deep seated static failure through foundation	Moderate	Low	<ul style="list-style-type: none"> <li>▪ Engineering design to meet target factors of safety for stability (1.5 for static conditions, greater than 1.0 for post-seismic)</li> <li>▪ Stability assessment based on conservative parameters                             <ul style="list-style-type: none"> <li>– Consideration of frozen and unfrozen ground conditions</li> <li>– Reduced shear strength for placed tailings</li> </ul> </li> <li>▪ Conservative assumption for original ground friction angle</li> </ul>	<ul style="list-style-type: none"> <li>▪ Slope Inclinometers</li> <li>▪ Survey Monuments</li> <li>▪ Vibrating Wire Piezometers</li> </ul>
PFM-002	Global slope instability - deep seated static failure through tailings	High	Low	<ul style="list-style-type: none"> <li>▪ Engineering design to meet target factors of safety for stability (1.5 for static conditions, greater than 1.0 for post-seismic)</li> <li>▪ Stability assessment based on conservative parameters                             <ul style="list-style-type: none"> <li>– Consideration of frozen and unfrozen ground conditions</li> <li>– Reduced shear strength for placed tailings</li> <li>– Conservative assumption for original ground friction angle</li> </ul> </li> <li>▪ Implementing standard procedure for placement and compaction based on completed field trials</li> <li>▪ Monitoring tailings placement and facility performance per OMS for signs of movement or distress</li> </ul>	<ul style="list-style-type: none"> <li>▪ Survey monuments at areas of concern</li> </ul>
PFM-003	Global slope instability - deep seated static failure through liner interface	High	Low	<ul style="list-style-type: none"> <li>▪ Engineering design to meet target factors of safety for stability (1.5 for static conditions, greater than 1.0 for post-seismic)</li> <li>▪ Stability assessment based on conservative parameters                             <ul style="list-style-type: none"> <li>– Residual shear strength at liner interface</li> <li>– Reduced shear strength for placed tailings</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Slope Inclinometers</li> <li>▪ Survey Monuments</li> <li>▪ Vibrating Wire Piezometers</li> </ul>
PFM-004	Tailings liquefaction during seismic event	Moderate	Low	<ul style="list-style-type: none"> <li>▪ Design targets minimum densities to reduce risk of liquefaction</li> <li>▪ Advanced laboratory testing being completed to evaluate credibility of PFM</li> <li>▪ Quality control during construction and operation to ensure compliance with design</li> <li>▪ CPT Investigation program to measure behaviour of Phase 1 tailings</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed instrumentation</li> </ul>
PFM-007	Static liquefaction of tailings	High	Moderate	<ul style="list-style-type: none"> <li>▪ Design targets minimum densities to reduce risk of liquefaction</li> <li>▪ Advanced laboratory testing being completed to evaluate credibility of PFM</li> <li>▪ Quality control during construction and operation to ensure compliance with design</li> <li>▪ CPT Investigation program to monitor in situ density</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed instrumentation</li> </ul>
PFM-009	Crest / side-slope erosion (i.e., vehicle traffic, heavy equipment, lack of compaction, general precipitation erosion on side-slopes)	Moderate	Low	<ul style="list-style-type: none"> <li>▪ Quality control during construction and operation to ensure compliance with design</li> <li>▪ Visual assessment during construction and operation and following large storm events</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed instrumentation</li> </ul>
PFM-010	Large differential settlement or deformation due to permafrost thaw, leading to surface tailings exposure and/or breach of seepage collection system	Moderate	Moderate	<ul style="list-style-type: none"> <li>▪ Potential for differential movement accounted for in design</li> </ul>	<ul style="list-style-type: none"> <li>▪ Ground Temperature Cables</li> </ul>
PFM-011	Geochemical compatibility of tailings and seepage collection system	High	Low	<ul style="list-style-type: none"> <li>▪ Change management process to ensure changes in mill processes do not introduce chemicals into the tailings that are incompatible with the liner.</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed instrumentation</li> </ul>
PFM-012	Compromised physical performance of seepage collection system (puncture, lack of overlap, etc.)	High	Low	<ul style="list-style-type: none"> <li>▪ Drainage blanket designed with maximum particle size to reduce potential for liner damage. A non-woven geotextile has been implemented as a cushion layer between the drainage blanket layer and the GCL.</li> <li>▪ Placement of liner system and drainage blanket will be monitored by Construction Monitor to verify compliance with specifications. Proper QAQC during construction to verify adequate bearing surface with no protrusions prior to liner installation.</li> <li>▪ Groundwater monitoring systems installed in foundation and in above- and below-liner drains</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed geotechnical instrumentation</li> </ul>
PFM-017	Release of dust from facility impacting off-site air quality, soils, or water	High	High	<ul style="list-style-type: none"> <li>▪ Dust monitoring will occur as per the Dust Abatement and Monitoring Plan</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed geotechnical instrumentation</li> </ul>
PFM-018	Operational safety due to poor construction (e.g. vehicle roll over). This impacts AKHM's reputation and could possibly delay material placement for investigations or clean up	High	Low	<ul style="list-style-type: none"> <li>▪ Monitoring during material placement to verify compliance with design</li> <li>▪ Development of operational procedures to safe guard against accidents (ie. Minimum set backs from crest, hazard assessment)</li> </ul>	<ul style="list-style-type: none"> <li>▪ No proposed instrumentation</li> </ul>

<sup>1</sup>Risk class based on current FMEA (under revision). IMP will be updated as required

## 3.0 INSTRUMENTATION SUMMARY

### 3.1 Ground Temperature Cables

#### 3.1.1 General

The DSTF P2 facility is underlain by discontinuous warm permafrost, typically above -0.4°C. Localized zones of ice-rich material are known to exist, particularly in the northwest corner of Phase 2 DSTF. Thermal modelling, supported by observations of foundation ground temperatures in the Phase 1 DSTF indicates that this permafrost will thaw over the coming decades. Thawing permafrost, particularly ice-rich permafrost may lead to settlement, development of increased pore water pressure, and ponding of water.

Ground temperature monitoring will be completed within the DSTF P2 footprint. This will provide baseline data for ground conditions and provide monitoring data in support of PFM-10 (Differential settlement due to permafrost thaw)

#### 3.1.2 Instrumentation Plan

GTCs typically consist of temperature sensor (thermistor) beads installed at multiple positions along a single cable. Measurement accuracy is typically about 0.1°C.

Seven ground temperature cables (GTCs; see Table 3-1) have been installed within the DSTF P2 footprint as part of previous investigations. These GTCs will be maintained and incorporated into the monitoring plan for DSTF P2E.

**Table 3-1: Ground Temperature Cable Information Within the DSTF P2 Footprint**

Borehole Number	GTC Cable Type & No.	No. of Beads	Original Ground Elevation (m)	Bottom of Borehole Elevation (m)
BH22-01	Tetra Tech #2819	16	917	902.5
BH22-05	Tetra Tech #2820	16	931.7	904.9
BH22-06	Tetra Tech #2821	16	933	902.5
BH22-07	Tetra Tech #2822	16	924.4	909.9
BH22-08	Beaded Stream #4473	36	926.5	903.6
BH22-09	Tetra Tech #2823	16	924.1	895.8
BH22-10	Beaded Stream #4474	25	918.6	896

The existing GTCs in the P2E footprint will be protected during construction and their leads extended to central locations outside of the footprint, as shown in the construction drawings (revision in progress). The leads should extend nominally horizontally to a central location outside the DSTF tailings footprint where they will be connected to data loggers removing the need for manual readings. The as-built location of the cables should be surveyed during installation.

## 3.2 Slope Inclinometers

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### 3.2.1 General

Key PFMs (PFM-001 to PFM-003) identified during the FMEA process included mechanisms of movement, either in the foundation soils, at the liner system interface, or within the tailings.

Slope inclinometers (SI's) are commonly used to measure distributed creep deformations and shear movement along discrete discontinuities or zones of deformation within a structure and/or its underlying foundation. SI's consist of end-capped, grooved casing installed within a borehole to a target depth, ideally into a stable layer.

A probe is lowered into the casing within these grooves and readings collected at specified increments. Once baseline measurements are collected, subsequent measurements/surveys are completed at regular frequencies and/or after specified events such as earthquakes. Sensors measure probe tilt at the various depths, and movement relative to the baseline measurements can be determined.

### 3.2.2 Instrumentation Plan

An SI will be installed to monitor for potential creep or shear movement in the foundation soils and P2E buttress. The SI will be installed towards the north end of the P2E buttress, where the buttress height is greatest and ice-rich ground conditions are known to exist. The SI will be installed near the downstream crest of the buttress, and advanced into bedrock.

Tailings placement within the DSTF P2E footprint will be completed in lifts over several months or years. SI installation within the tailings would require tailings to be placed around the instrumentation and the instrumentation to be extended during operations. This is not considered practical as there is a high risk of instrumentation damage during tailings placement. SI installation within the tailings can be considered as part of closure once tailings placement within the P2E area is complete; however, it is not included as part of this instrumentation plan.

During final construction of Phase 2 (i.e., Phase 2 West), the SIs will be extended vertically to the final closure surface. Inclinometers will need to be read pre and post raise to re-baseline the readings..

## 3.3 Survey Monuments

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Survey monuments will be installed in select locations of the P2E buttress and tailings slope and crest as designated in the Construction Drawings. Monuments will consist of either metal pins driven into the substrate (for short-term monitoring); or pins connected to a base plate buried at depth (for longer-term installations).

Monuments should be surveyed using conventional survey methods. Movement observed may be indicative of shallow or surficial movement, or potentially related to other deep-seated movement and correlated with other instrumentation.

## 3.4 Vibrating Wire Piezometers

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### 3.4.1 General

Increased porewater pressure and/or the presence of a phreatic surface at the base of the tailings (i.e., above the GCL) may indicate conditions where drains are not functioning properly, and reduce the effective strengths of the foundation materials.

Rapid thawing of permafrost in the near-surface native soils (i.e., below the GCL) may lead to an increase in porewater pressure, hydraulic gradients and/or the presence of a phreatic surface in the foundation soils and drainage blanket material underneath the DSTF and liner system.

Development of a phreatic surface at the base of the tailings or near native ground surface is not anticipated based on the DSTF design. However, porewater pressures should be monitored to assess DSTF performance against design expectations. If a phreatic surface were to develop, it would be expected to be observed perched at the topographic low-point of the prepared native ground surface and installed GCL, near the designed drainage structures.

Vibrating wire piezometers (VWPs) sense porewater pressure indirectly by measuring the resonant frequency of a vibrating steel wire attached to a flexible diaphragm. Changes in porewater pressure change the resonant frequency of the wire by moving the diaphragm. The resonant frequency is also affected by changes in temperature and atmospheric pressure; embedded thermistors (for temperature) and weather station data (for atmospheric pressure) are used to correct for these parameters in post-processing. Piezometric elevation (i.e., groundwater elevation) can be calculated for VWPs installed at a known elevation.

VWPs may be measured using a readout box which commonly displays vibration frequency in “B-units” ( $\text{Hz}^2 * 10^{-3}$ ) and temperature. They can also be connected to dataloggers to automatically record readings at specified intervals.

### 3.4.2 Instrumentation Plan

Two VWPs will be installed near the base of the DSTF at the topographic low-point of the prepared native ground surface (to be determined by as-built survey during construction). One VWP should be positioned within the drainage blanket (i.e., slightly above native ground surface) and one VWP should be installed in the liner cover material (i.e., slightly above the GCL).

VWP sensors should be “heavy duty” models suitable for burial in granular soil. Prior to installation, VWP sensors should be prepared in accordance with manufacturer guidelines (e.g., filter saturation and collection of initial readings).

The VWP sensors should be installed per details in the design drawings (revisions in progress) The coordinates and elevations of the VWP sensors should be surveyed during installation.

VWP cables should be buried and installed in appropriate bedding material or within a protective conduit to protect from equipment damage, and should extend nominally horizontally to a central location outside of the DSTF tailings footprint where they will be connected to a data logger. The as-built location of the cables should be surveyed during installation.

## 4.0 MONITORING FREQUENCY AND REPORTING

Table 4-1 below summarizes the minimum monitoring requirements and frequencies for the instrumentation discussed above. These monitoring requirements are to be incorporated into the next revision of the OMS manual.

**Table 4-1 – Instrumentation Minimum Reading Frequencies**

<b>Instrumentation</b>	<b>Minium Reading Frequency</b>
Ground Temperature Cables	Monthly
Slope Inclometers	Monthly for first 12 months after installation, then quarterly
Survey Monuments	Monthly
Vibrating Wire Piezometers	Monthly

Instrumentation readings should be collected by AKHM per the minimum frequencies noted above and provided to Tetra Tech within one week. At a minimum, quarterly readings will be collected by Tetra Tech for quality assurance purposes.

In addition to the above, event-driven readings may be required such as during spring freshet, after a seismic event, or if a change in physical conditions is observed. Updated event-driven reading requirements will be summarized in the next update of the DSTF OMS manual.

Thresholds and a trigger action response plan (TARP) are essential for safe operation and facility performance. The current TARP for the DSTF is defined in the OMS manual, and will be updated to incorporate the P2E instrumentation.

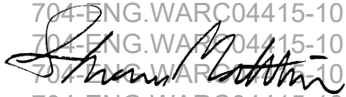
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## 6.0 CLOSURE

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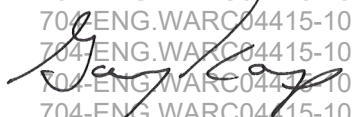
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Unless stipulated in the report, TETRA TECH has not been retained to explore, address or consider and has not explored, addressed or considered any environmental or regulatory issues associated with development on the subject site.

## 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.