TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Aaron Marsh P.E., Tailings Manager, Hecla	**Date:**	May 31, 2024
cc:		**Memo No.:**	2024-001
From:	Ian MacIntyre, P.Eng.	**File:**	704-ENG.WARC04307-02
Subject:	Differential Settlement and Imposed Strains on GCL DSTF Phase 2 Expansion, Keno Mine		

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) has been retained by Hecla Mining Company (Hecla) to complete the detailed design of Phase 2 expansion of the dry stack tailings facility (DSTF) at the Keno Hill Mine, located near Keno City, YT.

Based on recent discussions during a design review workshop completed on April 24, 2024, Tetra Tech was requested to provide additional details, information, and calculations related to differential thaw settlement and imposed strains on the geosynthetic clay liner (GCL) of the seepage collection system.

2.0 THAW SETTLEMENT

Thaw settlement is defined by the total volume change of thawing soils from their initial frozen state to the equilibrium state reached after the thawing and consolidation process. Based on Tetra Tech's experience and knowledge of the soil and permafrost conditions within the facility footprint, thaw settlement is expected to be the primary contributor to differential settlement imposed on the GCL.

In estimating thaw settlements, Tetra Tech:

- Reviewed borehole logs, moisture contents on collected samples, ground ice observations, and jar test results; and
- Estimated thaw settlement using the empirical correlation noted below, considering incremental layer thicknesses based on sample spacing, and summing all such layers and their incremental settlements within a borehole.

The empirical correlation used during this exercise is as follows (G. Dore – Advanced Course on Permafrost Engineering, Applied to Transportation Infrastructure, adapted from Frozen Ground Engineering, Second Edition, Andersland and Ladanyi 2004).

$$\varepsilon = 43.03 \times \ln(w) - 140.1$$

where w = moisture content

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A summary of the estimated thaw settlements for each of the 2022 boreholes is shown in Table 1, below.

Table 1 – Summary of Estimated Thaw Settlements at each Borehole

Borehole	Estimated Thaw Settlement (cm)	General Location in Facility
BH22-01	2.5 cm	Southeast of facility, near collection/conveyance sump (outside of GCL limits)
BH22-02	0.1 cm	Southern end of toe buttress (outside of GCL limits)
BH22-03	111.1 cm	Northern end of toe buttress (edge of GCL limits)
BH22-04	Negligible	Southern portion of facility (under liner)
BH22-05	15.0 cm	Northeast edge of facility (edge of GCL limits)
BH22-06	76.4 cm	Outside of facility limits to the east
BH22-07	Negligible	Northern portion of facility, near 1B (under liner)
BH22-08	1.2 cm	Near middle of facility (under liner)
BH22-09	15.4 cm	Near middle of facility (under liner)
BH22-10	42.6 cm	North from middle of toe buttress (outside of GCL limits)

Figure 1 below provides a plan view of the results presented above at each borehole location.

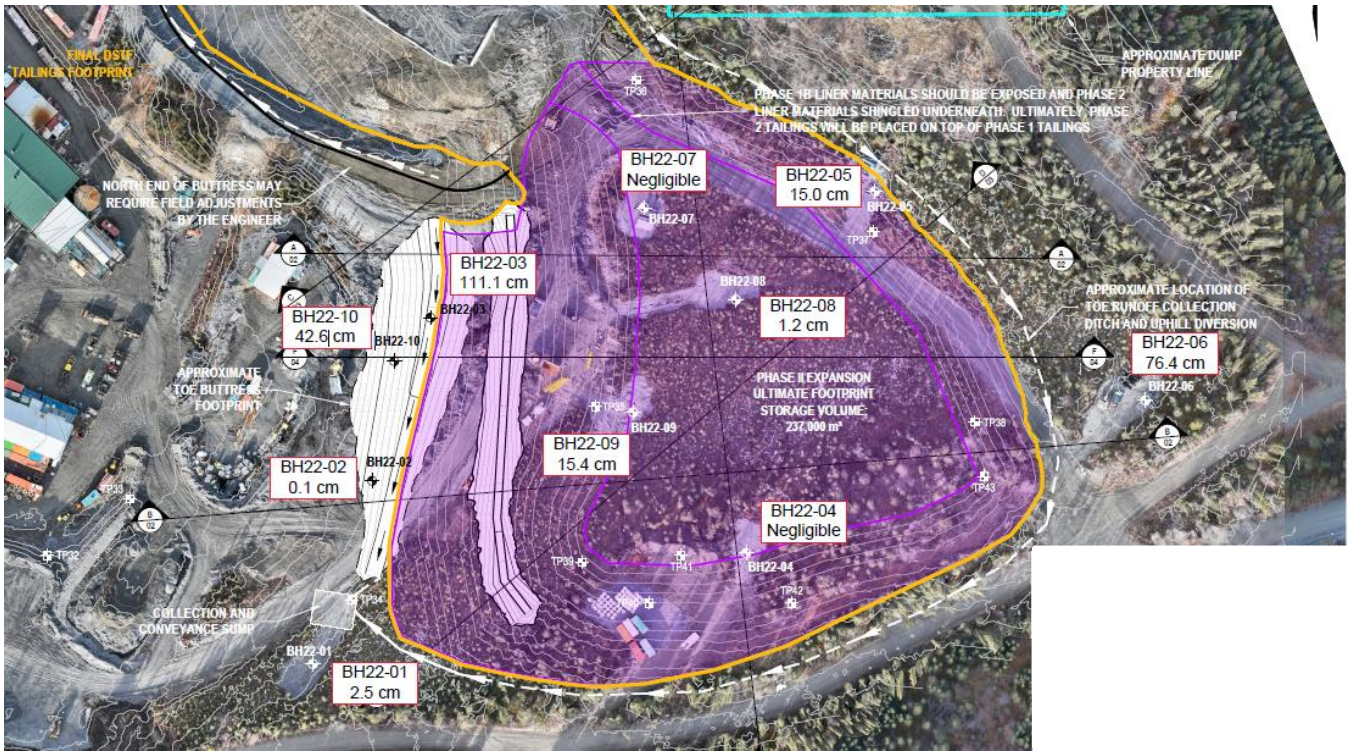

Figure 1 – Plan view illustrating borehole locations and respective estimated thaw settlement.

3.0 GEOSYNTHETIC CLAY LINER AND STRAIN ESTIMATES

Tetra Tech was requested to provide assurance that strains imposed on the GCL by differential settlement did not exceed 5%, which is less than the expected threshold for liner damage of about 10-15%.

During this review, Tetra Tech:

- Reviewed settlement magnitudes estimated in Section 2;
- Reviewed distances between adjacent boreholes, and their respective estimated differential settlement; and
- Estimated strain along the GCL in the following scenarios:
  - A maximum differential settlement was selected, comparing 1.11 m estimated at BH22-03, to negligible movement estimated at BH22-07, and assuming a distance of 50 m apart (conservative estimate). Assuming strain is evenly distributed along the GCL, a strain of 0.025% was estimated.
  - A hypothetical abrupt change in ground ice conditions over a 10 m distance was evaluated using the selected maximum 1.11 m differential movement. A strain of 0.614% was estimated.
  - To impose 5% strain on the GCL, a significant amount of differential settlement would be required to occur over a very localized area (e.g., massive ground ice surrounded by non-ice rich soil). Considering 1.11 m of differential settlement, the localized area would need to be approximately 3.5 m in radius, assuming no adjacent differential movement.
- This process was repeated, applying a factor of 1.5 to the estimated maximum differential settlement, as follows:
  - A maximum differential settlement was selected comparing 1.7 m (1.11 m from BH22-03, multiplied by 1.5) to negligible movement estimated at BH22-07, assuming movement over a distance of 50 m. A strain of 0.06% was estimated.
  - A hypothetical abrupt change in ground ice conditions over a 10 m distance was evaluated using the selected maximum 1.7 m differential movement. A strain of 1.43% was estimated.
  - To impose 5% strain on the GCL, a significant amount of differential settlement would be required to occur over a very localized area (e.g., massive ground ice surrounded by non-ice rich soil). Considering 1.7 m of differential settlement, the localized area would need to be approximately 5.3 m in radius, assuming no adjacent differential movement.

4.0 SUMMARY

Based on our experience, including all boreholes, testpits, and samples collected, permafrost in the southern facing Phase 2 area consists of localized ice-rich till with no abrupt changes in ground ice content.

In the Phase 2 footprint, the presence of localized massive ground ice that would contribute to more than 5% strain in the GCL is highly unlikely.

Based on the review completed, Tetra Tech expects strains imposed on the GCL caused by differential settlement to remain within the acceptable limits of the GCL and to not exceed 5%.

5.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Hecla Mining Company 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 Hecla Mining Company, 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.

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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May 31, 2024

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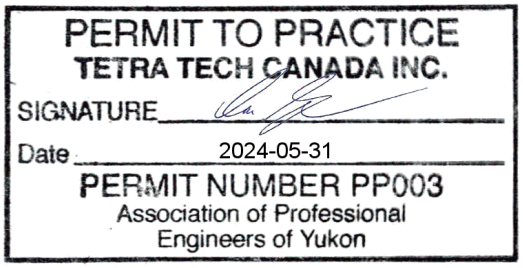

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Enclosure: Appendix A – Limitations on the Use of this Document
Appendix B – Calculations (Microsoft Excel .xls print out and sample hand calculations)

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

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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.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

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.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

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

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

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

CALCULATIONS (MICROSOFT EXCEL .XLS PRINT OUT AND SAMPLE HAND CALCULATIONS)

Strain % Calc (Andersland and Ladanyi, Dore, and others):

$$\varepsilon = 43.03 \times \ln(w) - 140.1$$

where w = moisture content

Blue indicates permafrost

Tan indicates layer thickness manually selected based on logs

Borehole	Sample ID	Depth (m)	Moisture Content (%)	Strain (%)	Dist. b/t top of samples above and below (m)	Assuming afftected layer is 50% distance between tops of samples above and below: Est Layer Thickness (m)	Est. Thaw Settlement (cm)
BH22-01	SA11	0.460	20.11	0.00	0	0.000	0.00
	SA12	1.830	14.10	0.00	0	0.000	0.00
	SA13	3.810	0.95	0.00	0	0.000	0.00
	SA14	5.330	12.42	0.00	0	0.000	0.00
	SA15	5.790	28.56	4.14	1.220	0.610	2.53
	SA16	6.550	5.91	0.00	0.000	0.000	0.00
	SA17	8.080	7.41	0.00	0.000	0.000	0.00
	SA18	9.300	23.48	0.00	0.000	0.000	0.00
	SA19	10.820	5.91	0.00	0.000	0.000	0.00
	SA20	12.340	0.41	0.00	0.000	0.000	0.00
	SA21	13.870	3.66	0.00	0.000	0.000	0.00
						Total TS	2.53
BH22-02	SA22	0.610	12.65	0.00	0.000	0.000	0.00
	SA23	2.290	18.91	0.00	0.000	0.000	0.00
	SA24	3.810	10.73	0.00	0.000	0.000	0.00
	SA25	4.420	17.41	0.00	0.000	0.000	0.00
	SA26	4.720	10.11	0.00	0.000	0.000	0.00
	SA27	5.640	6.25	0.00	0.000	0.000	0.00
	SA28	6.550	23.78	0.00	0.000	0.000	0.00
	SA29	7.770	25.99	0.09	2.900	1.450	0.12
	SA30	9.450	21.80	0.00	0.000	0.000	0.00
	SA31	11.130	15.39	0.00	0.000	0.000	0.00
	SA32	12.850	9.26	0.00	0.000	0.000	0.00
	SA33	14.480	12.25	0.00	0.000	0.000	0.00
	SA34	15.700	10.29	0.00	0.000	0.000	0.00
	SA35	17.230	11.23	0.00	0.000	0.000	0.00
	SA36	18.750	13.93	0.00	0.000	0.000	0.00
	SA37	20.270	1.12	0.00	0.000	0.000	0.00
	SA38	21.800	1.49	0.00	0.000	0.000	0.00
	SA39	23.620	5.52	0.00	0.000	0.000	0.00
	SA40	24.540	8.49	0.00	0.000	0.000	0.00
	SA41	26.370	3.65	0.00	0.000	0.000	0.00

	SA42	28.200	3.59	0.00	0.000	0.000	0.00
	SA43	29.420	1.64	0.00	0.000	0.000	0.00
						Total TS	0.12
BH22-03	SA44	0.610	13.18	0.00	0.000	0.000	0.00
	SA45	1.980	4.03	0.00	0.000	0.000	0.00
	SA46	3.510	12.26	0.00	0.000	0.000	0.00
	SA47	5.030	70.83	43.22	3.040	1.520	65.70
	SA48	6.550	58.56	35.03	2.130	1.065	37.31
	SA49	7.160	30.83	7.43	1.220	0.610	4.53
	SA50	7.770	14.26	0.00	1.220	0.610	0.00
	SA51	8.380	21.55	0.00	1.980	0.990	0.00
	SA52	9.750	13.27	0.00	2.750	1.375	0.00
	SA53	11.130	12.68	0.00	3.050	1.525	0.00
	SA54	12.800	27.38	2.32	3.040	1.520	3.53
	SA55	14.170	9.81	0.00		0.000	0.00
	SA56	15.700	10.85	0.00		0.000	0.00
	SA57	17.530	9.68	0.00		0.000	0.00
						Total TS	111.07
BH22-04	SA58	0.760	5.06	0.00		0.000	0.00
	SA59	1.980	10.21	0.00		0.000	0.00
	SA60	3.810	2.69	0.00		0.000	0.00
	SA61	5.030	7.91	0.00		0.000	0.00
	SA62	7.160	2.43	0.00		0.000	0.00
	SA63	8.080	3.98	0.00		0.000	0.00
	SA64	9.600	10.45	0.00		0.000	0.00
	SA65	11.130	2.18	0.00		0.000	0.00
	SA66	13.260	7.60	0.00		0.000	0.00
	SA67	14.170	7.61	0.00		0.000	0.00
	SA68	15.700	10.87	0.00		0.000	0.00
	SA69	17.220	11.79	0.00		0.000	0.00
	SA70	19.350	15.34	0.00		0.000	0.00
	SA71	19.960	4.12	0.00		0.000	0.00
						Total TS	0.00
BH22-05	SA72	0.300	290.22	100.00	0.300	0.150	15.00
	SA73	2.290	13.87	0.00		0.000	0.00
	SA74	3.510	14.13	0.00		0.000	0.00
	SA75	5.030	17.49	0.00		0.000	0.00
	SA76	6.550	7.66	0.00		0.000	0.00
	SA77	8.380	8.12	0.00		0.000	0.00
	SA78	10.210	22.10	0.00		0.000	0.00
	SA79	11.130	11.28	0.00		0.000	0.00
	SA80	13.260	9.68	0.00		0.000	0.00
	SA81	14.170	12.59	0.00		0.000	0.00
	SA82	17.220	5.56	0.00		0.000	0.00

	SA83	19.350	6.47	0.00		0.000	0.00
	SA84	20.880	5.15	0.00		0.000	0.00
	SA85	22.100	4.70	0.00		0.000	0.00
	SA86	23.620	4.46	0.00		0.000	0.00
	SA87	24.840	0.92	0.00		0.000	0.00
						Total TS	15.00
BH22-06	SA88	0.760	37.58	15.95	0.050	0.050	0.80
	SA89	2.290	182.86	84.03	0.900	0.900	75.63
	SA90	3.200	11.82	0.00		0.000	0.00
	SA91	5.330	3.58	0.00		0.000	0.00
	SA92	6.550	17.69	0.00		0.000	0.00
	SA93	8.080	8.77	0.00		0.000	0.00
	SA94	10.210	21.73	0.00		0.000	0.00
	SA95	11.130	7.25	0.00		0.000	0.00
	SA96	13.260	2.36	0.00		0.000	0.00
	SA97	13.870	1.00	0.00		0.000	0.00
	SA98	16.000	24.09	0.00		0.000	0.00
	SA99	17.220	8.58	0.00		0.000	0.00
	SA100	19.050	8.82	0.00		0.000	0.00
	SA101	20.270	5.44	0.00		0.000	0.00
	SA102	22.710	16.06	0.00		0.000	0.00
	SA103	23.320	5.19	0.00		0.000	0.00
	SA104	25.450	4.39	0.00		0.000	0.00
	SA105	26.670	19.53	0.00		0.000	0.00
	SA106A	28.500	5.49	0.00		0.000	0.00
	SA107A	29.110	23.84	0.00		0.000	0.00
						Total TS	76.43
BH22-07	SA106B	0.760	20.14	0.00		0.000	0.00
	SA107B	2.290	12.55	0.00		0.000	0.00
	SA108	3.510	15.19	0.00		0.000	0.00
	SA109	5.030	24.63	0.00		0.000	0.00
	SA110	6.250	19.78	0.00		0.000	0.00
	SA111	7.470	18.36	0.00		0.000	0.00
	SA112	9.600	7.83	0.00		0.000	0.00
	SA113	11.430	9.22	0.00		0.000	0.00
	SA114	13.260	6.73	0.00		0.000	0.00
	SA115	14.480	18.83	0.00		0.000	0.00
	SA116	14.480	9.41	0.00		0.000	0.00
	SA117	16.000	23.34	0.00		0.000	0.00
	SA118	19.050	13.69	0.00		0.000	0.00
	SA119	19.660	24.17	0.00		0.000	0.00
	SA120	20.270	19.55	0.00		0.000	0.00
	SA121	22.100	22.67	0.00		0.000	0.00
	SA122	23.320	23.44	0.00		0.000	0.00
	SA123	24.840	11.29	0.00		0.000	0.00

	SA124	26.370	15.63	0.00		0.000	0.00
						Total TS	0.00
BH22-08	SA125	1.070	32.68	9.94	0.250	0.125	1.24
	SA126	1.980	20.11	0.00		0.000	0.00
	SA127	3.510	22.13	0.00		0.000	0.00
	SA128	5.030	11.42	0.00		0.000	0.00
	SA129	6.860	10.60	0.00		0.000	0.00
	SA130	7.770	10.55	0.00		0.000	0.00
	SA131	9.600	8.46	0.00		0.000	0.00
	SA132	9.910	4.78	0.00		0.000	0.00
	SA133	13.260	23.25	0.00		0.000	0.00
	SA134	14.170	22.10	0.00		0.000	0.00
	SA135	16.000	20.78	0.00		0.000	0.00
	SA136	17.220	21.13	0.00		0.000	0.00
	SA137	18.750	23.53	0.00		0.000	0.00
	SA138	20.570	2.87	0.00		0.000	0.00
	SA139	22.400	13.31	0.00		0.000	0.00
	SA140	23.620	10.53	0.00		0.000	0.00
	SA141	25.450	10.92	0.00		0.000	0.00
	SA142	26.670	9.68	0.00		0.000	0.00
	SA143	28.500	2.58	0.00		0.000	0.00
	SA144	29.410	8.41	0.00		0.000	0.00
						Total TS	1.24
BH22-09	SA145	0.760	24.88	0.00		0.000	0.00
	SA146	1.980	10.18	0.00		0.000	0.00
	SA147	3.510	14.86	0.00		0.000	0.00
	SA148	4.720	11.04	0.00		0.000	0.00
	SA149	6.550	24.27	0.00		0.000	0.00
	SA150	7.470	10.85	0.00		0.000	0.00
	SA151	9.600	7.86	0.00		0.000	0.00
	SA152	11.730	32.79	10.08	3.050	1.525	15.37
	SA153	12.650	11.35	0.00		0.000	0.00
	SA154	14.170	11.00	0.00		0.000	0.00
	SA155	16.000	8.97	0.00		0.000	0.00
	SA156	17.530	8.66	0.00		0.000	0.00
	SA157	20.570	7.66	0.00		0.000	0.00
	SA158	21.790	7.22	0.00		0.000	0.00
	SA159	23.320	9.12	0.00		0.000	0.00
	SA160	25.150	8.30	0.00		0.000	0.00
	SA161	26.670	6.87	0.00		0.000	0.00
						Total TS	15.37
BH22-10	SA162	0.460	5.11	0.00		0.000	0.00
	SA163	1.980	5.79	0.00		0.000	0.00
	SA164	6.860	18.91	0.00		0.000	0.00

	SA165	7.770	20.59	0.00		0.000	0.00
	SA166	8.990	45.30	23.98	2.440	1.220	29.26
	SA167	10.210	14.23	0.00		0.000	0.00
	SA168	11.130	10.16	0.00		0.000	0.00
	SA169	13.260	31.67	8.59	3.040	1.520	13.06
	SA170	14.170	20.44	0.00		0.000	0.00
	SA171	17.220	9.71	0.00		0.000	0.00
	SA172	19.350	26.05	0.18	3.350	1.675	0.31
	SA173	20.570	13.67	0.00		0.000	0.00
	SA174	22.710	0.60	0.00		0.000	0.00
						Total TS	42.63

Keno H.11 DSTA Phase 2

Double check on Thaw Settlement Calcs (see xls.)

BH22-03 – Samples in permafrost reviewed
– Samples w/ Moisture > 25% considered
(Andersland/Ladanyi: -2004)

Emperical Correlation:

$$\varepsilon(\%) = 43.03 \ln(w\%) - 140.1$$

where w is moisture content

	w	Effective Layer Thickness*	ε %	**Settlement (cm)
SA47	70.83%	6.55 - 3.51 = 3.04 → x50% = 1.52m	43.22%	65.69 cm
SA48	58.56%	7.16 - 5.03 = 2.13 → x50% = 1.065m	35.03%	37.31 cm
SA49	30.83%	7.77 - 6.55 = 1.22 → x50% = 0.61m	7.43%	4.53 cm
SA-54	27.38%	14.17 - 11.13 = 3.04 → x50% = 1.52m	2.31	3.51 cm

Total = 111.04 cm

* Assumes extends 50% to samples above & below
** Settlement = layer x ε %

Kaw M.11 DSTF Phase 2

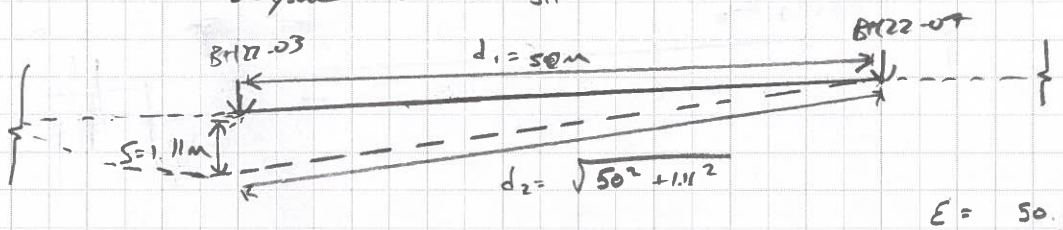
Sample Thaw Settlement & Differential Movement / GCL Strain Calcs:

- BH22-03 → Largest thaw settlement est @ 1.11m

  BH22-07 → Negligible thaw settlement est ≈ 0m

  → Approx 75m b/t BHs → Assume 50m to allow for some conservatism / similar soil conditions in area around each BH

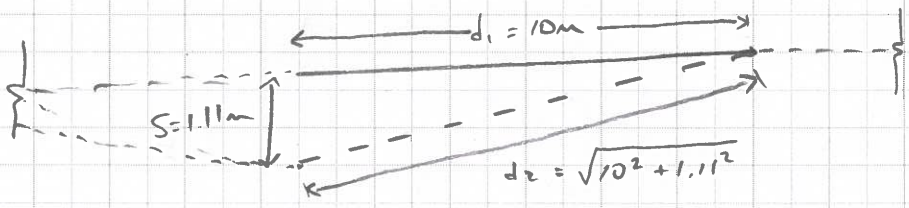
  → Assuming simple slope b/t locations & liner continues beyond each BH



$= 50.0123m$

$\varepsilon = \frac{50.0123 - 50}{50} \times 100\% = 0.025\%$

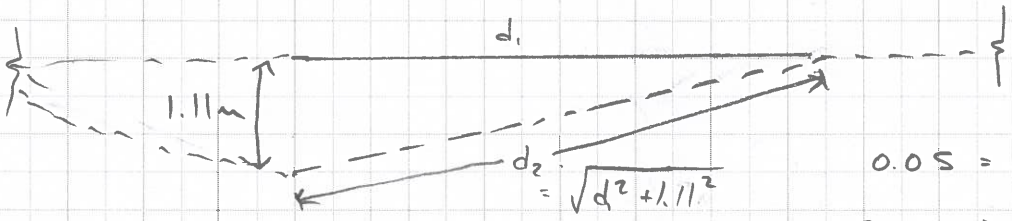
- Considering a hypothetical abrupt change in ground ice over 10m:



$= 10.0614m$

$\varepsilon = \frac{10.0614 - 10}{10} \times 100\% = 0.614\%$

- Considering 1.11m as max diff. movement, how "small" of a pocket (i.e. massive ice wedge) to impose a 5% strain?



$\varepsilon = \frac{d_2 - d_1}{d_1} = 0.05$

$0.05 = \frac{\sqrt{d_1^2 + 1.11^2} - d_1}{d_1}$

Solving for d_1 ....

$d_1 = 3.47m$

Tt_Metric Graph Pads.cdr