TECHNICAL MEMORANDUM

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TO Baffinland Iron Mines Corporation

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ASSESSMENT OF ACTIVE ZONE DEPTH CONSIDERING SSP1-2.6 CLIMATE CHANGE PROJECTIONS AT MARY RIVER MINE

1.0 INTRODUCTION

Baffinland Iron Mines Corporation (BIM) has retained WSP Canada Inc. (WSP) to develop a conceptual thermal model to predict the impact of climate change on the depth of ground subject to seasonal freezing and thawing (active zone), in support of preliminary assessment of the required thickness of a thermal cap to be implemented on top of the waste rock pile at closure.

BIM has requested WSP to model and report on the climate change projection scenario SSP1-2.6 with the rationale that it represents more sustainable socioeconomic factors that influence contributions to global climate change, which aligns with current Canadian policy and global climate change targets under the Paris Agreement.

This technical memorandum presents the relevant background information, the methodology used, and the model results for the requested climate change scenario.

2.0 CLIMATE CHANGE PROJECTIONS

Baseline climate data was processed and assessed by (WSP 2023a), which compared air temperature data from several surrounding regional stations to site-specific measurements to generate a representative database. The average annual air temperature between 1940 and 2022 was found to be -15.3°C, and between 2000 and 2020, it was -13.4°C.

Publicly available annual temperature climate projections from the Environment and Climate Change Canada (ECCC) Coupled Model Intercomparison Project (CMIP6) were compiled and analyzed to determine the climate change projections for the Mary River Mine (ECCC 2024a). Previous climate change assessments completed for Mary River Mine (BIM 2018) used projections based on CMIP5, the predecessor CIMP6. Increased spatial resolution and enhanced Shared Socio-Economic Pathways (SSP's) were implemented for CIMP6; therefore, climate change projections for this study consider those provided in CIMP6 (ECCC 2024b). At the request of BIM, climate change projection scenario SSP1-2.6 was used.

Historical air temperature data compiled as part of the baseline climate dataset (WSP 2023a) was used to calculate the projected change in air temperature and was referenced between 1971 and 2000. To account for more recent climate data, the projected changes in air temperature were adjusted to consider historical climate averages between 2000 and 2020. The annual mean air temperature between 2000 and 2020 was used as a baseline in further modelling. Furthermore, original climate periods were adjusted to consider overlapping projection periods and the start date of the climate model.

Climate change projections were available over 80 years between 2020 and 2100. To assess the variation in the active zone through 2120, it was assumed that a linear temperature change, equal to that projected between 2070 and 2100, represents future decades through 2124. Table 1 summarizes historical mean annual air temperature and climate change projections for SSP1-2.6.

Table 1: Summary of Climate Air Temperature Change Projections

Scenario	Original Period	Adjusted Period	Mean Annual Temperature (°C)	Adjusted Cumulative Projected Change in Temperature [b, c] (°C)	Annual Rate of Temperature Increase (°C)
Historical	1971 – 2000	–	-14.2	–	–
	2000 – 2020	–	-13.4	–	–
SSP1-2.6	2021 – 2050	2024 – 2045	-11.2[a]	2.2	0.10
	2041 – 2070	2046 – 2070	-10.7[a]	2.8	0.02
	2071 – 2100	2071 – 2100	-10.4[a]	3.0	0.01
	–	2101 – 2124	-10.1[a]	3.3	0.01

Notes:

(a) Average annual temperature was provided for the original time periods. Data was taken from the baseline climate dataset compiled in WSP 2023a.

(b) Projected temperature change is referenced to the historical period between 2000 and 2020 and was applied to the adjusted time periods. Data was taken from the baseline climate dataset compiled in WSP 2023a.

(c) Values reported are rounded to the nearest tenth.

3.0 NUMERICAL MODEL

3.1 Objectives and Model Setup

A one-dimensional (1D) transient thermal model was prepared using the finite element software TEMP/W developed by Geo-Slope International Ltd. (Version 2023.1.0) to predict the potential variation in active zone depths in the long term over 100 years.

The progression of the active zone over time was modelled by varying the ground surface temperature of the waste rock based on the publicly available climate change projections. All other model parameters remained constant over time. Section 3.3.2 summarizes the derivation of the ground surface temperature function.

3.2 Model Geometry

A 30-m tall column of waste rock was used to simulate a waste rock pile assumed to be homogeneous in depth with uniform material properties.

A mesh discretization was assigned based on the depth of the waste rock below the ground surface. The model geometry between the ground surface and 4 metres in depth was assigned a mesh sizing of 0.1 m, and the remaining mesh was assigned a 1 m spacing.

3.3 Boundary Conditions

3.3.1 Initial Temperature Profile

A steady-state model was used to establish the initial temperature profile of the waste rock column. Thermistor data recorded in BH1, BH2, and BH3 from January 2019 to August 2022 was used to establish the temperature profile for the model start time in January 2024.

A constant temperature of -7.5°C was applied to the bottom of the waste rock column. This temperature was derived from thermal gradients measured in thermistors BH1, BH2, and BH3 between 2019 and 2022. This value has been used in previous thermal models calibrated to the measured thermistor data (WSP 2023b).

3.3.2 Transient Conditions

Transient conditions were used to simulate heat transfer considering the effects of climate change for 100 years between 2024 and 2124. Thermistor data measured in BH1 at approximately 0.1 metres below ground surface was used to establish a baseline average monthly ground temperature function. Data from this location was used as no additional waste rock has been placed over BH1 during the monitoring period, which provides a representative ground surface temperature measured between 2019 and 2022.

The projected changes in annual air temperature summarized in Table 1 were directly applied to the ground surface temperature function over each period. It is assumed that there is a linear increase in temperature over time and the rate of temperature increase is uniform over summer and winter months.

During the transient model stages, a constant temperature of -7.5°C was applied to the bottom of the model geometry, consistent with previous studies and thermistor data at BH1 (WSP 2023b).

Table 2 summarizes average monthly baseline and projected air and ground temperatures at the start of the model and after 100 years of climate change. Figure 1 shows the ground surface temperature function with time.

Table 2: Summary of Average Baseline and Projected Air and Ground Temperatures

Month	Baseline Air Temperature (°C)	Baseline Ground Temperature (°C)	SSP1 – 2.6 50th Percentile	
			2124 Air Temperature (°C)	2124 Ground Temperature (°C)
Jan	-32.1	-12.3	-28.7	-8.9
Feb	-33.3	-13.9	-29.9	-10.5
Mar	-29.3	-17.3	-25.9	-13.9
Apr	-20.4	-14.3	-17.0	-10.9
May	-7.7	-7.6	-4.3	-4.3
Jun	3.1	-0.7	6.5	2.7
Jul	8.1	6.5	11.5	9.9
Aug	6.2	5.5	9.6	8.9
Sep	-1.0	0.7	2.4	4.1
Oct	-8.8	-0.5	-5.4	2.9
Nov	-20.3	-3.8	-16.9	-0.4
Dec	-26.7	-8.5	-23.3	-5.1
Average	-13.5	-5.5	-10.1	-2.1

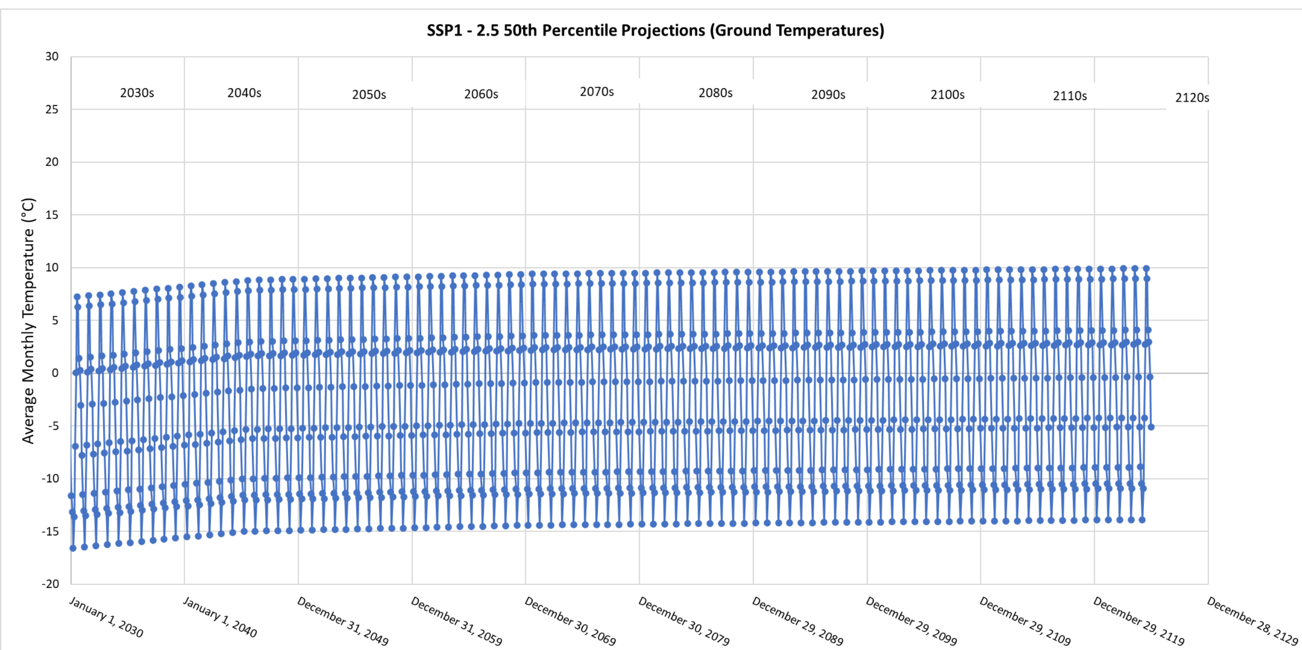

Figure 1: Ground Surface Temperature Functions Derived for Climate Change Scenario SSP1-2.6

3.4 Material Properties

Thermal properties of the waste rock were taken from WSP (2023b), which were based on laboratory measurements and further calibrated to in situ temperature measurements in BH1, BH2, and BH3. The volumetric heat capacity in frozen and unfrozen conditions is 1,700 and 2,000 kJ/m^3/°C respectively. Frozen and unfrozen thermal conductivity values for the waste rock are determined to be 168.5 and 155.6 kJ/d/m/°C respectively. It is assumed the waste rock maintains a constant volumetric water content of 8% (approximately 25% saturation) throughout the model duration.

3.5 Model Results

Figure 2 shows the computed ground temperature at the maximum depth of the active zone over time. The model results suggest that the thermal cap would need to be at least 3 m thick to maintain the PAG rock away from the active zone.

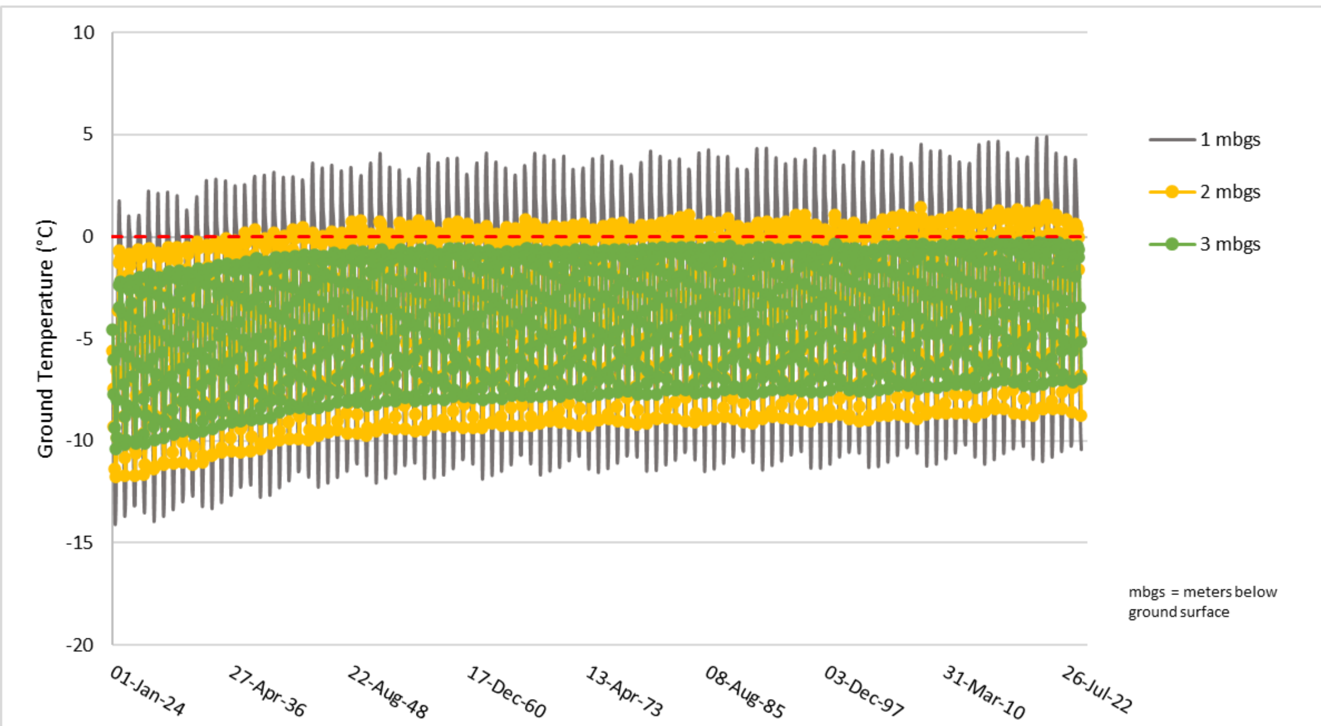

Figure 2: Predicted Evolution of Ground Temperature and Depth of Active Zone with Time

3.6 Model Assumptions and Limitations

The analysis described in this technical memorandum constitutes a simplification of the field reality and carries assumptions and limitations that shall be taken into consideration during the interpretation of the results. The most important assumptions and limitations are as follows:

- The model considers a homogeneous waste rock mass, and the one-dimensional nature of the column can only capture heat transfer in the vertical direction and does not consider lateral heat transfer from adjacent areas.
- Uncoupled thermal models do not incorporate the impact of heat transfer associated with air and water flow through the pile, and only consider heat flow due to conduction. The thermal properties of waste rock materials change with variations in water content, and air and water convection can affect the depth of the active zone.
- The ground surface temperature function is derived assuming the projected average annual temperature increase occurs linearly over time and is uniformly applied for each month. This is a simplification as the rate of variations in air temperature in winter and summer is different. In addition, ground temperature variations do not follow the same pattern of air temperature variations, with ground temperature in general being warmer than air temperature.
- This model assumes that the existing waste rock is similar to the material used to construct the closure cover. Material properties of the thermal cover should be re-assessed if a different gradation of rock is to be used.
- Model inputs (porosity, water content, thermal conductivity, heat capacity, and boundary temperature fluxes) are based on a preliminary dataset. Additional data collection will improve model confidence.

4.0 CLOSURE

We trust that this report provides the information that you require at this time. Please do not hesitate to contact the undersigned if you have any questions or require any clarification.

WSP Canada Inc.

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https://wsponlinecan.sharepoint.com/sites/ca-ca00202744798/shared documents/06. deliverables/issued/ca0020274.4798-005-tm-rev2/ca0020274.4798-005-tm-rev2-active zone ssp1-2.6 climate change assessment 04oct_24.docx

PERMIT TO PRACTICE
WSP Canada Inc.
Signature ______ October 4 , 2024
Date ______ October 4, 2024
PERMIT NUMBER: P407
NT/NU Association of Professional Engineers and Geoscientists

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