Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

GIANT MINE REMEDIATION PROJECT

Arsenic Trioxide Frozen Shell Management and Monitoring Plan

May 2021

Version 1.1

314-Arsenic Trioxide MMP-35-RPT-0001-Rev1.1_20210528

LAND ACKNOWLEDGEMENT

The Giant Mine Remediation Project acknowledges the Indigenous Peoples and the importance of the land in and around the Giant Mine site, which is located in Chief Drygeese Territory. From time immemorial, it has been and is the traditional land of the Yellowknives Dene First Nation. We acknowledge that the Giant Mine site is also within the homeland of the North Slave Metis Alliance and the Tłı̨chǫ Mǫwhì Gogha Dè Nı̨ı̨tłèè boundary. The Giant Mine Remediation Project respects the histories, languages, and cultures of First Nations, Metis, Inuit, and all First Peoples of Canada, whose presence continues to enrich our vibrant community.

PLAIN LANGUAGE SUMMARY

This is the Giant Mine Remediation Project (GMRP or the Project) “Arsenic Trioxide Frozen Shell” Management and Monitoring Plan that explains the management of freeze contained arsenic trioxide dust at the Site. Arsenic trioxide dust was made during the roasting of the ore. It is necessary to contain the dust and separate it from water, as it can dissolve and is toxic to humans and the environment. Part of the Giant Mine Remediation Project requires that all the underground storage areas that contain arsenic trioxide dust be frozen in place. The ground will be frozen using thermosyphon pipes installed around the perimeter of each arsenic trioxide underground storage area. Thermosyphons are pipes filled with carbon dioxide (CO_2) gas that have a portion of the pipe sticking out above the ground surface.

Thermosyphons freeze the ground by having the heat from the ground warm the CO_2 in the bottom portion of the pipe. As the CO_2 gas warms, it rises until it reaches the length of the pipe that is sticking up into and exposed to the cold winter air. As winter air cools the gas, it condenses to a liquid. The cooled CO_2 then flows back down to the bottom of the pipe, where it is again heated by the ground, evaporates, and rises to the top of the pipe. This process continues if the air is cold enough to condense the gas and the ground is warm enough to evaporate it. When the air temperature gets warmer than the ground, the process temporarily stops. In Yellowknife, even with predicted global warming, there is more winter cooling time than summer shutdown time during any full year so over several years, the ground cools gradually and then stays frozen. The ground around the thermosyphons will gradually freeze creating a “frozen shell”. Any water flowing into the frozen area will freeze, creating a barrier of ice in a self-sealing wall that will stop water flow from reaching the dust.

This Plan is required as part of the Water Licence (#MV2007L8-0031). It is related to the overall Closure and Reclamation Plan that describes the remediation plan for Giant Mine. This version of the Arsenic Trioxide Frozen Shell Management and Monitoring Plan focuses on how the thermosyphons will be operated, maintained, and monitored. The plan will be updated as necessary as work progresses and if any changes are needed.

This Plan also summarizes requirements for reporting to the Mackenzie Valley Land and Water Board. This includes reporting on ‘action levels’. When to act if monitoring shows an issue related to the ground freezing is called an ‘action level’. If a pre-set level is reached, the Giant Mine Remediation Project would initiate a response to prevent an unwanted effect to the environment. The Giant Mine Remediation Project wants to provide a clear approach to responding to monitoring results and when to act - using these action levels will determine whether frozen shell management is occurring as planned. The Giant Mine Remediation Project will report every year to the Mackenzie Valley Land and Water Board including information on the action levels.

VERSION HISTORY

Version	Date Issued/ Effective Date	Description of Version
0.2	July 27, 2020	Circulated to Working Group for Pre-engagement prior to Submission to Mackenzie Valley Land and Water Board
1.0	January 22, 2021	Submitted to the Mackenzie Valley Land and Water Board as per Water Licence MV2007L8-0031, Part F, Condition 15. This Plan addresses the Board Directives included in the Water Licence and commitments made during the water licencing process.
1.1	May 28, 2021	Submitted to the Mackenzie Valley Land and Water Board as per Water Licence MV2007L8-0031, Part F, Condition 15. Changes to this Plan include updates to address Board's direction dated April 13, 2021. A summary of changes is appended to the cover letter submitted with this version.

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List of Acronyms and Abbreviations

Acronym	Definition
AANDC	Aboriginal Affairs and Northern Development Canada
AECOM	AECOM Canada Ltd.
AR1	Freeze Area 1
AR2	Freeze Area 2
AR3	Freeze Area 3
AR4	Freeze Area 4
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
CRP	Closure and Reclamation Plan
EHSC	Environment, Health and Safety, and Community
ETP	effluent treatment plant
FOS	Freeze Optimization Study
GMRP	Giant Mine Remediation Plan
GNWT	Government of Northwest Territories
GNWT-ENR	Government of Northwest Territories - Environment and Natural Resources
MCM	Main Construction Manager
MMP	Management and Monitoring Plan
MVLWB	Mackenzie Valley Land and Water Board
NETA	International Electrical Testing Association
PLC	Programmable Logic Controller
PSPC	Public Services and Procurement Canada
RAID	Redundant Array of Independent Disks
Remote I/O	Remote Input/Output panels
RTD	Resistance Temperature Detector
SDS	Safety Data Sheet
SNAP	Scenarios Network for Alaska and Artic Planning
TCA	Tailings Containment Area
UPS	Uninterruptible Power Supplies
WTP	water treatment plant

Note: When key words from the Water Licence Glossary are referenced in this document text they will be capitalized to note they may have special significance in this context.

1 INTRODUCTION

The Giant Mine (Site) is located within the City of Yellowknife boundary, approximately 1.5 kilometres (km) from the community of Ndilǫ and 9 km from the community of Dettah. The Site is situated on Commissioner's Land administered by the Government of the Northwest Territories (GNWT); Reserves (R622T and 85 J/8-257-2) have been established to allow for the implementation of the remediation of the Site. Ongoing care, maintenance and remediation of the Site is known as the Giant Mine Remediation Project (GMRP or the Project). For a history of the Giant Mine and planned remediation activities, please refer to the Closure and Reclamation Plan (CRP).

The Site consists of eight abandoned open pits; an underground mine with arsenic trioxide storage areas; Tailings Containment Areas (TCAs) with associated rock fill dams; mine waste rock that buttresses Dams 11, 21B and 21D; a tailings re-treatment plant (out of service since 1990); an effluent treatment plant (ETP); a Mill Complex; several warehouses; and a townsite. Baker Creek flows through the Site seasonally with one ponded area. The Site features prior to remediation activities are outlined in Figure 1.1-1.

1.1 Plan Objectives and Linkages

This Arsenic Trioxide Frozen Shell Management and Monitoring Plan (Arsenic Trioxide Frozen Shell MMP) focuses on the arsenic trioxide frozen shell management. It summarizes the existing management and monitoring practices, actions and contingencies and provides direction for additional management practices that will be required to continue to protect health, safety, and the environment.

This Arsenic Trioxide Frozen Shell MMP has been developed to satisfy applicable Water Licence conditions set forth in Water Licence MV2007L8-0031 (Appendix A), Land Use Permit MV2019X0007, and Measures from the Environmental Assessment process. Updates to the Arsenic Trioxide Frozen Shell Management and Monitoring Plan will be ongoing through the life of the GMRP to provide more details on future management.

Arsenic Trioxide Frozen Shell Management and Monitoring Plan Objectives

The objectives of the Arsenic Trioxide Frozen Shell MMP are to outline:

- How the freeze containments system is to be constructed and operated
- What instrumentation and data types are being collected
- How to interpret data in the short and long term

What maintenance (anticipated / responsive) is necessary.

Where appropriate, safety requirements with respect to operator qualifications are included. There is also a discussion related to potential upset conditions due to unexpected events (e.g., storm damage, vandalism) as well as a contingency section related to Response Frameworks to offset as yet unpredicted long-term climate warming.

Closure Criteria Related to this Plan

There are also numerous closure objectives and criteria that will apply once remediation is complete. The two that are relevant to this Arsenic Trioxide Frozen Shell MMP are provided below, with a full list presented in the CRP:

- F1. Arsenic trioxide dust and arsenic-impacted waste disposal areas are not, and will not become, a source of contamination to the environment:
  - F1-1. Design engineering drawings are signed and stamped by a Qualified Professional and the specifications outlined therein are met, to contain the arsenic trioxide waste and dust.
  - F1-2. The dust and waste will be considered contained when a 5 metre (m) –wide frozen shell at -5 degrees Celsius (°C) or colder exists in the bedrock or fill around each arsenic containing chamber, stope, drift or fill in pit.
- F2. Reversibility for future technology developments in remediation will be maintained:
  - F2-1. Design engineering drawings are signed and stamped by a Qualified Professional and the specifications outlined therein are met, such that reversibility for future access is maintained.
  - F2-2. Each chamber, stope, drift or pit filled with arsenic trioxide dust and/or arsenic-impacted waste is contained in a frozen shell, which can be reversed by thawing and/or excavation
  - F2-3. Backfill at minimum 100 kiloPascals (kPa) strength can be excavated to access chambers.

Linkages to Other Plans

The Arsenic Trioxide Frozen Shell MMP will be implemented in conjunction with other Site management and monitoring plans to support the overall GMRP goals and closure objectives. Other GMRP management and monitoring plans that are relevant to this MMP are illustrated in Figure 1.1-2. An overview of the Site-wide monitoring during Active Remediation and Adaptive Management (Phase 2) and during Post-Closure (Phase 3) is illustrated in Figure 1.1-3.

The environmental MMPs for the GMRP have been developed to complement each other while reducing repetition and overlap between plans. As a result, the environmental MMPs are cross-referenced within other plans to indicate where more information can be found. The linkage figures assists with the understanding of how these plans work together to manage and monitor site activities; these are high-level figures representing overall relationships. Figure 1.1-2 is reflective of the current scope of the plans (i.e., the first few years), but includes all major activities anticipated over the life of the Water Licence.

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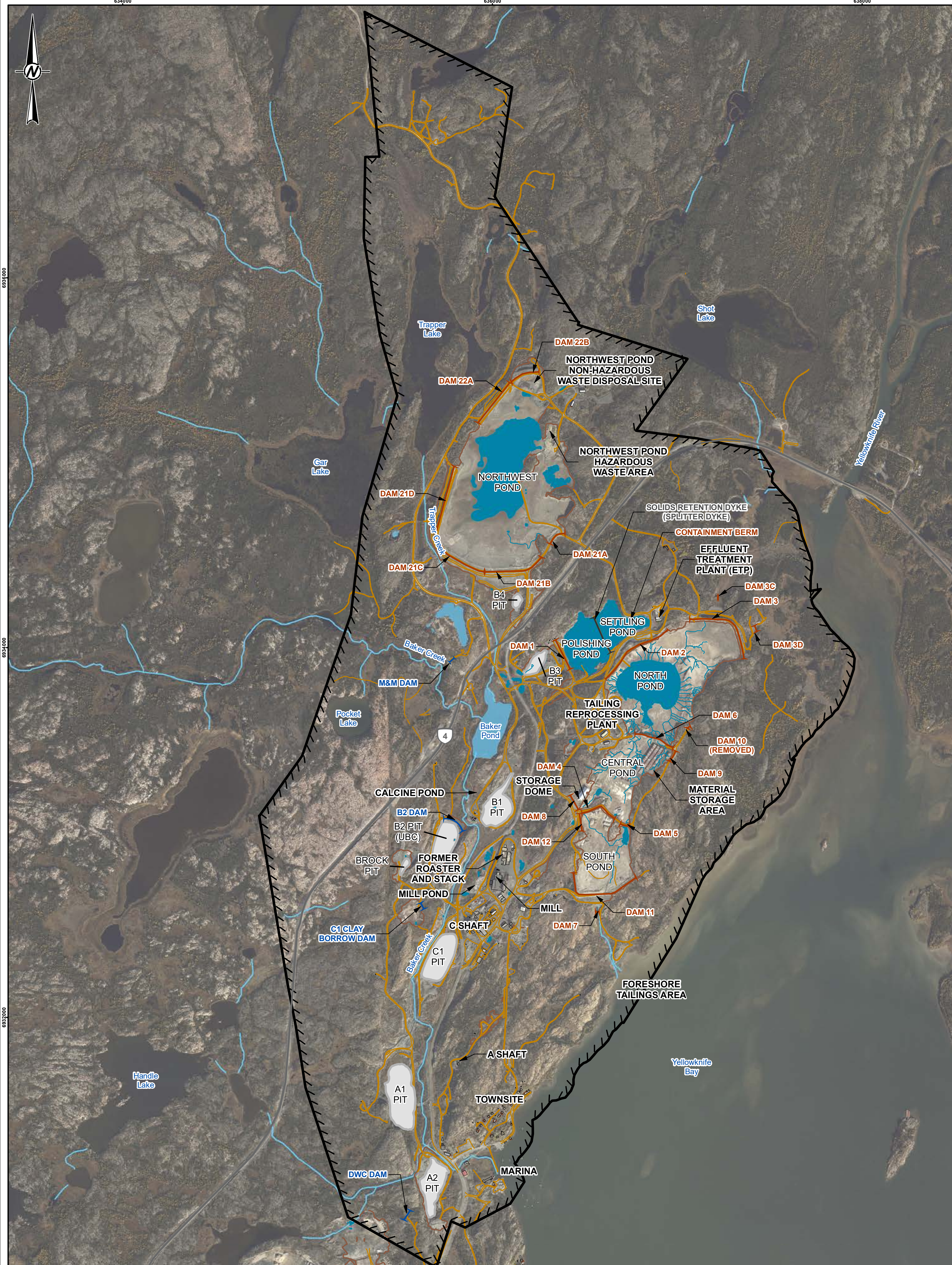

LEGEND

- BUILDING
- GIANT MINE PROJECT BOUNDARY
- HIGHWAY
- INDUSTRIAL WATERCOURSE
- INFRASTRUCTURE
- ROAD
- SPLITTER DYKE
- SURFACE WATER MANAGEMENT DAM/DYKE
- TAILINGS OR SLUDGE RETENTION DAM
- WATERCOURSE
- INDUSTRIAL WATERBODY
- PIT BOUNDARY
- WATERBODY

0 500 1,000

1:20,000 METRES

REFERENCE(S)

HYDROLOGY AND TRANSPORTATION DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. 2018 ORTHOPHOTO PROVIDED BY AECOM. DATUM: NAD 83 PROJECTION: UTM ZONE 11

PROPONENT

Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

PROJECT

Giant Mine Remediation Project

YYYY-MM-DD	2021-03-18
DESIGNED	J. LACRAMPE
PREPARED	A. AUCOIN
REVIEWED	T. HALL
APPROVED	T. HALL

TITLE

GIANT MINE SITE LAYOUT

PROJECT NO.	CONTROL	REV.	FIGURE
20137939	02-74-0599	0	1.1-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

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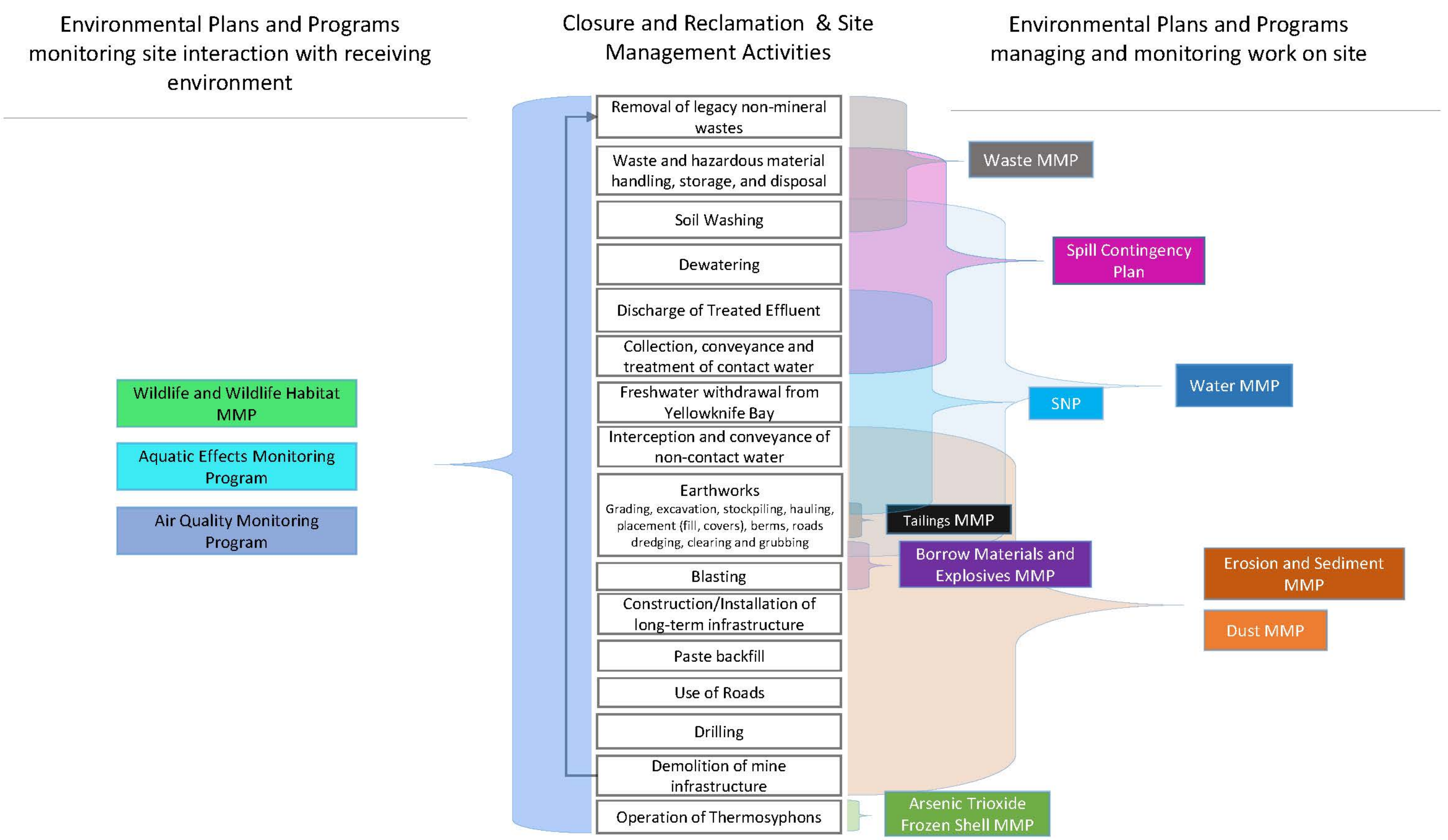
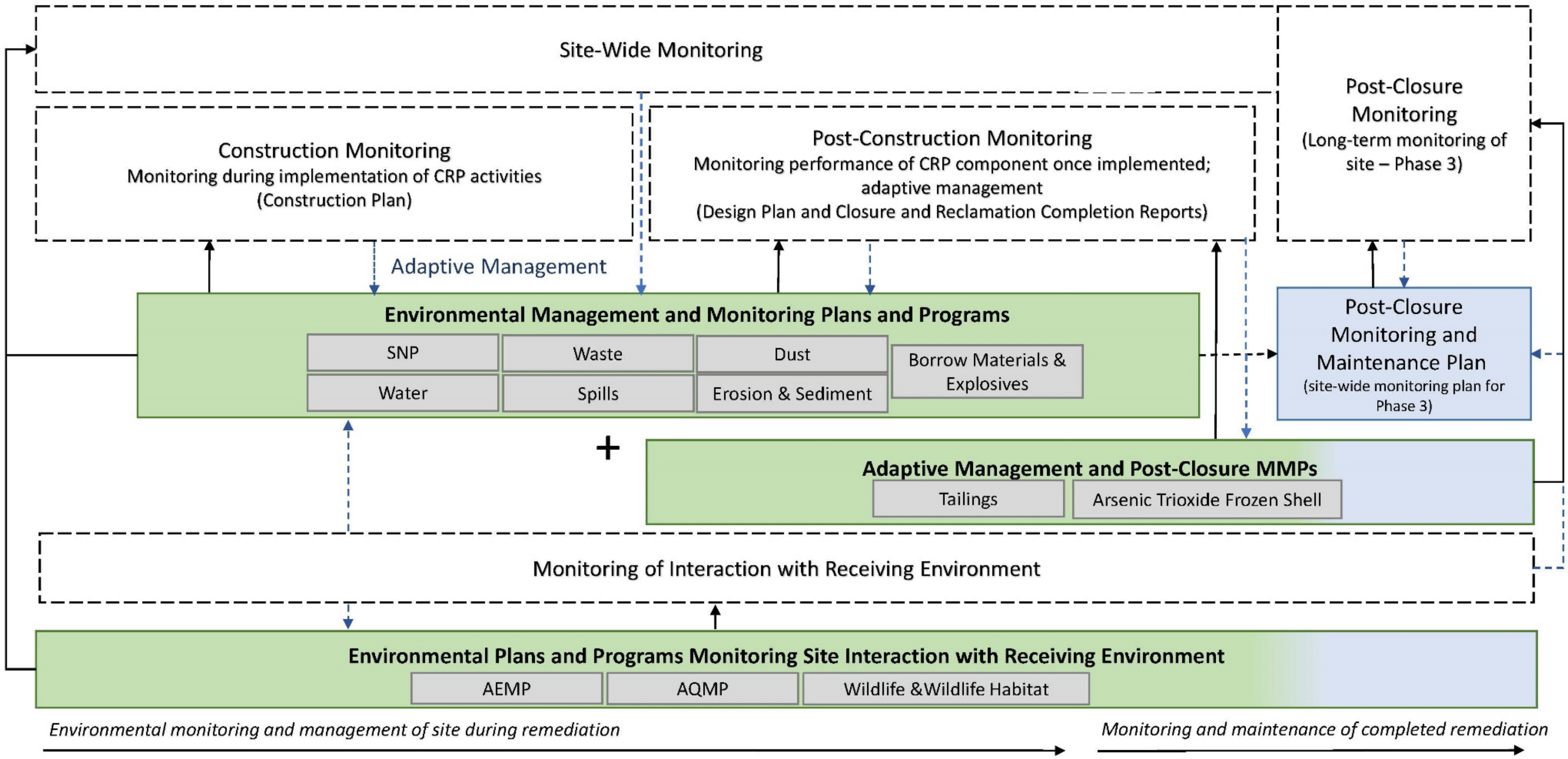
Figure 1.1-2: Linkages Between Management and Monitoring Plans for Giant Mine



Note: there is also an OMS manual for the existing tailings containment area and dam management relevant to the Canadian Dam Association guidelines; it is not for MVLWB approval but is available here for interested parties: https://giantminerp.ca/glance-giant-mine-remediation-project

Figure 1.1-3: Linkages Between Environmental Management and Monitoring Plans, Construction and Design Plans for Giant Mine



1.2 Project Team

The GMRP is jointly managed through a Cooperation Agreement, with the Government of Canada and the GNWT. The GMRP Team consists of Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) and the Government of the Northwest Territories – Environment and Natural Resources (GNWT-ENR) acting as co-proponents with respect to the Environmental Assessment and other regulatory considerations. Public Services and Procurement Canada (PSPC) provides contracting services, contract management, and technical support services to CIRNAC. PSPC has awarded the Main Construction Manager (MCM) contract to Parsons Incorporated. This contract will be used to complete implementation activities for the GMRP. The MCM is responsible for overall Site management including emerging risks on Site and supporting planning efforts for closure and reclamation during the GMRP.

For this Arsenic Trioxide Frozen Shell MMP, the GMRP is responsible for, and has retained the services of the MCM, to verify that required management controls are in place and working properly. The MCM and their procured subcontractors will be required to adhere to management and monitoring details once Design Plans are approved. The MCM will oversee the implementation of the CRP and associated activities. Refer to Table 1.2-1 for staff responsible for management for the GMRP.

Table 1.2-1: Giant Mine Remediation Project Site Contacts

Company	Contact	Role	Information
CIRNAC	Natalie Plato	Deputy Director	Phone: 867-669-2823 Email: natalie.plato@canada.ca
	Candace DeCoste	Regulatory Manager	Phone: 867-444-9783 Email: candace.decoste@canada.ca
	Curtis Duffy	Senior Engineer	Phone: 867-444-9400 Email: curtis.duffy@canada.ca
PSPC	Brad Thompson	Senior Project Manager	Phone: 780-918-6277 Email: brad.thompson@pwgsc-tpsgc.gc.ca
Parsons	Doug Hayes	Mine Manager	Phone: 867-669-3715 Email: doug.hayes@parsons.com
	Norlito Cezar	Environment Manager	Phone: 867-669-3725 Email: Norlito.cezar@parsons.com
	Lex Lovatt	Senior Safety Specialist Security	Phone: 867-669-3719 Email: lex.lovatt@parsons.com

CIRNAC = Crown-Indigenous Relations and Northern Affairs Canada; PSPC = Public Services and Procurement Canada.

1.3 Environment, Health and Safety and Community Policy

Within the GMRP, the health and safety of employees and protection of the environment are an over-riding priority. Management is committed to doing everything possible to prevent injuries and to maintain a healthy environment.

The overall goals of the GMRP are:

- minimize public and worker health and safety risks
- minimize the release of contaminants from the Site into the environment
- remediate the Site in a way that inspires public trust

implement an approach that is cost-effective and robust over the long term

In keeping with these overall goals for the Project, the specific objectives of this policy are:

- protecting the environment and the health and safety of its employees, contractors, and the general public
- engaging meaningfully with stakeholders and rights holders
- recognizing the important contributions of Elders and community members, and incorporating Traditional Knowledge and community knowledge across the Project
- delivering local social and economic benefits
- recognizing the Project is an opportunity to advance reconciliation
- continuing to look for opportunities to further reduce greenhouse gas emissions and incorporate climate change adaptation into the Project

being a recognized leader in Environment, Health & Safety, and Community (EHSC) management among public environmental remediation projects

The full GMRP EHSC Policy is available upon request.

1.4 Regulatory Framework

This plan was developed in consideration of regulatory requirements including legislation, guidance documents, Water Licence requirements, and GMRP commitments and conditions. A full list of requirements/commitments relevant to this plan can be found in Appendix A. Relevant federal and territorial legislation and permits/licences that apply to the Site include:

- *Mackenzie Valley Resource Management Act*
- *Government of Northwest Territories Mine Health and Safety Act* and Regulations
- Type A Water Licence (MV2007L8-0031)
- Type A Land Use Permit (MV2019X0007)
- *Canadian Environmental Protection Act* and the Toxic Substances Lists
- *Fisheries Act* and the Metal and Diamond Mining Effluent Regulations

Water Act and the Mackenzie Valley Federal Areas Water Regulations

There are two environmental assessment measures that inform the freeze containment design (MVEIRB 2013):

- **Measure 18 – Freeze Design:** Prior to preparing chambers and stopes for freezing, the Developer will conduct a comprehensive quantitative risk assessment evaluating both wet and dry methods for the initial freezing design, with respect to current risks and implications for future removal. This will include an evaluation of potential effects of the proposed freezing and wetting method on the thawing or frozen excavations, and potential impacts of ongoing design changes prior to implementing the Project. The Developer will release a plain language report to the public describing its considerations and the resulting design.
- **Measure 19 – Reversibility:** Considering the results of the risk assessment described in Measure 18, the Developer will not adopt any method of freezing that significantly reduces opportunities for future arsenic removal or other remediation by future technologies.

Reference to how these measures are addressed is provided in the Design Considerations as required by Water Licence section of the Freeze Design Plan, and more specifically in the CRP, Consideration of Closure Objectives (Section 5.2.4). The following excerpt from Section 5.2.4 in the CRP is provided in response to Measures 18 and 19:

"…findings from the Freeze Optimization Study (FOS, described below), were used to further modify the frozen block alternative by removing the need for freeze pipes underneath the chambers and stopes and eliminating the need to wet the dust within them. In support of the reversibility closure objective, keeping the dust dry facilitates potential future extraction if alternative ex situ remediation technologies evolve to better manage the arsenic trioxide dust. The recommended design thereafter became known as the dry frozen shell method. The alterations are presented in the Freeze Optimization Study Update for MVEIRB and Parties (SRK 2012). Key considerations driving the selection of closure activities for the containment of arsenic trioxide dust is shown in Figure 5.2-1."

For greater clarity, the FOS findings and subsequent design recommendations have been addressed by both SRK in their preparation of the design basis report (see Closure and Reclamation Plan for details), and by AECOM in their subsequent design work leading to the development of the plans included in Appendix D of this report. The adopted FOS recommendations in the design satisfy the Water Licence Schedule 3, Condition 2 requirement.

There is no specific Federal or Territorial legislation regarding ground freezing applications. The following guidance/policy documents were used to support the Arsenic Trioxide Frozen Shell MMP:

- Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories prepared by the Mackenzie Valley Land and Water Board (MVLWB) and Aboriginal Affairs and Northern Development Canada (AANDC) (MVLWB and AANDC 2013)
- Standard Outline for Management Plans (MVLWB 2013)
- Water and Effluent Quality Management Policy prepared by the MVLWB (March 2011)

Best practice from other Canadian mines utilizing ground freezing for water control including among others: McArthur River Mine (Cameco Corporation), Cigar Lake Mine (Cameco Corporation) and Jansen Mine Shafts (BHP Billiton).

1.5 Engagement

Two topics related to the freeze program were identified through engagement during the Water Licence process:

- How climate change predictions were incorporated into the design and modelling; and,
- How greenhouse gas emissions from an active freeze system would affect the environment and associated mitigation measures.

In response, the GMRP has confirmed that the latest climate change predictions were incorporated into the freeze design and this design is based on a passive, not active, freezing system. A fully passive system does not have a carbon footprint and no greenhouse emissions.

Review and engagement activities on this Arsenic Trioxide Frozen Shell MMP has included pre-engagement with the Giant Mine Working Group 10 August 2020. For further detail on the general engagement that has occurred for the GMRP please refer to the CRP and Engagement Plan.

1.6 Traditional and Community Knowledge

The consideration of Traditional and Community Knowledge has been integrated into project planning, wherever relevant and available. The Closure and Reclamation Plan outlined how this knowledge influenced project decisions. The Engagement Plan, specifically Appendix C, summarizes the Traditional and Community Knowledge provided to date. The GMRP Team is committed to continuing to incorporate Traditional and Community Knowledge into the implementation of remediation and future versions of this plan, where information is available and appropriate. Since the Closure and Reclamation Plan was filed, the GMRP did not hear Traditional and Community Knowledge specific to the Arsenic Trioxide and Frozen Shell MMP beyond the concepts already incorporated into the Project.

1.7 Project Activities Relevant to Plan

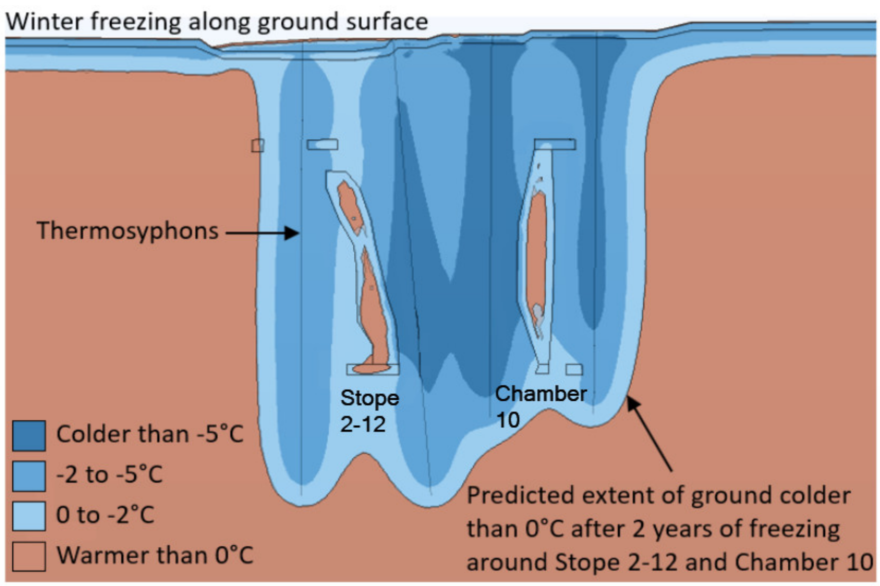
This Arsenic Trioxide and Frozen Shell MMP is a post-construction monitoring and management plan. This Plan covers the monitoring and maintenance activities after the thermosyphons have been installed and are actively cooling the ground. The frozen shells will slowly develop over a 10-year period after thermosyphons are installed. They will continue to grow and will ultimately respond to very long-term climate trends. The system has been designed to meet the containment criteria in both the short and longer term with allowance for uncertainty in climate change projections.

2 FREEZE PROGRAM OVERVIEW

The Giant Mine was an active gold mine from 1948 to 2004. After the gold was mined, it went through a milling process whereby arsenic trioxide dust was created as one of the waste products. Arsenic trioxide dust is hazardous to human health and the environment and it can dissolve readily in water, so it is necessary to contain the dust. During mining, large openings underground, called stopes were dug out and over the years, these were used to store much of the dust. In some areas of the mine, purpose-built chambers were also excavated to house additional dust. Once a chamber or stope was full, it was sealed with bulkheads that intended to keep the dust safely underground and prevented it from getting to the surface or into the water and adversely impacting the environment. While working toward a long-term solution to contain the dust, pumps were used to keep the water table artificially lowered in the vicinity of these dust filled chambers/stopes. Figure 2-1 outlines the arsenic trioxide filled stopes and chambers, and the thermosyphon conceptual design for Areas 1 to 4 from the CRP.

A wide variety of options to safely and effectively manage the arsenic trioxide over the long-term at Giant Mine were investigated. For more information on all the options considered, refer to the Design Basis Report (SRK 2016). Ultimately, it was decided that the ground should be frozen in, and around, each of the arsenic filled underground chambers/stopes using passive heat pumps called thermosyphons, which do not require electrical power or energy. Over several years, the thermosyphons develop a frozen shell in the surrounding bedrock or fill around the storage chambers, stopes, B1 pit and other mine workings to prevent the release of arsenic as shown in Figure 2-1.

Figure 2-1: Conceptual Image of Frozen Ground Developing around Typical Chambers/Stopes



2.1 Objectives

By freezing the ground and creating a frozen barrier, the ice prevents any water that enters the area from reaching the arsenic. The practice of freezing ground to control the flow of water has been used around the world since the 1800s and it has proven very effective. The arsenic dust contained in the chambers/stopes has been kept “dry” in case there is a future desire to reverse the freezing process to extract the dust and treat/dispose of it in another manner. The reversibility of the freeze program has been a deliberate design consideration as thawing dry frozen ground takes less time and energy than thawing wet frozen ground (Figure2.1-1).

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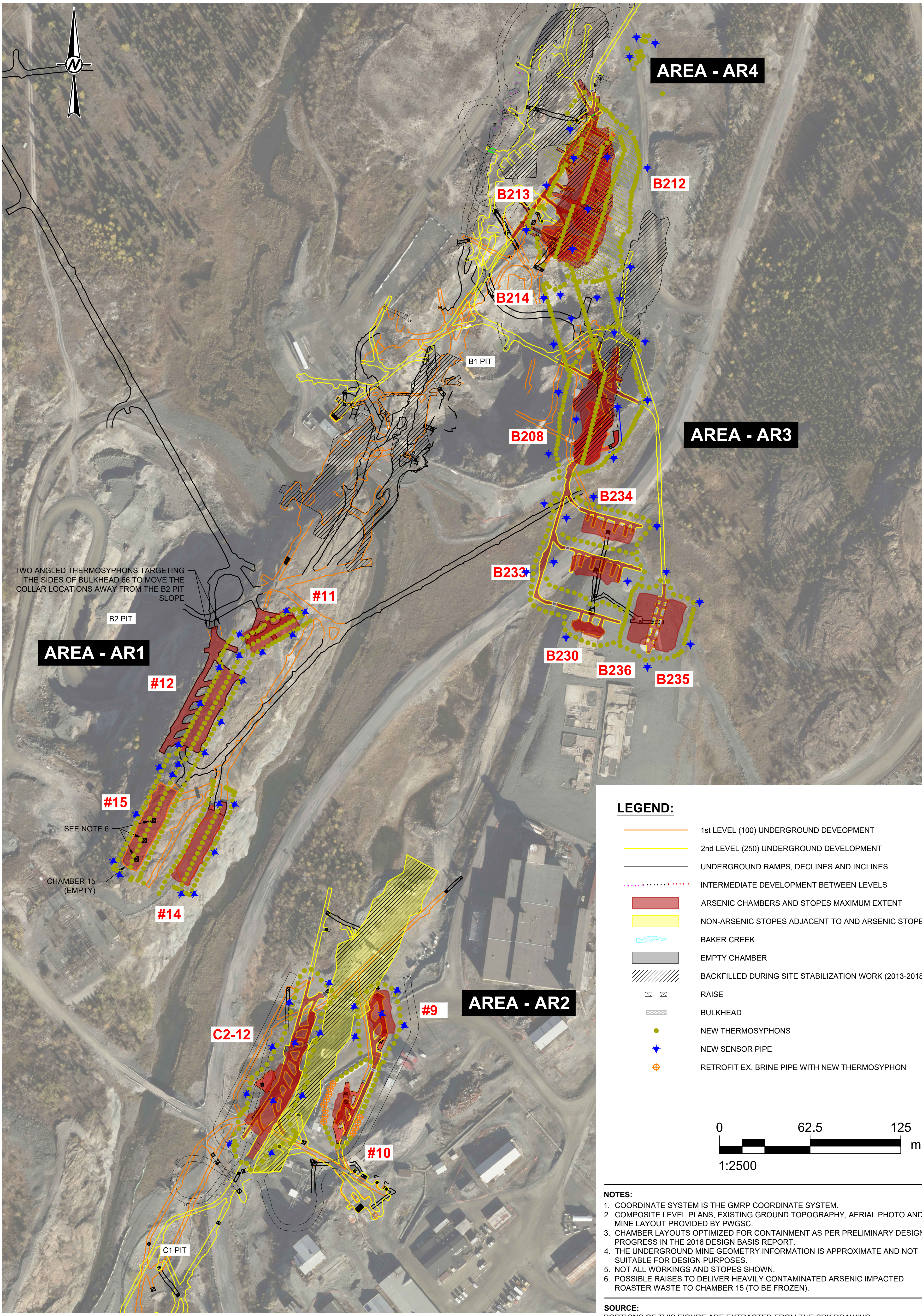


NOTES:

1. COORDINATE SYSTEM IS THE GMRP COORDINATE SYSTEM.
2. COMPOSITE LEVEL PLANS, EXISTING GROUND TOPOGRAPHY, AERIAL PHOTO AND MINE LAYOUT PROVIDED BY PWGSC.
3. CHAMBER LAYOUTS OPTIMIZED FOR CONTAINMENT AS PER PRELIMINARY DESIGN PROGRESS IN THE 2016 DESIGN BASIS REPORT.
4. THE UNDERGROUND MINE GEOMETRY INFORMATION IS APPROXIMATE AND NOT SUITABLE FOR DESIGN PURPOSES.
5. NOT ALL WORKINGS AND STOPES SHOWN.
6. POSSIBLE RAISES TO DELIVER HEAVILY CONTAMINATED ARSENIC IMPACTED ROASTER WASTE TO CHAMBER 15 (TO BE FROZEN).

SOURCE:

PORTIONS OF THIS FIGURE ARE EXTRACTED FROM THE SRK DRAWING "Variant9Layout.dwg" FROM THE 2016 FREEZE PROGRAM DESIGN BASIS REPORT. OTHER PORTIONS ARE TAKEN FROM GOLDER FIGURE 5.1-5 WITHIN THIS REPORT.

PROPONENT

Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

YYYY-MM-DD	2021-05-11
DESIGNED	SRK Consulting
PREPARED	C. Eros
REVIEWED	M. Gregg
APPROVED	R. Schmidtke

PROJECT

Giant Mine Remediation Project

TITLE

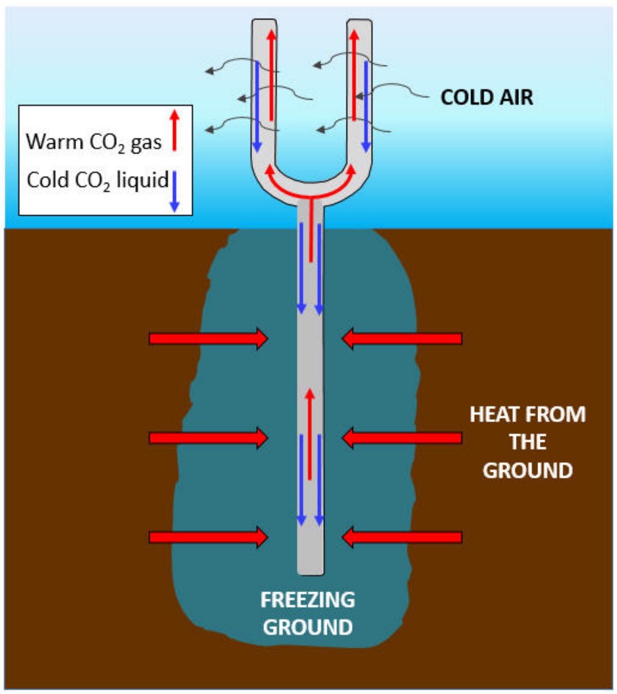
THERMOSYPHON CONCEPTUAL DESIGN LAYOUT (VARIANT 9)

REV.	FIGURE
1	2.1-1

2.2 Thermosyphon Technology

A passive freeze system can only be used in far northern climates. It does not require a mechanical freeze plant as it uses specially designed pipes called thermosyphons that respond to the temperature between the ground and the climate where they have been installed. The thermosyphon is a continuous, closed system consisting of two main sections. The evaporator section is the length of pipe that exists underground. The condenser section is the portion of the pipe that sticks out above the ground and is exposed to the climate. The condenser component consists of either 1 or 2 lengths of pipe that are "finned" to increase the surface area of the condenser exposed to the cold air. The thermosyphons are filled with a saturated carbon dioxide (CO_2) vapour as shown in Figure 2.2-1.

Figure 2.2-1: Description and Function of a Thermosyphon



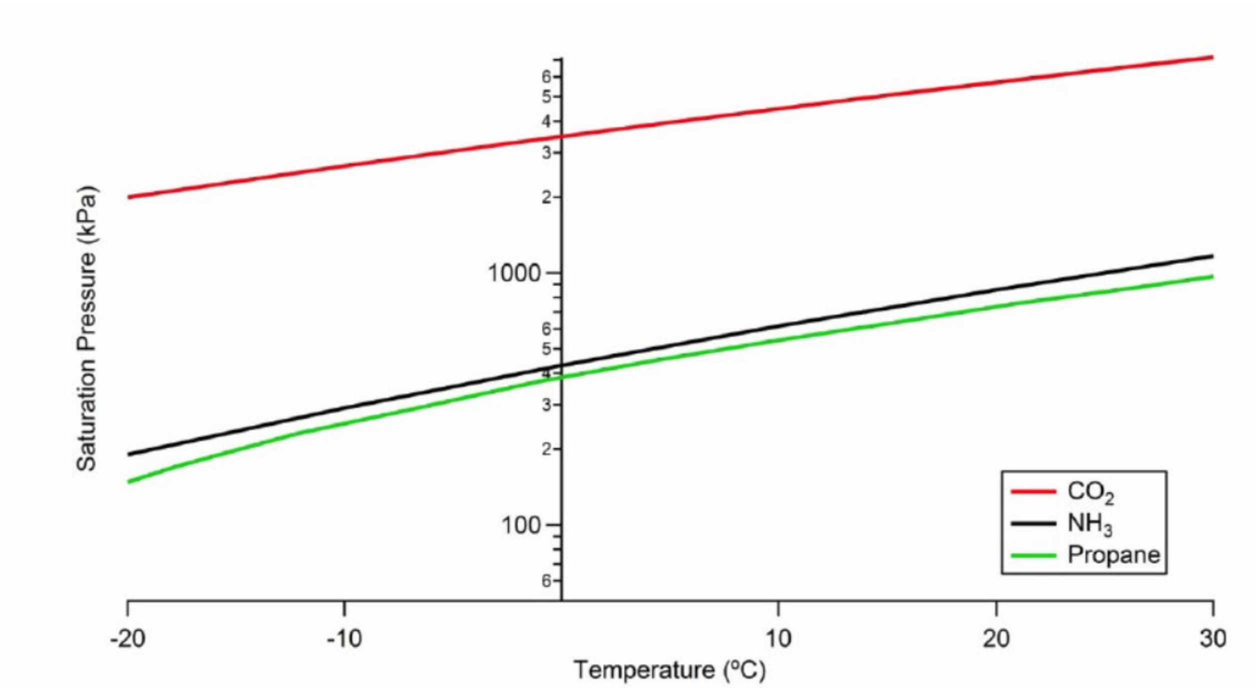
The pressurized CO_2 acts as the heat transfer medium. Heat from the ground evaporates the CO_2, which then rises to the top of the pipe. When air temperatures are cold enough, the CO_2 releases heat to the atmosphere and condenses. The CO_2 flows back to the bottom of the pipe and the process repeats. Over time, the ground cools and establishes the frozen shell. The process continues as long as the air is cold enough to condense the gas and the ground is warm enough to evaporate it. When the air temperature gets warmer than the ground, as is the case during the summer, the process temporarily shuts down. In Yellowknife, there is more winter cooling time than summer shutdown time during any full year, so over several years, the ground continues to gradually cool and then stays frozen.

In a passive freeze system, the time it takes to initially freeze the ground depends on many considerations, such as the initial temperature of the ground, how many thermosyphons are installed, and how much winter cool-down versus summer shutdown time exists from year to year. To monitor the initial freezing process temperature sensors are installed at various depths around each chamber/stope.

The active operation of the freeze system is limited to monitoring activities. The freeze system is a fully passive design and does not require any regular operating intervention for control. Monitoring temperature sensors can be used in conjunction with thermal models developed by engineers to assess the freeze status at any point in time. They are also critical to help identify potential issues that may have an impact on the integrity of the frozen shell.

Each thermosyphon needs to be properly charged with CO_2 in order to function properly. Figure 2.2-2 shows a pressure temperature chart for CO_2 (and two other gases) with the range of operating pressures and temperatures for the GMRP thermosyphons shown as a red data series. During operations, the state of liquid/vapour inside the thermosyphon follows the red highlighted saturation line. Changes in temperature induce pressure changes that force the saturated vapour to rise up within the thermosyphon or increase in density and flow back down. At the time the thermosyphons are filled, the temperature will likely be closer to room temperature, which means the pressure build up inside the pipe will range as high as 50 bar (5,000 kPa). For information related to the initial charging of a thermosyphon, refer to the Operations section of this report and if possible, consult the equipment vendor directly.

Figure 2.2-2: Operating Pressure and Temperature Range in Typical Thermosyphons



Note: The operating "state" for the GMRP thermosyphons lies on the red saturation vapour pressure line shown for CO_2.

2.3 Performance Criteria

The arsenic trioxide dust is contained and isolated from the groundwater once the surrounding rock at each chamber or stope is surrounded by a frozen shell. At Giant Mine, a single freeze criterion has been adopted to identify when the ground has been adequately encapsulated to consider the dust fully contained and isolated. Adopting a single criterion to describe the integrity of a frozen shell around the arsenic trioxide dust storage areas means the dust is inherently contained at all times once the criterion is satisfied.

The freeze containment criterion for the Giant Mine freeze program is:

A minimum 5 m wide zone of bedrock or fill at -5°C or colder surrounding all sides of each arsenic containing chamber, stope, drift or pit fill.

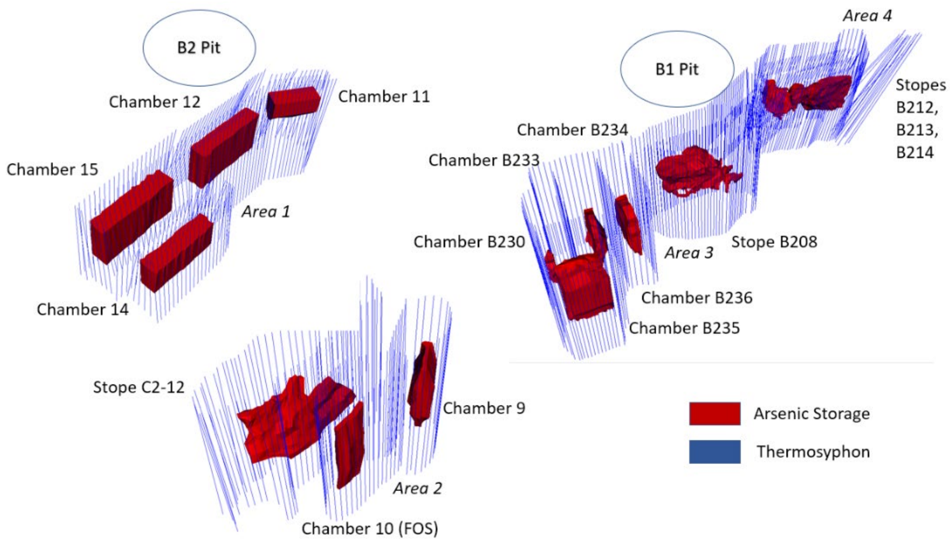
The frozen shell will significantly isolate the dust once it cools below a temperature of -2°C, as the ground will be frozen enough to greatly reduce the hydraulic conductivity in fractures and porous materials. This significantly reduces risk. The -5°C target over a distance of 5 m provides a margin of safety against local variability in freezing rates, rock properties, and porosity.

Integrity of the frozen shell can be confirmed by comparing temperatures from sensors installed well outside of the dust filled chambers and by comparing those values to modelling predictions (refer to Section 5.1.1.1). These temperatures will indicate if there are warming trends with the potential to exceed the containment criterion. Trends that deviate from the predictive models will require investigation and, if necessary, mitigation. A freeze data interpretation checklist summary has been developed for the freeze program that identifies when mitigation is required to maintain the integrity of the frozen shell for various scenarios requiring a Response Framework (refer to Section 5.4)

2.4 Freeze Design Summary

There are four main freeze areas at Giant Mine (AR-1, AR-2, AR-3 and AR-4) as well as a B1 Midpit freeze area located between AR-3 and AR-4 (Figure 2.4-1). The thermosyphons within each area are uniquely designed to satisfy the containment criteria within 10 years and to protect the frozen shell against future climatic warming. As such, the length, angle of installation and distribution of thermosyphons varies significantly within and between each area. In general, deep, i.e., longer length, perimeter pipes are distributed around individual chambers/stopes. Shallow, i.e., shorter length, thermosyphons have been installed above some of the chambers and stopes to offset the longer-term climate warming effects near the surface. The shallow thermosyphons have one finned condenser section while deep thermosyphons have two finned condenser sections.

Figure 2.4-1: Overview of All Four Freeze Areas relative to B1 and B2 Pits



The thermosyphons consist of seamless tubing with welded joints to provide a gas-tight seal. Any work done on them must be done according to Boiler and Pressure Vessel Code CSA B51. The thermosyphons are designed such that smaller diameter pipes can telescope inside the original thermosyphon casing should refitting of individual freeze holes be required. Replacing a thermosyphon can be done by removing the above ground portion of an existing thermosyphon and telescoping in a smaller 76 mm inside diameter (ID) pipe inside the original 101 mm (ID) pipe. If needed, the original 101 mm (ID) pipe could also be removed as the pipes will be grouted into the boreholes using a weak grout. The grout, however, would have to first be defrosted by heating the pipe. More information on maintenance can be found in Section 6 of this document.

In total, the design includes 706 deep thermosyphons, 152 shallow thermosyphons and 76 monitoring holes installed across all freeze areas (Table 2.4-1). Monitoring sensors also co-exist and have been included along the length of select thermosyphons to validate heat extraction for modelling purposes.

Table 2.4-1: Summary of Thermosyphon and Monitoring Pipe Quantities

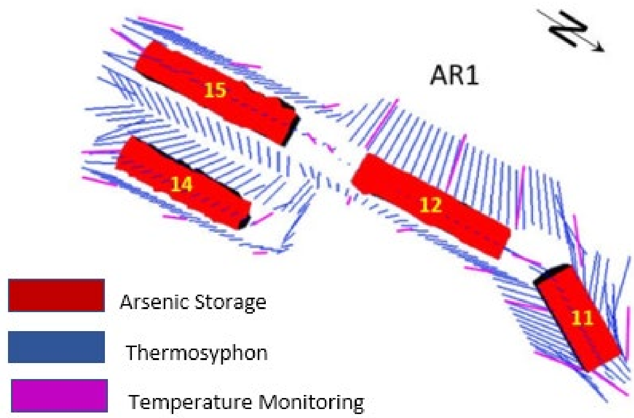
Area	Deep Thermosyphons	Shallow Thermosyphons	Monitoring Holes
1	189	67	23
2	124 plus 12 already at FOS	0	15 plus existing FOS
3, 4 and B1 Midpit	381	85	38
Total*	706	152	76

Note: Total thermosyphons: 858 (12 already running, 26 to be retrofitted at the FOS)
FOS = Freeze Optimization Study

2.4.1 AR-1

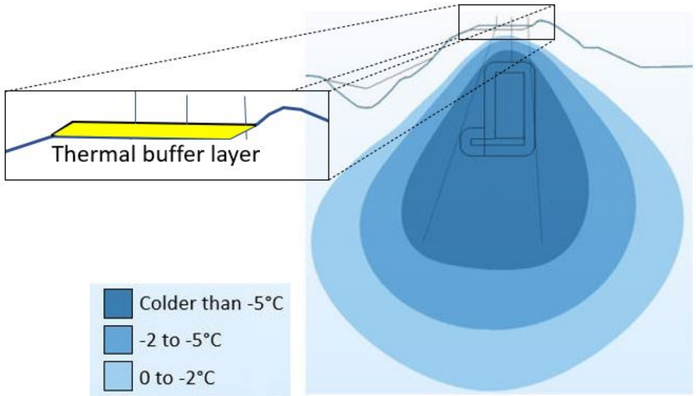
There are 189 deep thermosyphons, 67 shallow thermosyphons and 23 monitoring holes located in AR-1. There are several features unique to AR-1 that control the freeze design. AR-1 is located at the top of a bedrock hill with the B2 Pit located to the West and Baker Creek to the East. The chambers in AR-1 include C11, C12, C14, and C15 as shown in Figure 2.4-2. Chambers 11 to 14 store dry arsenic-trioxide dust, whereas Chamber 15 has been used to dispose of miscellaneous arsenic impacted waste.

Figure 2.4-2: AR-1 Chambers (top view)



The chambers are in close proximity to the ground surface. As such, the spacing between deep thermosyphons is generally closer together than elsewhere in the freeze program and the shallow thermosyphons installed above each chamber are an important feature to protect the frozen shell against future climate warming, additional detail is provided in the Freeze Containment Design Plan. In addition, a coarse rock, “thermal buffer layer” was constructed on the modified ground surface above Chambers 15, 12 and 11 as shown in Figure 2.4-3. This layer was dual purpose, providing traffic access and level drilling platforms (i.e., freeze pads) to facilitate initial drilling of the thermosyphon holes in addition to providing a large void, thermal barrier layer to reduce summertime heating of the underlying ground surface.

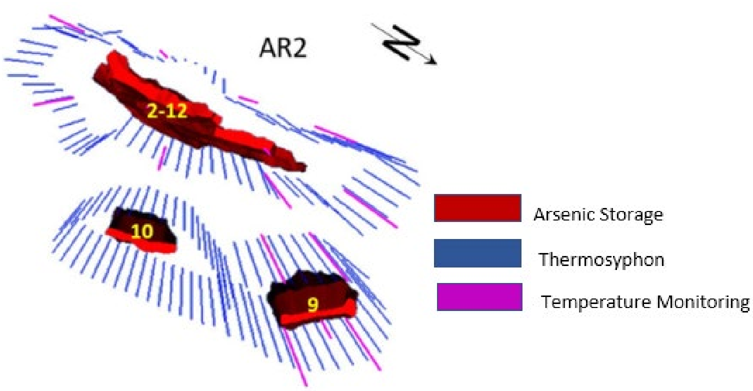
Figure 2.4-3: Thermal Buffer Layer and Development of Frozen Shell around Chamber at 100 Years



2.4.2 AR-2

AR-2 encompasses chambers C2-12, C10, and C9 as shown in Figure 2.4-4. There are 136 deep thermosyphons and 15 monitoring holes located in AR-2 excluding many monitoring holes left over from the Chamber 10 Freeze Optimization Study (FOS). In general, these chambers are located at a greater depth than those in AR-1, therefore shallow thermosyphons over the chambers were not required.

Figure 2.4-4: AR-2 Chambers (top view)

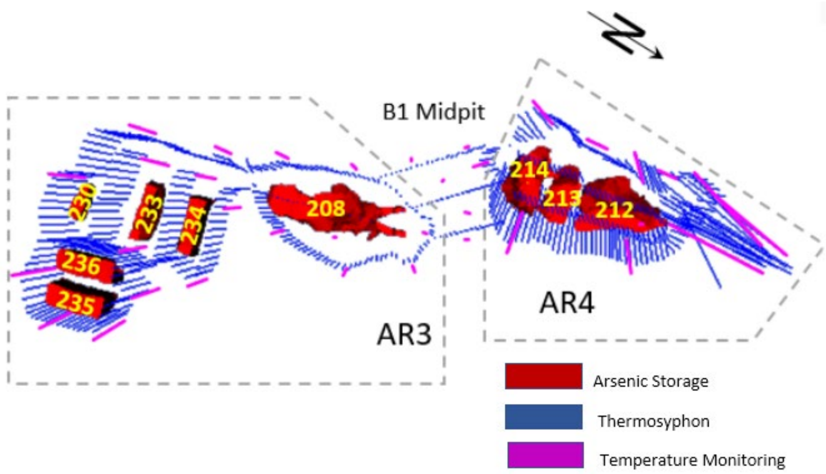


Chamber 10 was the location of FOS from 2010 to 2015. The FOS was a full-scale physical trial that evaluated both active and passive freeze systems. The study considered different pipe spacing, installation techniques, and construction materials and provided proof of concept that ground freezing was a successful method for dust containment at Giant Mine. Although the current freeze design only uses passive thermosyphons, there is still abandoned active freeze infrastructure and monitoring equipment that exists around Chamber 10.

2.4.3 AR-3 and AR-4

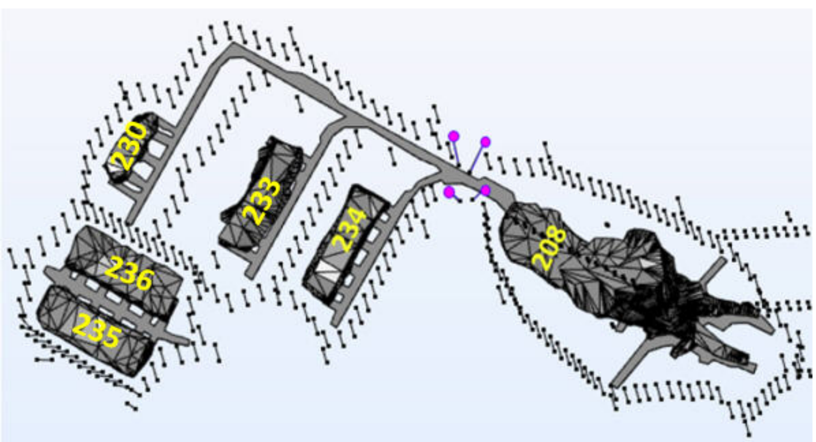
AR-3 encompasses chambers C230, C233, C234, C235, C236, and stope B208. AR-4 encompasses stopes B212, B213, and B214 as shown in Figure 2.4-5.

Figure 2.4-5: AR-3, B1 Midpit and AR-4 Showing Chambers and Stopes (top view)



There are 381 deep thermosyphons, 85 shallow thermosyphons and 38 monitoring holes throughout AR-3, B1 Midpit, and AR-4. Special design considerations included the increased spacing between thermosyphons at the south end of B208 to facilitate surface drainage and road access as shown in Figure 2.4-6.

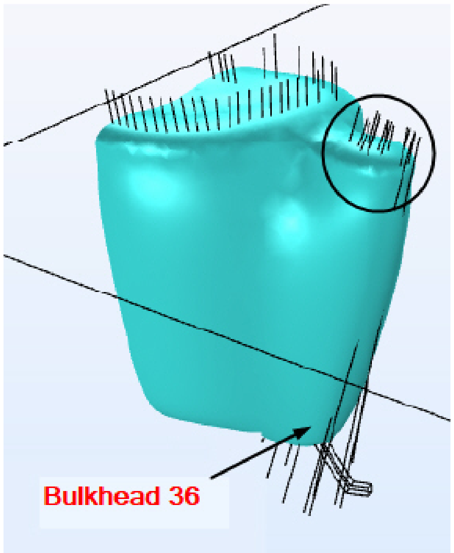
Figure 2.4-6: Pipes (purple bullets) Adjusted to Allow for Road Access and Ditch Drainage



Unlike AR-1, thermosyphon spacing is closer together in AR-3 not because the chambers are near the ground surface, but because the distance between and across groups of chambers is much larger.

Bulkhead 36 at the very north end of AR-4 is located tens of meters below the base of the B 212 stope. As the drift above the bulkhead was arsenic dust filled, it was necessary to incorporate the bulkhead into the frozen shell established in AR-4. Given the number of underground workings, design and placement of the thermosyphons specific to freezing around Bulkhead 36 resulted in a unique freeze pattern to minimize intersection between thermosyphon pipes and underground drifts as shown in the 3D modelling result in Figure 2.4-7.

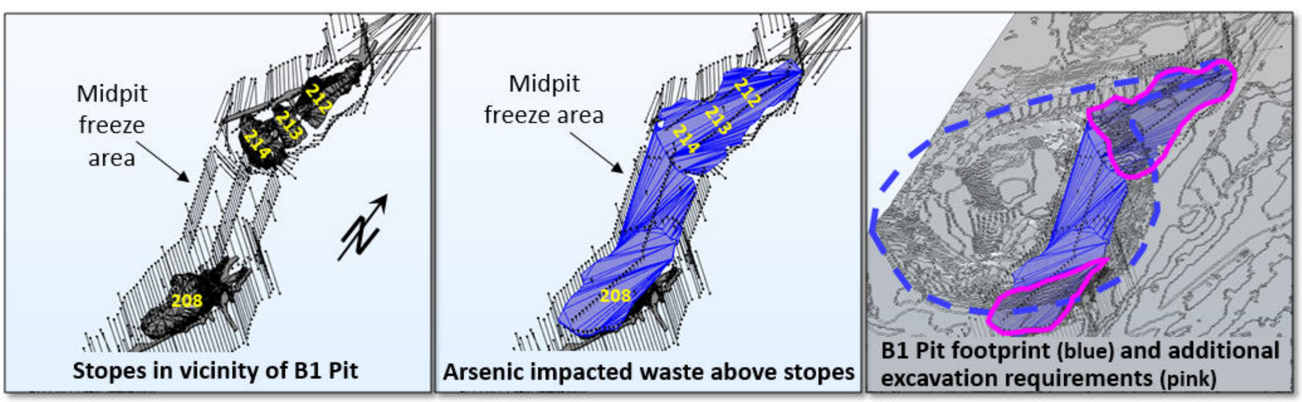
Figure 2.4-7: Bulkhead 36 Unique Cluster of Thermosyphons



2.4.3.1 Arsenic Impacted Waste Containment

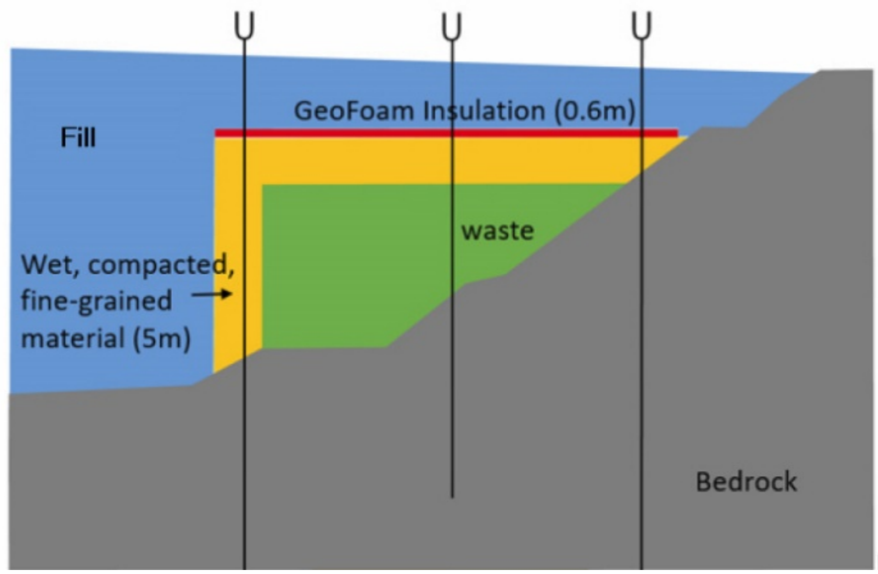
While the freeze designs for chambers/stopes in AR-3 and AR-4 are considered separate they are connected through the near surface disposal of arsenic impacted waste (i.e., contaminated soils and roaster waste) that occurred in the B1 Pit area. This arsenic impacted waste will be deposited on the eastern side of the B1 pit as well as in some shallow zones above stopes B208 and B214 / B213 as shown in Figure 2.4-8.

Figure 2.4-8: Select AR-3 and AR-4 Chambers (left), arsenic impacted waste disposal extents (middle) and in the vicinity of the B1 Pit footprint (right).



The disposal of the arsenic impacted waste incorporates a layer of GeoFoam™ insulation or equivalent engineering insulating material (to be confirmed) as shown in Figure 2.4-9.

Figure 2.4-9: Schematic of the Use of GeoFoam™ (or similar) Insulation over the Arsenic Impacted Waste Disposed of in the Vicinity of B1 Pit.



The insulation layer is placed deep enough to protect it from seasonal thawing and exposure to water, which is the general cause of R-value degradation. Keeping it deeper and frozen will prevent it from any freeze thaw cycling. If, over the long term, additional insulation is needed to offset unexpected climate warming, a second layer could be added nearer to the surface to avoid any excessive excavation work.

3 INSTRUMENTATION OVERVIEW

The monitoring program involves a combination of in-ground monitoring (excluding the arsenic trioxide dust contained in the chamber and stope) as well as thermosyphon wall temperature monitoring in selected longest or most inclined holes. The FOS validated freeze performance in vertical, 100 m long thermosyphons. Monitoring temperatures in longer or inclined holes will provide confirmation of thermosyphon efficiency. Furthermore, every thermosyphon has a temperature sensor at a depth of 5 m to enable confirmation of passive re-start of each device in the fall season when the air temperature cools. The total number of ground monitoring holes is approximately 10% of the number of perimeter thermosyphons; with each hole having up to 10 sensors spaced over the length of the hole. The monitoring-to-freeze hole ratio provides adequate coverage to assess freezing performance in both the short and long term. It also provides some redundancy in the event some sensors fail. The 10 to 1 ratio is common in the ground freezing industry (e.g., McArthur River Mine, Cigar Lake Mine, BHP Jansen Mine Shafts, Washington DC Water Main freeze project, Vancouver Second Narrows freeze project). Monitoring locations target areas of anticipated higher heat ingress and provide data, with redundancy, for model calibration purposes. The sensor holes are designed to allow for repair and replacement while the redundancy allows for flexibility in the timing of repair. Resistance Temperature Detector (RTD) sensors are used and installed within tubing filled with Dynalene or an equivalent heat transfer medium (e.g., they are not grouted in place). This facilitates removal for inspection or replacement.

To reduce future troubleshooting time for a failed sensor, junction boxes and remote input/output panels (Remote I/O) have been strategically placed within each freeze area, to significantly reduce wiring requirements and cable lengths. Fibre optic cables are used to transmit data from the remote I/O cabinets to a new Programmable Logic Controller (PLC) and data management system housed in the water treatment plant (WTP).

3.1 Objectives

The objective of the instrumentation design is two-fold. Most sensors are installed in strategic locations to measure ground temperatures and monitor the growth and extents of the frozen shell for both short and long-term conditions. Monitoring of ground temperatures will allow for a comparison against anticipated trends and if observations deviate from expectations, allow for adaptive management strategies to be implemented. This is particularly important given the uncertainty surrounding long term climate change impacts on passive thermosyphon performance.

In addition to ground temperature monitoring, temperature sensors are installed at a depth of approximately 5 m on every thermosyphon pipe wall. These sensors' primary purpose is to confirm that the thermosyphons have reactivated following each dormant summer season. Ground temperatures at a shallow depth will respond to summer surface heating and should exist in a warmer state than deeper down as each winter season approaches. When the air temperature drops several degrees below the ground temperature, the thermosyphon should reactivate and the sensors installed at the 5 m depth should show a similar and timely response. If the ground temperature at 5 m depth does not respond in a timely manner to colder ambient climate conditions, then this would indicate a potential malfunction of the thermosyphon, and additional steps, as outlined in Section 5 would be followed.

3.2 Instrumentation Technology

The primary technology for temperature measurement is the RTD as they are more accurate and have better long-term stability. Data signals from each RTD in the ground temperature sensor strings are collected at a local termination box and then a single cable transmits that data to a Remote I/O panel. Data from all Remote I/O panels are then transmitted to the Main PLC and local data storage computer located in the WTP. A cloud-based data storage back-up also allows for remote access to all field data.

In addition to automatically collected field temperature data, handheld thermal imaging camera technology (e.g., FLIR or similar) will be used to manually confirm successful operation of the passive thermosyphons in the early winter of each year (to start with) and then on an as needed basis over the long term. The thermal camera will also be used to trouble shoot suspected inoperable thermosyphons; which will be identified during surveillance.

All temperature data will be collected from the field by the PLC and trended using a 1-hour sampling frequency. Data will be stored in the data historian twice a day (at 2pm and 2am). Over the longer term, once initial freeze containment is achieved (e.g., within 10 years) and to minimize data storage needs, data can be saved on a daily 24-hour average basis.

3.3 Power Supply and Data Loggers

3.3.1 Power Supply

Power supply at Remote I/O is primarily from the overhead mains, and small local uninterruptible power supplies (UPS) are in each cabinet for temporary short time outages.

Power supply at the main PLC is primarily from the incoming utility mains to the WTP. The WTP has a local generator capable of energizing during a sustained Utility outage. The main PLC also has a local UPS to provide backup power capable to support 1hr+ power outage.

3.3.2 Data Loggers

Data collected by the PLC will be timestamped and stored in Redundant Array of Independent Disks (RAID) storage media. Depending on the RAID level (to be determined in detailed design), at least 2 solid state storage devices will be used to store data. In case of failure of one solid state storage device, data will be backed up in another storage device. Remote access will be provided to the storage devices to access data for back-up on remote storage (cloud storage or remote hard drive storage – and will need to be determined during detailed design).

The data storage will be set up as a circular storage file also called a first-in-first-out file. This means that the data will be added until the storage location is full. At that point, the old data will start to be overwritten. The exact duration until the data disk will be full and is overwritten will be determined during detailed design but shall meet or exceed 10 years. The recorded data will be backed up remotely on a regular basis.

3.4 Weather Data

Historical weather data is available from Environment Canada, as collected at the Yellowknife airport. Longer term climate predictions can be obtained from the University of Alaska Scenarios Network for Alaska and Arctic Planning (SNAP) Resource or other sources approved by the project management advisory team.

Additional information on the wind and dust monitoring at Site, including a description of the on-site Meterological Station is included in the Monitoring section of the Dust MMP and the Air Quality Monitoring Plan (which is an appendix to the Dust MMP).

4 OPERATIONS

The overall design intent for using a passive freezing system is to minimize any direct day to day operations. The freeze containment must remain effective indefinitely maintaining the option for reversibility should a different technology for arsenic dust treatment/disposal become available. While day to day operational oversight is not needed, there are operational procedures that must be accounted for in both the short and long term.

Note that this section of the Plan will need revision once as-built information is available after construction.

4.1 Construction and Start-up

Construction and initial charging of the thermosyphons will be carried out under the supervision of the MCM.

Once the thermosyphons are installed and charged with CO_2, they are able to self-activate when the air temperature cools to below the average ground temperature of 3°C. Unless all the CO_2 charging occurs over one summer season, it is likely that all freeze areas will not have the same ground cooling initiation day.

Passive operations of the thermosyphons is expected to result in reaching the initial freeze containment criteria within a 10-year time period as measured from the start of the first winter of thermosyphon operations. The expected duration of initial freezing for each chamber is shown in Table 4.1-1 below.

Table 4.1-1: Freeze Performance Summary using All Passive Thermosyphons

Area	Chamber / Stope	Time to Satisfy Containment from Start of Freezing (years)
AR-1	C14 South	6.75
AR-1	C15 South	8.75
AR-1	C14 North	6.75
AR-1	C15 North	9.5
AR-1	C12	9
AR-1	C11 South	8.75
AR-1	C11 Central	9
AR-2	C212 South	9.5
AR-2	C212 Central	8.5
AR-2	C10 (FOS)	8.25
AR-2	C212 North	7.5
AR-2	C9	8.75
AR-3	B235	9.25
AR-3	B236	9.25
AR-3	B230	7.25
AR-3	B233	10
AR-3	B234	7.75
AR-3	B208	9.75
AR-4	B1 Midpit	9.75
AR-4	B214	10
AR-4	B213	9
AR-4	B212	8
AR-4	Bulkhead 36	10

As noted in the table, some chambers will reach initial containment sooner than others and well under the 10-year target. It should also be expected that freeze performance could be accelerated or delayed if climate conditions are warmer or colder than modelling assumptions within the first 10 years. The surveillance program will track the freeze performance to affirm that all chambers are showing temperature cooling trends that will result in containment within the 10-year target.

It is also important to note that while the freeze criterion targets -5°C for containment, the frozen host rock will be sufficiently cold at temperatures just below 0°C to prevent water ingress or egress.

4.2 Charging Thermosyphons with CO_2

As noted above, the thermosyphons are to be considered a pressure vessel and treated as such according to the Canadian boiler and Pressure Vessel Code CSA B51. Each thermosyphon has a charge port with a shut off valve that will connect to pre-filled carbon dioxide canisters. Canisters will be shipped to site, directly discharged into a thermosyphon, and shipped back empty to the supplier for refilling or re-use by others. A typical canister could contain 50 pounds (lbs) of liquid CO_2 under about 50 bar (725 psi) of pressure at room temperature. Each thermosyphon will require a different amount of liquid CO_2 based on its diameter and length. For example, a 75 mm diameter thermosyphon that is 100 m in length would require 240 lbs or just shy of five, 50 lb canisters of liquid CO_2.These quantities will be confirmed by a qualified vendor. If the thermosyphons are obtained as a supply / install / commission contract, then the thermosyphon vendor will be responsible for the initial charge of CO_2.

Once the thermosyphons are charged, the charge port valve will be closed and a steel cap with tamper resistant screws will be secured over top. Due to the unlikely potential for a faulty charge port valve to leak CO_2 and build up pressure beneath the steel cap, the cap should only be removed by a thermosyphon repair or maintenance person qualified as required under the Boiler and Pressure Vessel Code CSA B51.

Given the long term nature of the project life, it is not reasonable to expect the original thermosyphon vendor to be a viable entity, thus the project will develop a strategy to obtain or develop technical details related to thermosyphon manufacture, charging, maintenance, and replacement. Should the project proceed to develop and use its own thermosyphon design, then these items will need to be recorded and appended to this operations and maintenance manual.

4.3 Site Access and Security

There are four different freeze areas and each area will have restricted access. The roads leading to each area are to be maintained, as are any gates, fences, and signage.

4.4 On-site Facilities

On-site freeze related facilities include:

- Thermosyphons
- Instrumentation holes, junction boxes, remote I/O cabinets, cable racks
- Power supply and transmission lines to feed instrumentation systems

Instrumentation PLC and data storage

All of these will need inspection as part of the maintenance program outlined below.

4.5 Estimated Staffing

No special staffing or personnel are required for freeze system operations. Maintenance duties and on-site surveillance would be carried out by a member of the water treatment plant staff. An engineering firm will be contracted to conduct periodic reviews (as per Section 5.1.1.4) and provide progress or status reporting, as requested.

5 SURVEILLANCE

Surveillance is defined as the process of retrieving, viewing, interpreting, and taking action regarding field measured data or observations. The types of instrumentation being collected at, in support of managing the frozen shell, have been described above. This section of the manual considers each type of data to provide some context as to what expected data values are, what the significance of data values outside expected values are, and when and what actions will be considered to adaptively manage freeze performance.

5.1 Surveillance Activities

5.1.1 Freeze Program Performance Monitoring

5.1.1.1 Data Sources

The primary data type collected is temperature, however the locations of various sensors have been selected for different reasons. Temperatures will be collected using RTD technology. RTD strings will be inserted into a closed pipe containing a non-freezing fluid that allows for removal and replacement. Note that figures presented in this section are based on models of actual chambers; however, they are presented here for illustrative and discussion purposes. The full model results are included in the appendix of the Design Plan.

5 m Depth Sensors on each Thermosyphon

The information from these sensors will be used to confirm reactivation of each thermosyphon in the fall of every year. During summers the thermosyphons will go dormant and the near ground surface will start to warm in response to the surface – climate interaction. During the fall, when the air temperature drops below the CO_2 condensation point, the thermosyphons will start to operate once more. The condensed and colder CO_2 will flow down the thermosyphon and will be detected by the 5 m depth temperature sensor. If the thermosyphon is functioning properly, the 5 m depth sensor is anticipated to trend within approximately 2°C of the measured air temperature. The first two winters of operation will be used to observe climate and 5 m depth sensor data in order to determine the anticipated activation sensitivity for the thermosyphons. The data acquisition system will then be programmed to monitor the 5 m depth sensors and air temperatures and trigger a notification should the anticipated re-activation patterns not be observed.

If the 5 m depth sensor does not reflect the anticipated re-activation pattern in the fall, then further investigation of the possible malfunction of that thermosyphon will be initiated. This investigation will include a visual inspection of the thermosyphon radiator with a thermal imaging camera to confirm that the radiator fins are warmer than the ambient air temperature. Warmer fins indicate that they have absorbed heat from the condensing CO_2 vapour which is a sign that the thermosyphon is operating. If the visual inspection suggests the thermosyphon is not operating then the procedures outlined in the maintenance guidelines for checking or replacing the CO2 charge should be followed.

Full Length Sensor Strings that Extend below the Chambers and are Installed Inside the Perimeter Row of Thermosyphons Closer to Chambers / Stopes

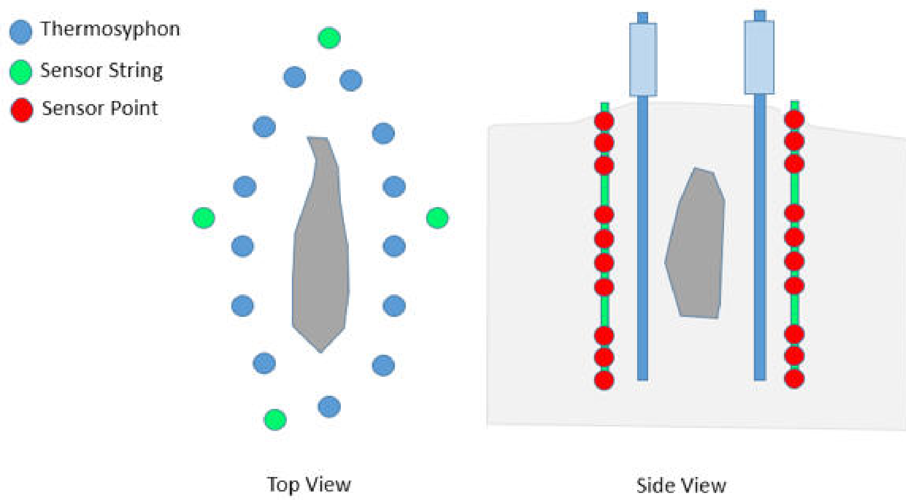
These sensors exist in only a few locations because for the most part, the design intent was to not install sensors if they needed to pass through a dust filled chamber or stope. In several locations, deep sensors have been installed near to chambers, but wholly in rock. These deep sensors are part of a string of 10 sensors distributed along the length of a single pipe with three sensors near surface, three near the bottom, and the remaining four evenly spaced in the mid-section of pipe.

The primary purpose of these sensors strings is to confirm that the perimeter thermosyphon pipes are effective at creating a frozen shell beneath the chambers. While the models clearly show this will happen, it is important to measure this in a few places to help validate the model. Where variance exists between field and model, these deep internal sensors, which are located further away from the direct influence of a thermosyphon, will help to calibrate the models.

Full-length Sensor Strings installed 2 to 4 m Outside the Perimeter Row of Thermosyphons

There are many full-length sensor strings installed outside the perimeter row of thermosyphons as shown in Figure 5.1-1.

Figure 5.1-1: Plan and Side View of Temperature Monitoring Locations

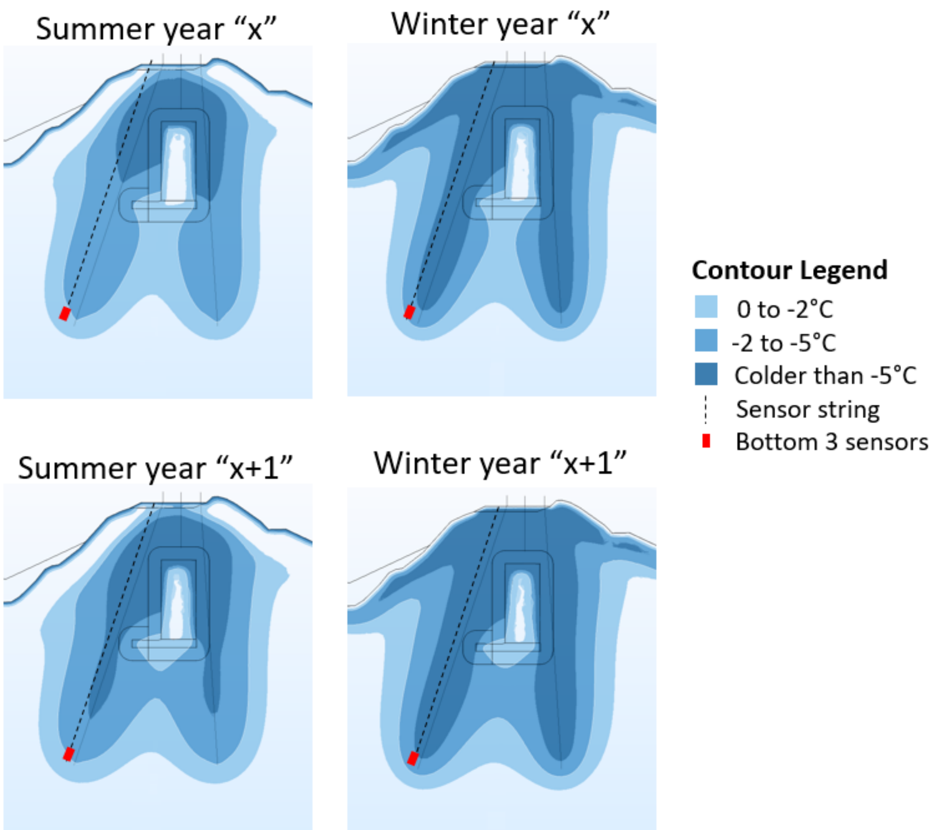


The sensors strings are located outside the perimeter row of thermosyphons because, over time, the heat sources acting to restrict or potentially reverse the growth of the frozen shell will be from outside the frozen area. In addition, by design, sensor locations were chosen so that they did not come into contact with the arsenic dust. The intent of the freeze program is not to freeze the dust, but to encapsulate it in a frozen shell. Monitoring the ground temperatures outside the thermosyphon rows will provide early detection of warming trends as well as confirmation of containment during the initial shell development.

Bottom 3 Sensors in the String

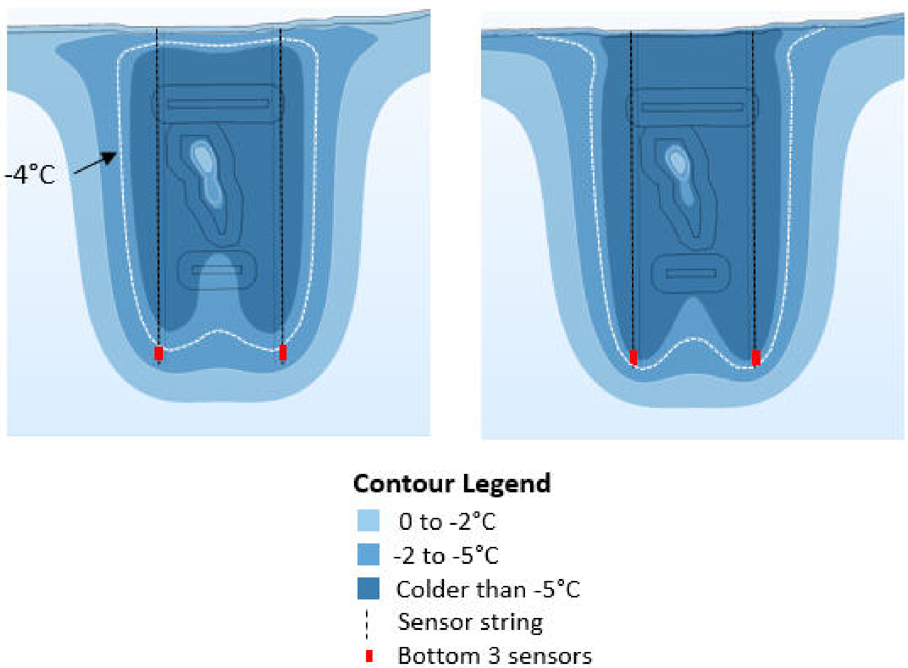
Once the bottom 3 sensors are colder than -2°C for two winters in a row, modelling has shown that it is very likely that the freeze shell is colder than -2°C at all points below a chamber or stope which signifies a large drop in risk for the project as shown in Figure 5.1-2.

Figure 5.1-2: Freeze Modelling for Bottom 3 Sensors Colder than -2°C for 2 Subsequent Winters



Once the bottom 3 sensors are colder than -4°C then it is very likely that the -5°C over 5 m containment criteria is reached at all points below a chamber or stope as shown in Figure 5.1-3. Note that the sensors on both sides of a chamber must meet this to say that the frozen shell has satisfied criteria.

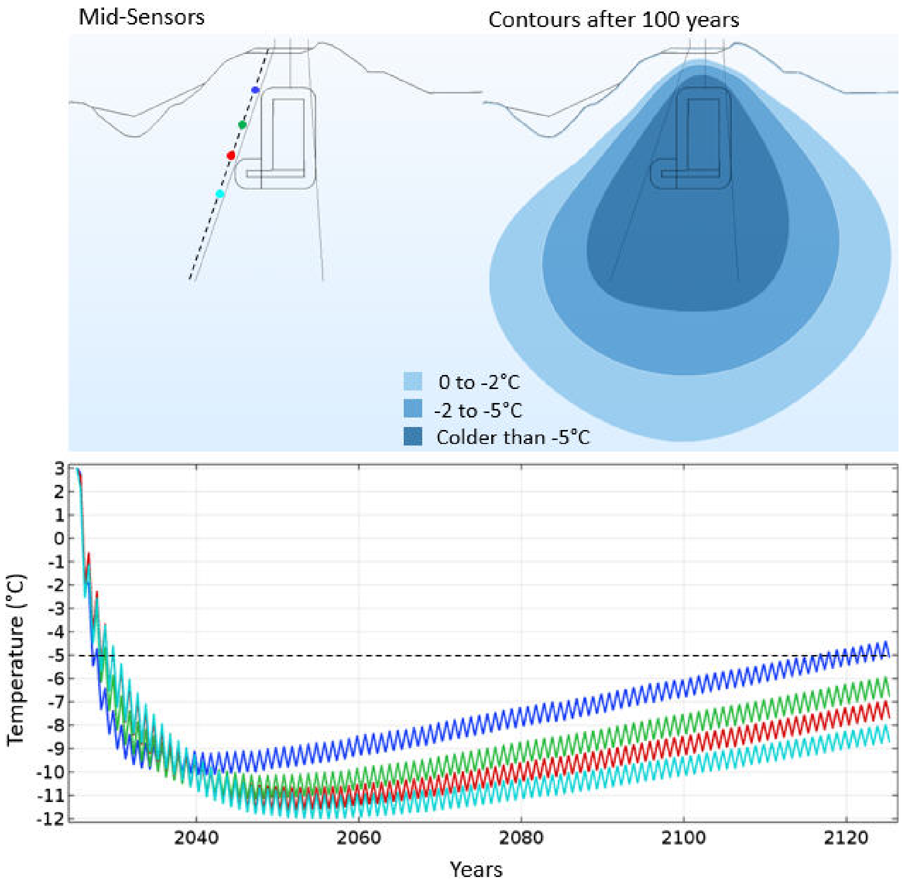
Figure 5.1-3: Freeze Modelling for Both Sides of a Chamber Colder than -4°C



Mid Elevation Sensors

Figure 5.1-4 shows temperature with time data for 4 mid-elevation sensors. For some of the chambers in AR-1, the design only just maintains the frozen shell on the pit side “shoulder” of the chamber. Since the sensor strings are installed slightly outside of the 5 m shell, they can be expected to trend very close to, or even slightly above -5°C. A well calibrated model, using as-build sensor locations, will confirm whether the temperatures at these sensors are anticipated or indicative of excessive warming.

Figure 5.1-4: Mid-Elevation Trends to Assess the Need to Execute a Response Framework.

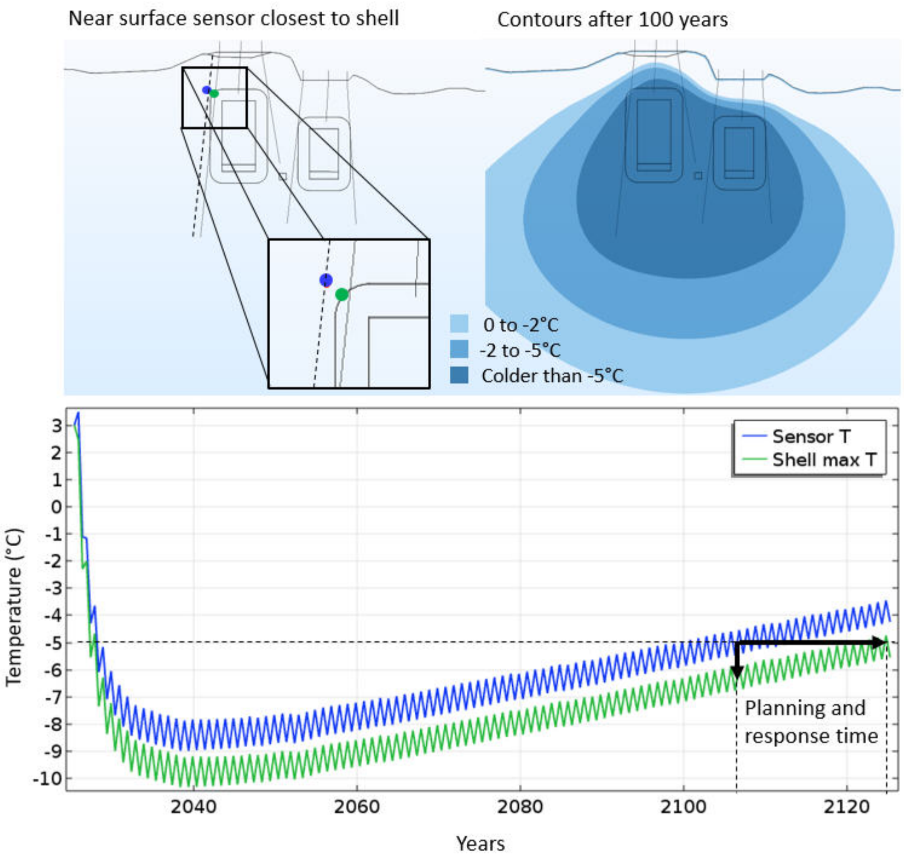


Near Surface Sensors

The nearest sensor in the string corresponding to the top of chamber, including a 5 m buffer zone elevation, is not anticipated to warm above -5°C due to climate warming once containment is reached. If it does trend towards -5°C, as shown in the example in Figure 5.1-5, it should be noted that the temperatures within the shell will be colder, allowing for a Response Framework to be implemented before the freeze criteria is no longer satisfied.

Other shallow near surface sensors will be used to calibrate models and for back analyses in the event actual freeze performance is not meeting expectations. These do not need to be tracked regularly as they will fluctuate widely in response to summer / winter. These sensors will prove essential if any near surface heat balance work is required in the future.

Figure 5.1-5: Near Surface Sensor Monitoring Related Response Framework Requirements



Shallow Arsenic Impacted Waste Sensors below Insulation

For shallow arsenic impacted waste disposal stored below near surface insulation, flat loop sensors are installed directly below the insulation to verify that the base of insulation cools to, and stays colder than, -5°C.

Deep Sensors Strings in the Bulkhead 36 Area

There are three deep sensor strings included in the AR-4 Bulkhead 36 freeze area that will initially be used to calibrate a 3D model of the freezing in that zone. After that time, target upset temperatures will be established for longer term monitoring. In general, Bulkhead 36 freezing should not be impacted by climate warming once containment is reached, so the installed sensors are anticipated to settle at a fairly consistent value over time with only a minor rise in temperature.

Thermal Imaging Camera

Thermal imaging technology will be used when visual confirmation of individual thermosyphon operations is required. This will occur at least once per winter season for each thermosyphon or whenever a thermosyphon is suspected to be underperforming. The following field test steps will be performed when the air temperature is colder than –15°C to confirm individual thermosyphon system operation (CSA 2014):

a) Acquire a digital contact thermometer or an infrared surface temperature scanner with a sensitivity of 0.1°C.

b) Measure the temperature of the radiator (the surface of the pipe) and compare this to the surrounding air or a white painted metal plate (preferred method) kept adjacent to the riser for this purpose. The project will consider installing a metal plate "reference" panel in each freeze area for this purpose. The procedure would be to use the thermal imaging camera to establish the temperature of the thermosyphon radiators. If these temperatures are warmer than the air or of the reference plate, it can be concluded that the thermosyphon is operating. If the air or reference temperature is the same, this is an indication that the thermosyphon is not operating.

c) Should a thermosyphon be initially suspected of not functioning using the above procedure, the process will be repeated within a few days for confirmation, preferably at a colder outside air temperature.

5.1.1.2 Data Sensor Collection, Storage, Access

During the initial freezing period, it is necessary to collect data more frequently as the thermal gradients are steeper and any abnormal trending may be detected more readily. However, once the freeze criteria are met, then the frequency of data collection and storage can be reduced. During the first two years, data will be collected twice a day (e.g. at 2 am and 2 pm) which will provide a comparison of changes to near surface conditions and thermosyphon operational periods in response to warmer and cooler times in the day. Between years 2 and 10 (when initial temperatures gradients have reduced and freeze containment criteria will be starting to be satisfied), data should be collected daily at 2 pm. After Year 10, data can be collected weekly as a minimum. If there are no concerns about data storage, then continue with daily collection of all automatically measured data.

Data storage is available on the hard drive of the computer located in the water treatment plant in addition to the off-site "cloud" storage. It is assumed the cloud storage and local hard drive will be primary back-ups of all data, however a complete set of data will be backed up along with all Giant Mine site data on a frequency established by the overall project management and environmental management system.

It is assumed that the cloud stored data will be available for access off site by authorized personnel.

5.1.1.3 Responsibilities

The installed temperature data will be configured to be automatically collected and stored according to the details noted above.

5.1.1.4 Freeze Model Performance Assessments

During the initial two years, the automatically collected data will be reviewed on a semi-annual basis in order to confirm early and consistent thermosyphon operations, and to allow for the first pass at model calibration to as built conditions (e.g., actual locations and orientations of thermosyphons, actual climate data, updated climate data projections etc.). Any variances in ground conditions such as rock type, water contents, bulkhead and drift backfill locations and materials, will be factored into the models.

Part of the early period assessments will include checking the shallow temperature sensors installed on each thermosyphon as noted in Section 5.1.1.1 above.

Between years two and 10, the data and associated models will be updated yearly during the summer months when the thermosyphons are dormant and there is easier access to site if any physical observations are needed as follow up to data review and interpretation efforts.

After Year 10, when the freeze criteria have been met, the data needs to be reviewed at least every second year with model updates and long term predictive model updates completed every 10 years.

5.1.2 Site Observations and Inspections

For the life of the project (100 years), an on-site annual inspection will be required to identify and track visual changes in freeze equipment, ground conditions, and road access to each freeze pad. The checks will happen in summer when there is no snow cover and easier access to each thermosyphon. The site inspection will, as a minimum look for:

- Storm damage (slope erosion, rock fall and wind and ice damage).
- Settlement that may impact thermosyphon alignment or road access (e.g., potential for leaning of pipes in B1 Midpit area where pipes are in fill material and not bedrock).
- Animal damage (birds eating wire insulation, burrowing animals near shallow waste areas, etc.).
- Vandalism (bullet holes, tampering of charge valve covers, tampering of instrumentation panel boxes, wires, cable trays etc., theft).
- Wear and tear (paint loss, cyclic movement of thermosyphons resulting in near surface softening of the ground or openings that will require filling).

An inspection report will be generated and submitted to the overall project management team.

5.1.2.1 Responsibilities

The on-site inspections can be carried out by a local engineering consultant or project personnel, if available. No special training is required, other than the ability to document findings and generate an appropriate report.

5.2 Ongoing Engineering Oversight

5.2.1 Model Calibration and Performance Predictions

It will be very important to observe actual ground and climate temperature trends and then use this data to update ground thermal finite element models for use in understanding past performance and to assist with the Response Framework that deals with adoption of adaptive management strategies.

The data review and model calibration work will need to be performed under the supervision of a qualified Professional Engineer familiar with ground thermal modelling in the Arctic and in particular with thermosyphon heat extraction characteristics both from a practical and theoretical / analytical perspective.

5.2.2 Reporting

Reporting requirements are stated in the Board Water Licence (Part F Condition 19 - Geotechnical Inspections (Annual) and Part D Condition 7 – Performance Assessment Report (Every 5 years) and will be managed by the GMRP. Other reports are necessary depending on upset conditions experienced.

5.3 Upset Conditions Detection and Contingency Responses

While the freeze system is designed to operate without any direct human interaction or power inputs (other than monitoring), there may be upset conditions that impact the freeze infrastructure. Some potential events are presented below along with contingency action plans. It should be noted that this list may not be comprehensive, nor will every event listed warrant an immediate notification to the Board. The list is presented to help the GMRP understand potential types of events which may need follow up investigation. It is also important to understand that none of these events would trigger a near term failure of the freeze containment (e.g., frozen shell). Left unaddressed, they may lead, over many years, to a localized warming of part of a frozen shell, but other regular monitoring and reporting activities would detect warming trends and allow for adaptive management strategies to be developed and applied.

5.3.1 Unexpected Water Release Containing Arsenic

This is a very unlikely event once the initial containment is achieved. However, during early start up, external events may mobilize arsenic according to the same risk profile that currently exists at the site. There could be some potential for water to pass through arsenic drifts near chambers or stope that picks up some contamination. If this were to happen, the water treatment plant is designed to collect and treat arsenic impacted water.

Once the ground temperatures cool to or below -2°C, the ground will be frozen enough to greatly reduce the hydraulic conductivity in fractures and porous materials. This significantly reduces risk. Once the ground cools to -5°C, then the likelihood of any water being able to mobilize dust has been mitigated.

5.3.2 Seismic or Tornado Event Damage Assessments

A seismic event of significance has the potential to induce cyclic loading on thermosyphon welded joints which may, though unlikely, result in a loss of working fluid / gas pressure. A tornado event has the potential to bend or break a thermosyphon. Either of these events would not result in a reportable spill as CO_2 is not considered to be a hazardous material.

After a known seismic or tornado event, a full visual inspection of all equipment will be carried out. In addition, management will confirm thermosyphon passive restart in the first winter following the event because leaking thermosyphons may not be detected during a summer visual inspection.

5.3.3 Excessive Settlement in B1 Frozen Backfill Zones

Pit fill or freeze pad fill material may settle differentially, which has a small potential to induce a shear load on thermosyphons installed within the fill. The thermosyphons can handle some deformation but not to the extent where they might become pinched off or sheared. A slightly “out of round” pipe will continue to perform, however if bending is severe or shearing of the pipe occurs, then the piping will require replacement. Timing of the replacement is more critical in the first 8 to 10 years while initial freeze containment is sought, however after that time, any required pipe replacement can be carried out according to a methodical and scheduled plan as discussed in the Maintenance section of this Management and Monitoring Plan.

5.3.4 Major Collapse Underground that may Induce Stresses on Thermosyphons

A collapse underground may result in surface settlements. If so, a damaged thermosyphon would likely not function and steps outlined in the Maintenance section would need to be followed to repair or replace a unit. A major collapse underground does not mean that the freeze infrastructure will be damaged. It should serve as an indication that the integrity of the freeze infrastructure will need to be checked.

5.3.5 Accidental Exposure of Near Surface Insulation near B1 Pit

The current design requires the placement of a thin insulation layer about 5 m below ground surface. There is a minor risk that site construction activity may intersect it. If this were to occur, repairs or replacement of the insulation may be necessary, as well as to the overburden. Timing of repair should be within 6 months and ideally before the heat of summer occurs – which could result in a slight encroachment into the 5 m frozen shell above the shallow waste. To clarify, this shallow insulation is only located in the area near B1 Pit that is allocated for disposal of surface impacted arsenic waste material.

5.3.6 Longer Term Baker Creek Flooding or Premature / Excessive Mine Level Water Rise

Once the frozen shell is in place, it will continue to grow in extents for about 40 years at which point it will be at its maximum size. Ultimately the frozen shell will be very thick surrounding a chamber or stope. If Baker creek were to flood after containment is achieved in nearby chambers, or if the mine water level were to rise to intersect the frozen shell from below, numerical analyses have demonstrated that there would not be enough heat associated with the moving water to thaw the frozen shell sufficiently to result in a failure of the containment criteria.

5.3.7 Fire Damage / Lightning Strikes

Fire or lightning will not be factors with any significant associated risks. There are no combustible materials in a thermosyphon. Instrumentation would likely be impacted by either fire or lightning and any problems with the instrumentation would be detected by the scheduled monitoring or maintenance activities.

5.3.8 Excessive Climate Warming Negatively Impacting Freeze Criteria.

The current analysis of long term thermosyphon performance assumes a climate warming trend with a mean annual air temperature rise of +7.3 °C as required by the Water Licence. Under this scenario, the arsenic trioxide frozen shell will be established and maintained to be at least 5 m thick on all sides of any dust filled chamber, stope, drift, or pit fill. If the monitored field data at key locations, as identified in the Monitoring section of this report, suggest actual field data trending will result in unfrozen ground encroaching on the 5 m shell then action needs to be undertaken to maintain containment criteria.

Modelling has shown that the risk of a containment breach does not develop beside or below the chambers or stopes as the frozen shell in these areas grows to be many tens of meters thick as they are not impacted by surface boundary temperature fluctuations. The primary locations of concern are the upper “corners” of the frozen zone for the chambers or stopes in AR-1 (e.g., on the bedrock hill), or the top, middle area of near surface arsenic impacted waste in AR-3 and AR-4.

Contingency actions:

1. First, using a detailed assessment of actual and projected climate trending available at the time, determine if the 5 m frozen shell will be compromised at localized locations or if a more regional risk exists.
2. For localized areas of concern, assess if there are benefits to modifying the passive thermosyphons in a manner that would improve their effectiveness, such as increasing the exposed radiator fin surface area. Increasing the exposed radiator fin surface area would require welding on an additional length of vertical condenser or replacing the existing one with a longer condenser. This alteration to the initial design would enhance the rate of ground cooling during the colder days in winter, which may be sufficient to maintain satisfactory conditions over the rest of the winter.
3. It may also be possible to consider a surface treatment of buried insulation over a footprint that extends beyond the underlying chamber or stope so that top-down warming is limited. This would require careful excavation of the freeze pad, without interfering with existing thermosyphons, followed by placement of insulation and fill.
4. If none of the above approaches are possible or do not work, then individual thermosyphons in localized areas of concern may be converted to hybrid units without the need for additional drilling. Conversion to hybrid thermosyphons will quickly reverse any undesired warming trends regardless of the magnitude of climate warming. To convert to hybrid thermosyphons, the surface radiator section would be removed (according to steps noted in the Maintenance section of this report), a hybrid “cooling coil” section about 1 m long inserted, and the radiator section reinstalled above. The cooling coil section will be connected to a refrigeration unit that would be turned on periodically such that it offset the imbalanced cooling loads derived by warmer climate. It is NOT necessary to run the hybrid units all the time – only enough of the year to draw the ground temperatures back down to sufficiently cold values such that the new future trends satisfy the containment criteria.

5.4 Freeze Data Interpretation Checklist Summary

Section 5.1 and 5.3 present a discussion of the types of field data being collected and how to interpret that data as it pertains to either satisfying freeze criteria, or responding to unexpected events. This section summarizes key performance tracking parameters and provides the necessary response action and timing (Table 5.4-1). This table lists items of concern that would be relevant to the GMRP site operations / monitoring staff who may need to schedule maintenance or repair tasks. The last item in the table is most critical to the overall assessment of the freeze criteria and frozen shell containment. While climate induced increase in frozen shell bulk temperatures will take many years to manifest, it is important to keep stakeholders aware of the early detection of concerning trends, so that additional resources can be made available, if necessary, to provided added focus and study.

To reiterate, it should be well understood by the reader that the ground cools and warms very slowly (e.g., over many years) and that it would be very unlikely an upset scenario developed that required immediate action to protect the frozen shell integrity. As such, many of the Response Frameworks will recommend a “study” be undertaken, which will consist of a careful review of the existing data, a cross reference to the up to date calibrated thermal models, and then the formation of an appropriate action response timeline.

Table 5.4-1: Freeze Data Interpretation Checklist Summary

Observation	Assessment	Response	Timing
Thermosyphon stops performing	During the fall season inspection, an individual thermosyphon is found to not be extracting heat by confirmation that the temperature of the thermosyphon surface 5 m deep sensor temperatures differs more than 2°C on average from the air temperature.	Follow the steps in the Maintenance Section of this report to validate the observation and take action as noted.	Not critical. Suggest one year to repair or replace.
Deep sensors inside freeze perimeter report temperatures that are warmer than predicted during initial freezing of shell.	During initial freezing, the deep sensors suggest freezing is slower than anticipated below a chamber or stope (e.g., the actual temperature trends suggest it will take more than 1 year longer to satisfy criteria).	Confirm the nearest thermosyphons on either side of a chamber or stope are functioning properly. Cross reference performance with model predictions. Re-calibrate ground thermal properties and model.	Not critical. Suggest one year to study and decide if corrective action is necessary.
Deep sensors outside the freeze perimeter report temperatures that are warmer than predicted during initial freezing of shell.	If the bottom 3 sensors are not cooling to within 2°C on average of the modelled trends for these sensor locations within 4 years, this could indicate issues with thermosyphons or ground conditions.	The bottom 3 sensors being too warm could indicate issues with nearby thermosyphons. Confirm the nearest thermosyphons are functioning properly. Cross reference performance with model predictions. Re-calibrate ground thermal properties and model as necessary. If the mine underground has not yet been permanently closed off, check if there are U/G drifts nearby which may have unexpected heat sources.	Not critical. Suggest one year to study and take corrective action as necessary.

Table 5.4-1: Freeze Data Interpretation Checklist Summary

Observation	Assessment	Response	Timing
Lateral sensors installed below shallow waste insulation layers are warmer than predicted.	If the shallow sensors are not cooling or are responding to seasonal climate, they may be installed incorrectly, the insulation layer could be compromised, or the model may need to be calibrated and updated for the surface fill above the insulation.	Study the available data and compare with other shallow sensor installations. Carry out a sensitivity study related to thermal properties of the fill material above. Cross reference climate data with modelled climate data including issues such as excessive or lack of snow cover in winter or higher than normal precipitation in summers.	Not critical. Suggest one year to study and take corrective action as necessary.
Long term climate response ground temperature projections are warmer than previously predicted projections.	If field data trending starts to deviate more than 2°C on average from model when forward looking at least 10 years, action will be taken to understand why.	Study the available data and compare it to the most up-to-date calibrated thermal model. Consider if the climate in the recent years is warmer than model projections. Update the thermal model. If the frozen shell is on a warming trend to exceed criteria, inform the Board and consider a Response Framework as described in Section 5.3.8.	Not critical if detected at least 15 years prior to anticipated exceedance of freeze criteria. Study for a year and develop a mitigation strategy which might include conversion to hybrids or special ground surface treatments to insulate from surface down warming.

Section 7.1 presents the Action Levels and Contingencies derived from the table above as well as some additional explanation of the philosophy of data collection and assessment.

6 MAINTENANCE

The purpose of a maintenance plan is to provide the continual operation of all infrastructure, as well as to adjust infrastructure, as required, for proper operation in conformance with performance objectives. The plan is linked to surveillance activities and action response criteria described in more detail below.

There are two general types of maintenance: preventive and corrective. Preventive maintenance includes planned, recurring activities at fixed or approximate time intervals. These include activities not typically arising from results of surveillance and, as such, are pro-active, not reactive. Preventive maintenance for the equipment may require a combination of visual/mechanical inspections as well as actual testing. Each piece of equipment will have different requirements based on the type, manufacturer, and frequency of use. Below are guidelines to which this maintenance should be performed.

Corrective maintenance refers to necessary repairs to prevent further issues based on surveillance activities and field observations. These are reactive measures and not planned far in advance. Once an issue is identified, its impact on operations can be predicted and the necessary remediation can be planned. It is not always necessary to take immediate corrective action.

In an operating mine with significant equipment and ongoing processes, it is common to treat preventive and corrective maintenance separately. However, for the freeze program, where there are no moving parts and passive processes are being used, maintenance is predominantly going to be corrective in nature.

6.1 Thermosyphon Maintenance

In general, thermosyphons do not require scheduled maintenance. However, given the 100-year timeframe of the freeze program at Giant Mine, it can be expected that condenser sections will need to be replaced in the future. Current experience suggests that a thermosyphon should operate for at least 50 years before it requires maintenance. Field experience for the conditions existing at Giant Mine may show otherwise. Due to the uncertainty regarding the longevity of a thermosyphon, the project should plan on replacing the condenser section at some point within the 100-year initial project timeline.

6.1.1 Replacement of Thermosyphon Condenser Section

The condenser section is the portion of the thermosyphon that is welded to the portion of pipe protruding from the ground surface. If a thermosyphon vendor is available, they will be contacted to supply and install the replacement condenser. If a commercial vendor is not available, then the following items can be used to develop a replacement strategy.

6.1.1.1 Requirements

Reverse engineer the condenser section of the thermosyphon. Key issues to include in the design specification would be:

- The total surface area of the radiator fins (e.g., 19.5 m^2 surface area for each vertical condenser tube).
- Material type and paint specification.
- Develop a CO_2 charging procedure including establishing a target pressure and fill volume. It may be useful to measure the in-situ pressure of the neighboring thermosyphon (of similar length) to determine this value.

6.1.1.2 Qualifications and Competency

A Professional Engineer with pressure vessel design experience is mandatory for the design phase of any new thermosyphon manufacturing. Design and field work must be completed according to Boiler and Pressure Vessel Code CSA B51.

6.1.1.3 Safety Hazards and Procedures

If the thermosyphon being replaced is still under pressure (or if unknown), then appropriate care must be taken when removing the charge valve steel cap as pressure could have built up behind the sealed charge cap itself over time.

Secure the thermosyphon at the top of the condenser section to a crane using the existing lifting lugs prior to cutting the condenser free from the evaporator section. Crane operations and load rigging should be carried out by qualified operators.

6.1.1.4 Resources – Equipment, Materials, Personnel

Crane, crane operators, load riggers, Professional Engineer, certified pressure vessel welders/shop fabrication facilities.

It is assumed that if these tasks are to be taken on by the project and not a vendor, then detailed designs, risk assessments and procedures will be developed and incorporated into this manual.

6.1.2 Replacement of Thermosyphon Evaporator Section

The evaporator section is the portion of the thermosyphon that exists below the weld connecting it to the condenser section. The pipe has been designed to allow for telescoping a smaller diameter pipe into the existing evaporator section without removal of the original pipe. The resulting reduction in diameter will not have an adverse effect on the long-term thermosyphon performance. The FOS considered different sizes of evaporator pipes and the impact was only apparent in the first few months of cooling.

The evaporator section assumes that a small pipe will be telescoped into the original pipe. It would be possible, though difficult, to remove the original pipe, however, it is more likely that, over the long term, the smaller internal pipe be removed periodically before the effort to remove the outer pipe be attempted.

If there is significant ground deformation, which might inhibit removal of the original thermosyphon or insertion of a smaller diameter pipe, then consideration might need to be given for drilling a new hole. This should not be done unless a careful thermal analysis of the existing and predicted thermal performance be completed.

6.1.2.1 Requirements

The condenser section will have to be removed prior to insertion of the smaller diameter pipe (see Section 6.1.1). Any existing instrumentation should be left in place as it will continue to operate as intended following the retrofit.

It will be necessarily to fabricate an adaptor in order to weld the new smaller diameter pipe to the original, larger-diameter, condenser section pipe.

The retrofit pipe must have a welded end cap and welded joints to satisfy the Boiler and Pressure Vessel Code CSA B51.

The retrofit pipe should not be grouted into the existing pipe to allow for future replacement. Instead, a heat transfer medium such as Dynalene will be used to fill any void space between the old and new pipes. If Dynalene is not available, an alternative low corrosion fluid that has a freezing point below -40°C could be considered.

6.1.2.2 Qualifications and Competency

Field work must be completed according to Boiler and Pressure Vessel Code CSA B51.

6.1.2.3 Safety Hazards and Procedures

If the thermosyphon being replaced is still under pressure (or if unknown), then appropriate care must be taken when removing the charge valve steel cap as pressure could have built up behind the charge cap itself over time.

Secure the thermosyphon at the top of the condenser section to a crane using the existing lifting lugs prior to cutting the condenser free from the evaporator section. Crane operations and load rigging should be carried out by qualified operators.

The Safety Data Sheet (SDS) for Dynalene, a potassium formate, is readily available online (https://www.dynalene.com/data-sheets-msds/).

6.1.2.4 Resources – Equipment, Materials, Personnel

Crane, crane operators, load riggers, Professional Engineer, certified pressure vessel welders/shop fabrication facilities.

6.1.3 Stabilization of Thermosyphon

Over time, wind action on the condensers may cause the ground at the base of the condenser to loosen, resulting in continued and increasing movement of the condenser. It is important that the thermosyphons be as rigid as possible to prevent fatigue on welded joints. An operator should not be able to push on the thermosyphon and witness any movement of the pipe where it enters the ground.

6.1.3.1 Requirements

If the borehole opening grows or softens around the base of a thermosyphon, then action needs to be taken to fill in any voids at the base of the thermosyphon sufficiently to limit future swaying.

6.1.3.2 Qualifications and Competency

No special qualification or certifications are required.

6.1.3.3 Safety Hazards and Procedures

General site safety will be followed.

6.1.3.4 Resources – Equipment, Materials, Personnel

To be determined on a case by case basis.

6.1.4 Repair Minor Damage of Thermosyphon Condenser

Minor repairs include damage due to weather events, animal activities, vandalism, minor contact with a vehicle, a leaking charge valve etc. In other words, minor repairs do not require a replacement of the evaporator or condenser sections. Note: A few damaged radiator fins will not impact the overall performance of the thermosyphon. Other than ensuring there is protection from corrosion, this type of damage can remain unaddressed.

6.1.4.1 Requirements

Check for evidence of pressure loss e.g., a hole / perforation in the pipe, or a cracked weld. If it is suspected that the gas has vented, the options are to wait until winter to confirm operation, using thermal camera temperature sensing techniques, or to attach a pressure gauge to the CO_2 charge port. It should be noted that loss of a single thermosyphon is not considered a time critical maintenance activity, so waiting until winter is the preferred option. There is a risk associated with using the pressure gauge approach because it means opening up the valve, which has a risk of losing its seal upon attempted closure.

If the thermosyphon has lost pressure, then the reason must be identified. If there is no evidence of a hole or cracked weld problem, then the charge port valve may need to be replaced. If there is evidence of a perforation or cracked weld, then a weld repair will be required.

If the damage is primarily cosmetic, then repairs should be carried out to prevent corrosion including painting.

If the thermosyphon is off-plumb (i.e., non-vertical), then it needs to be straightened. If it cannot be repaired in place, the condenser section will need to be removed and replaced according to the procedures outlined in Section 6.1.1.

6.1.4.2 Qualifications and Competency

Any weld repairs or refitting of charge valves need to be carried out in accordance with the Boiler and Pressure Vessel Code CSA B51. Cosmetic repairs can be carried out by site operations personnel.

6.1.4.3 Safety Hazards and Procedures

General site safety will be followed.

6.1.4.4 Resources – Equipment, Materials, Personnel

To be determined on a case by case basis.

6.2 Instrumentation / Electrical / Data Collection and Storage Maintenance

6.2.1 Electrical Power Distribution Equipment - Preventive

There are several types of equipment used for the electrical power distribution in this system. This includes transformers, switchgear, panels, etc. See Table 6.2-1 for a list of equipment.

It is recommended to follow the International Electrical Testing Association's (NETA's) established procedures for electrical equipment installed for this project.

Table 6.2-1: Power Equipment Maintenance Schedule

Item Description	Visual & Mechanical Inspection	Testing	Estimated Service Life
Electrical Cable	Every 30 Months	Every 90 Months	50 Years
Pole Mounted Fused Cut-out Switch	Every 60 Months	Every 60 Months	25 Years
Pole Mounted Transformer	Every 30 Months	Every 90 Months	25 Years
UPS	Every 30 Months	Every 30 Months	25 Years
Batteries	Every 30 Months	Every 30 Months	5 - 8 Years
Distribution Panel / Junction Box	Every 30 Months	Every 60 Months	50 Years

6.2.1.1 Requirements:

Visual & Mechanical Inspection: Refer to the manufacturer's datasheet and (the latest available) 2019 ANSI/NETA MTS Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems - (Appendix B) to determine frequency of inspection requirements for each electrical power equipment specified in the Table 2 & 3 of Appendix D of Final Substantive Design Reports (AECOM 2020a) and (AECOM 2020b). Inspection frequency will be re-evaluated every 10 years based on condition and frequency of use changes. Also, it is recommended to carry out inspections for mechanical supporting materials like power poles, cable trenches and electrical conduits when performing inspections for the power equipment. Table 6.2-1 refers to initial estimation of frequency of inspection activity for power equipment.

Electrical Testing / Inspection Measurements: Refer to the manufacturer's datasheet and (the latest) 2019 ANSI/NETA MTS (Appendix B) to determine frequency of testing requirement for each electrical power equipment specified in the Table 2 and 3 of Appendix D of Final Substantive Design Reports (AECOM 2020a) and (AECOM 2020b). Testing frequency will be re-evaluated every 10 years based on condition and frequency of use changes. Table 6.2-1 refers to initial estimation of frequency of the testing activity for power equipment.

Device Replacement: Refer to the manufacturer's datasheet and results of electrical inspections to predict the condition of the equipment and to determine the frequency of replacement. This frequency shall also be based on service life, and availability of spare parts. An initial estimated service life for the power equipment can be found in Table 6.2-1.

Spare parts for key components should be verified as available and currently being manufactured (not obsolete) each 5 years. Key components include breakers, fuses, and other consumable spares.

6.2.1.2 Qualifications and Competency

Refer to 2019 ANSI/NETA MTS (Section 3) for the level of qualifications of testing personnel carried out for each equipment and test required.

6.2.1.3 Safety Hazards and Procedures

Please refer to manufacturer's datasheets, Operating and Maintenance Manuals, and 2019 ANSI/NETA MTS (Section 5 and Section 7, Part A and Part B) for safety hazards and to determine procedures for each type of testing / inspection.

Generally - electrical safe lockout procedures and safe limits of approach shall be followed for all electrical inspection, testing, and maintenance work.

6.2.1.4 Resources – Equipment, Materials, Personnel

The detailed design of the equipment shall outline required turnover documentation and literature resources which must be provided during the construction and installation of the project. These individual components Operating, and Maintenance Manuals shall be a key resource for Maintenance work on the electrical equipment.

Spare equipment and consumables shall be determined during detailed design and shall be included in the materials supply for the project. These spares shall be clearly labeled for which equipment they are suitable and stored per manufacturer's recommendations available for use on site during routine maintenance activity.

6.2.2 Electrical Power Distribution Equipment – Predictive

6.2.2.1 Requirements:

Following any service disruption, or after noting abnormal condition results from inspections or testing, equipment repairs and/or replacements may be deemed necessary for the continual operation of the system. Consult a qualified electrical worker or consultant for recommendations on equipment replacement.

Most electrical power equipment of this project is minimally serviceable and in general shall require replacement if a failure is encountered beyond simple consumables (breakers, fuses, etc.).

6.2.2.2 Qualifications and Competency

Repairs and/or replacements shall be completed by a qualified electrical worker after consulting the system operator so that adequate procedures and safeguards are in place.

6.2.2.3 Safety Hazards and Procedures

Hazards will exist when performing the required maintenance. These hazards may also include potential system upsets. The qualified worker performing the maintenance must assess hazards due to the work as well as consult the system operator for an assessment of hazards to the system. Hazards shall then be mitigated, and procedures used for both worker and system safety.

Generally - electrical safe lockout procedures and safe limits of approach shall be followed for all electrical maintenance work and equipment replacements.

6.2.2.4 Resources

The detailed design of the equipment shall outline required turnover documentation and literature resources which must be provided during the construction and installation of the project. These individual components of the Operating, and Maintenance Manuals shall be a key resource for Maintenance work on the electrical equipment. Specific manuals shall be included for:

- Transformers
- Distribution Panels
- UPSs

Batteries

Spare equipment and consumables shall be determined during detailed design and shall be included in the materials supply for the project. These spares shall be clearly labeled for which equipment they are suitable and stored per manufacturer's recommendations for available use on site during routine maintenance activity.

6.2.3 Controls / Instrumentation / Data Storage Equipment - Preventive

6.2.3.1 Requirements:

Inspection: Table 6.2-2 illustrates an initial estimation for maintenance on the controls and instrumentation equipment. Refer to the manufacturer's manuals and recommendations to determine actual frequencies for inspection of the equipment on the Table 2 and 3 of Appendix D of Final Substantive Design Reports (AECOM 2020a) and (AECOM 2020b).

Table 6.2-2: Controls & Instrumentation Equipment Maintenance Schedule

Item Description	Visual Inspections	Software / Hardware Upgrades
Remote I/O Cabinets	Every 36 months	As per Visual Inspection
Communication Cabinet	Every 12 Months	As per Visual Inspection
PLC	Every 12 Months	As per Manufacturer's literature
Temperature Sensors	Every 12 Months	As per Manufacturer's literature
Multi-point Temperature Sensor Assemblies	Every 12 Months	As per Manufacturer's literature
Solid State Storage Devices	Every 12 Months	As per Manufacturer's literature
Communication Cable	Every 12 Months	As per Visual Inspection
Signal Cable	Every 12 Months	As per Visual Inspection

Device Software and Hardware Upgrades/Replacements: It is recommended to consult the product manufacturer on a regular basis to determine the life expectancy of the equipment, as well as the availability of replacements. PLCs, servers and data storage equipment will be evaluated for both software and hardware for upgrades/replacements every 5 years.

6.2.3.2 Qualifications and Competency

Personnel who have been formally trained on the equipment, or who have been deemed qualified by the owner, shall perform these tasks. In addition, the equipment manufacturers and qualified electrical/instrumentation consultants may also be utilized to assist in these activities. This is particularly relevant for PLC programming and logic changes, as well as when required for the software/hardware upgrades.

Although not required for most visual inspections, a certified Instrumentation and Controls Technician or Technologist should perform maintenance on instrumentation when technical maintenance work, instrument replacements, and new instrument commissioning is being performed. RTDs are not complex, however the application and customized RTD string installations are not simple.

6.2.3.3 Safety Hazards and Procedures

For inspections, utilize qualified personnel and refer to manufacturer's manuals for safety hazards and procedures. Consult a qualified electrical consultant or the equipment manufacturer before making any replacements. As well, it is recommended that spare equipment requirements are analyzed so they are available as required.

6.2.3.4 Resources

The design of the instrumentation and PLCs shall outline required turnover documentation and literature resources that must be provided during the construction and installation of the project. These individual components Operating, and Maintenance Manuals shall be a key resource for Maintenance work on the instrumentation and controls equipment.

6.2.4 Controls / Instrumentation / Data Storage Equipment – Predictive

6.2.4.1 Requirements:

Sensor Calibration: Sensors need to be re-calibrated when data trending starts to vary from the anticipated trend, or when a single sensor in a sensor string digresses from the trends reported from neighboring sensors.

Set points to alarm the PLC for these values shall be determined during detailed design. Alternately, human intervention and flagging of specific instruments, needing recalibration, shall be performed each year based on evaluation of the data collected.

Device Replacement / Repair: Following any service disruption, or after noting concerning results from inspections, recalibrations, or testing, equipment repairs and/or replacements may be deemed necessary for continual operation of the system. Consult a qualified electrical worker or consultant for recommendations on equipment replacements.

6.2.4.2 Qualifications and Competency

Personnel who have been formally trained on the equipment, or who have been deemed qualified by the owner, shall perform these tasks.

The equipment manufacturers and qualified electrical/instrumentation consultants (PLC Programming Specialists) may also be utilized to assist in these activities. This is particularly relevant for PLC programming and logic changes, as well as when required for the software/hardware upgrades.

Although not required for most visual inspections, a certified Instrumentation and Controls Technician or Technologist should perform maintenance on instrumentation when technical maintenance work, instrument replacements, and new instrument commissioning is being performed. RTDs are not complex, however the application and customized RTD string installations are not simple.

6.2.4.3 Safety Hazards and Procedures

Consult a qualified consultant and refer to OSHA / NETA for safety hazards to carry out such tasks.

6.2.4.4 Resources

The design of the equipment shall outline required turnover documentation and literature resources which must be provided during the construction and installation of the freeze system. These individual components Operating, and Maintenance Manuals shall be a key resource for Maintenance work on the electrical equipment. Specific manuals shall be included for:

- Sensor Strings
- PLCs
- Remote I/O Cabinet Components
- Communication Cabinet Components

Table 6.2-2, and Table 6.2-3 outline the required maintenance schedule for various components of the freeze infrastructure.

Table 6.2-3: Electrical Supporting Material Maintenance Schedule

Item Description	Visual Inspection	Software / Hardware Upgrades
Cable Trench	Every 36 Months	As per Visual Inspection
Electrical Wood Pole	Every 36 Months	As per Visual Inspection
Conduits	Every 36 Months	As per Visual Inspection

Spare parts for key components should be verified as available and currently being manufactured (not obsolete) each 5 years. Key components include breakers, fuses, and other consumable spare parts.

6.3 Civil Maintenance

6.3.1 Road Grading and Freeze Pad Maintenance

6.3.1.1 Requirements

Road access to each freeze pad must be maintained to facilitate surveillance and freeze program maintenance activities. Maintain grades for roads and freeze pads to design standards to facilitate appropriate surface water drainage. Regular maintenance should also be provided for all ditches, culverts, storm water ponds, retaining walls, and barriers.

Freeze pads should not be used for storage of any equipment and should not be altered from design specifications. Alterations to the composition of the freeze pad surfaces could affect the freeze performance and should be undertaken only after review by the engineer of record.

It is not necessary to keep the freeze pads free of snow outside what is required for general access.

6.3.1.2 Qualifications and Competency

Appropriate qualifications and certifications are required prior to use of any site equipment.

6.3.1.3 Safety Hazards and Procedures

Operators need to be aware that freeze pads in AR-1 are located adjacent to steep slopes. Caution should be taken to avoid contact with any thermosyphons or barriers put in place to protect infrastructure.

6.3.1.4 Resources – Equipment, Materials, Personnel

To be determined by on-site management.

6.3.2 Fence Painting, Gate Hinge Oiling, Signage

Placeholder until minimum standards are identified for the overall site.

6.3.2.1 Requirements

To be determined on a case by case basis.

6.3.2.2 Qualifications and Competency

No special qualification or certifications are required.

6.3.2.3 Safety Hazards and Procedures

General site safety should be followed.

6.3.2.4 Resources – Equipment, Materials, Personnel

To be determined on a case by case basis.

6.4 Task Tracking, Completion Recording / Reporting

6.4.1 Maintenance Management Software (CMMS)

[Placeholder for future revision once site-wide maintenance management software is finalized]

6.5 Inventory of Critical Spare Parts

Most of the critical spare parts will be related to maintaining instrumentation. Lack of instrumentation will not impact the freeze performance; however, it could result in delayed identification of issues that do affect freeze performance (refer to Section 6.2 above).

Inoperative thermosyphons are a more time critical issue prior to freeze containment. However, after containment, a freeze data interpretation checklist summary exists to guide maintenance schedule planning.

7 ACTION LEVELS AND CONTINGENCIES

In general, should monitoring or inspection indicate that the frozen shell is not performing as anticipated, a series of actions would be initiated. An adaptive management approach is used to link monitoring results to actions with the purpose of maintaining the frozen shell as designed.

Section 5 of this Plan and this section provide a systematic approach to responding to the results of the monitoring. Section 5 covers maintenance related response to monitoring. If maintenance related monitoring issues have already been addressed, and a calibrated model has been established, any further performance deficiencies are likely climate response projection related. This section provides a systematic approach to responding to monitoring related to closure criteria. This includes:

- a description of how the results will link to those actions necessary to verify that changes remain within an acceptable range
- definitions, with rationale, for tiered action levels
- a description of the rationale for each action level
- a description of how exceedances of action levels will be assessed
- a description of actions that may be taken if an action level is exceeded

Briefly, the process involves:

- Action levels are evaluated based on monitoring findings in a given month or year.
- When an action level is exceeded, the actions for the action level exceedance should be completed, as appropriate.

Report exceedance to MVLWB Note that this plan includes the action levels in relation to freeze only. Other plans will address spills, erosion, dams, aquatic effects in the receiving environment, water, or site dust management.

Table 7-1 includes the following information:

- **Item**: name or title of relevant location or topic for action level
- **Risk**: list the key item of concern around which actions levels relate
- **Key information**: summarizes which measurement endpoints are assessed for each assessment endpoint.
- **Low (Action Level)**: the conditions under which the Low Action Level would be reached.
- **Moderate (Action Level)**: the conditions under which the Moderate Action Level would be reached.
- **High (Action Level**): the conditions under which the High Action Level would be reached.

Table 7-1 presents action levels, actions, and contingencies related to the integrity of the frozen shell in the freeze areas (AR1 to AR4 and B1 Pit). The risk related to the frozen shell integrity is associated with the potential for long term climate response projections to be warmer than previously predicted projections.

Table 7-1: Action Levels for the Arsenic Trioxide Frozen Shell Management and Monitoring Plan

Item	**Frozen shell integrity (Freeze areas AR1 to AR4 and B1 Pit)**	
Risk	Long term climate response projections are warmer than previously predicted projections	
Key Information	**Section 5.1.1.1** illustrates anticipated performance. Study the available data and compare it to the most up-to-date calibrated thermal model. Consider if the climate in the recent years is warmer than model projections to explain any variance. In general, the sooner an adverse trend in ground warming is detected, the more time there is to study, confirm and develop a mitigation strategy. Consider a Response Framework as described in Section 5.3.8.	
Action Level		**Types of Actions and Contingencies**
Low	If specific in-ground individual or grouped average temperature data trending starts to deviate more than 2°C from calibrated thermal model data at similar locations when forward looking up to 15 years, action should be taken to understand why. This issue is not critical if detected at least 15 years prior to anticipated exceedance of freeze criteria.	■ Study and reassess.
Moderate	If projected warming trends from specific in-ground individual or grouped average temperature data show possible exceedance of freeze criteria between 5 and 10 years…	■ Update thermal models ■ Re-assess the findings ■ Observe and update the action level as necessary.
High	If the calibrated thermal model, based on in-ground individual or grouped average sensor data indicates that the frozen shell is on a warming trend to exceed criteria (5 m wide zone of rock or fill at -5°C) in less than 5 years…. Five years should be sufficient lead time to develop, implement, and mitigate any adverse temperature trending.	■ Develop a mitigation strategy which includes conversion to hybrids or special ground surface treatments to insulate from surface down warming.

There are over 1500 individual temperature sensing points over the full freeze project and their locations have been chosen to allow for a full assessment of the growth and extents of frozen ground around all arsenic trioxide containing stopes and chambers. Many of the data sensors will report temperatures that are similar to other sensors in the same string, or to other strings in similar rock and at similar distances from the sides of chambers or stopes. As part of the standard operating procedure, and based on the actual as built and as surveyed locations of each sensor point, a calibrated thermal model will be developed that will closely match the field data and also interpolate between data locations. Once this is done, sensors that behave similarly can be identified and grouped and that data averaged by the data historian. The 1500 data points will be grouped into a more manageable set of data from which the operators can track actual ground temperature with model data for the same data point locations. There may be perhaps a set of 50 key data trending locations that will form the basis for tracking the freeze system. This will be determined based on actual field data recorded from the first few years of cooling in conjunction with the calibrated model findings. This approach was used for the FOS monitoring program as illustrated in Figure 7-1.

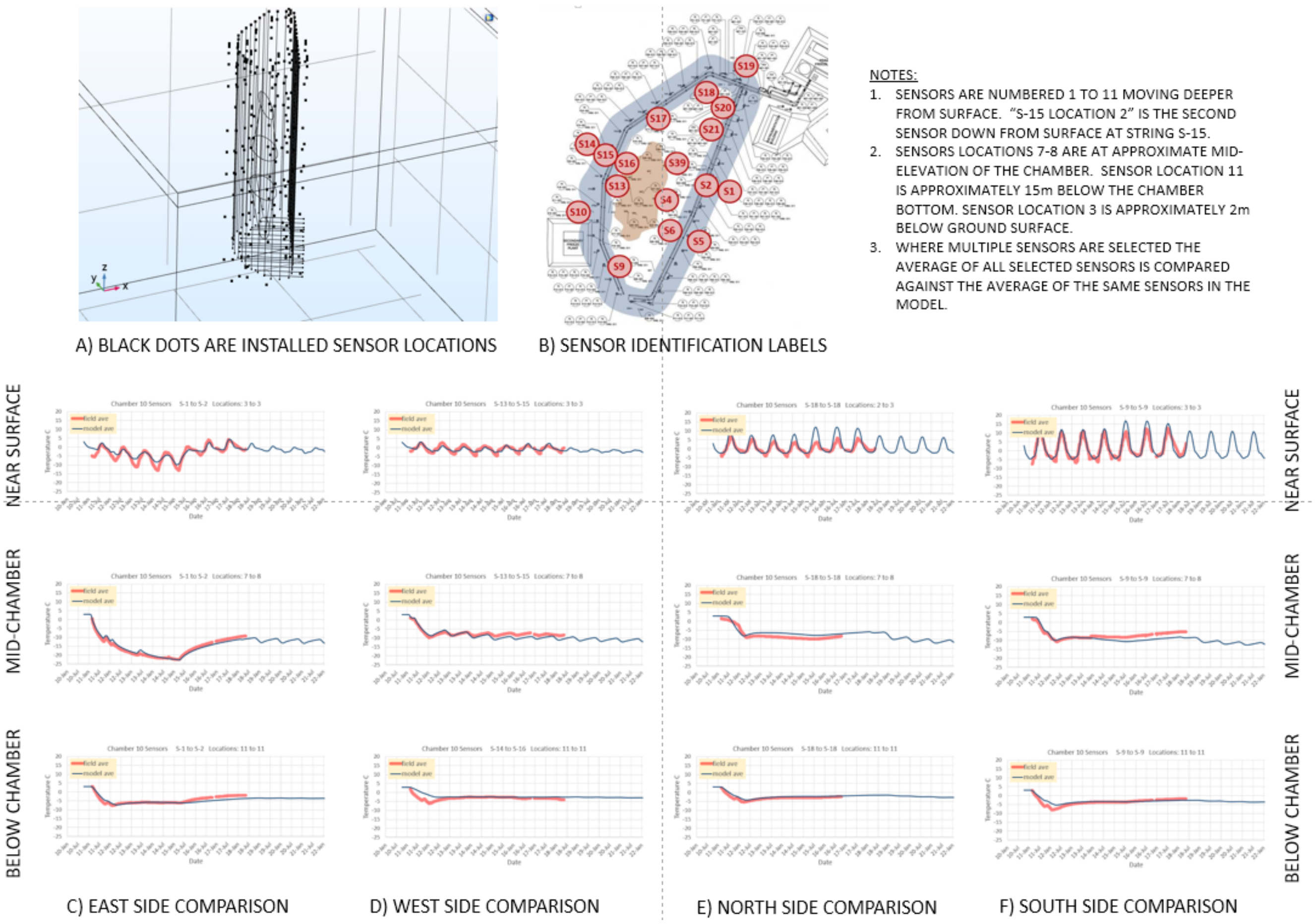


Figure 7-1: Example of how groups of average ground temperatures are compared to modeled data (from the FOS). Modelled data are the blue series and red data are field averaged from locations with similar trending.

8 REPORTING AND PLAN REVIEW

A minimum of 120 days prior to commencement of Construction of the Arsenic Trioxide Frozen Shell System, the GMRP shall submit to the Board, for approval, an Arsenic Trioxide Frozen Shell MMP.

In accordance with the Annual Water Licence reporting requirements, the GMRP will submit a summary of management and monitoring activities conducted in accordance with this Management and Monitoring Plan during the previous calendar year including:

- A summary of updates or changes to the process or facilities required for the management of the Arsenic Trioxide Frozen Shell.
- A summary and interpretation of monitoring results.
- A summary of Action Level exceedances and a description of actions taken in response to Action Level exceedances including any response or corrective actions taken.
- A summary of findings from any required inspections.

In accordance with the Water Licence, the GMRP will conduct an annual review of this Arsenic Trioxide Frozen Shell Management and Monitoring Plan and make any revisions necessary to reflect changes in operations, contact information, or other details. If no revisions are required to this plan, this plan will be listed as a document that has been reviewed and requires no revision in the notification letter sent for the GMRP to the MVLWB, no later than March 31 each year. If at any time, this plan is updated with proposed changes, the GMRP will submit the revised plans to the MVLWB for approval, a minimum of 90 days prior to the proposed implementation date for the changes. No changes shall be implemented until approved by the MVLWB.

9 REFERENCES

9.1 Acts and Regulations

Canadian Environmental Protection Act, 1999. SC 1999, c 33. Current to 28 July 2020. https://laws-lois.justice.gc.ca/eng/acts/c-15.31/.

Mackenzie Valley Resource Management Act. SC 1998, c 25. Current to 28 July 2020. https://laws-lois.justice.gc.ca/eng/acts/m-0.2/.

Mackenzie Valley Federal Areas Waters Regulations. SOR/93-303. Current to 11 Aug 2020. https://laws-lois.justice.gc.ca/eng/regulations/SOR-93-303/index.html.

Metal Mining Effluent Regulations, Part II, Vol. 136, No. 13 (with updates to 2018). Canada Gazette, SOR/2002-222. Available at: http://laws-lois.justice.gc.ca/eng/regulations/SOR-2002-222/. Accessed: July, 9, 2018.

Mine Health and Safety Act. SNWT 1994 c 25. In force 15 December 1995, amendments to SNWT 2010 C 16. https://www.justice.gov.nt.ca/en/files/legislation/mine-health-and-safety/mine-health-and-safety.a.pdf

Mine Health and Safety Regulations. R-125-95 under the *Mine Health and Safety Act*. Amendments to R-123-2018. https://www.justice.gov.nt.ca/en/files/legislation/mine-health-and-safety/mine-health-and-safety.r1.pdf

Waters Act. SC 1992, c 39. Repealed 2014, c 2, s 66. Current to 28 July 2020. https://laws-lois.justice.gc.ca/eng/acts/n-27.3/.

9.2 Literature Cited

AECOM Canada Ltd. (AECOM 2020a). "Substantive Freeze Design Report for Areas AR-3 and AR-4". Prepared for Public Services and Procurement Canada and dated June 8, 2020.

AECOM Canada Ltd. (AECOM 2020b). "Substantive Freeze Design Report for Areas AR-1 and AR-2 – Revised Design Criteria". Prepared for Public Services and Procurement Canada dated July 24, 2020.

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2013. Report of Environmental Assessment and Reasons for Decision on the Giant Mine Remediation Project. EA0809-001. Yellowknife, NT, Canada. 20 June 2013.

MVLWB (Mackenzie Valley Land and Water Board). 2013. Standard Outline for Management Plans. https://mvlwb.com/sites/default/files/documents/wg/Standard%20Outline%20for%20Managment%20Plans%20-%20October%202013.pdf

MVLWB and AANDC (Aboriginal Affairs and Northern Development Canada). 2013. Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories. http: wlwb_5363_guidelines_closure_reclamation_wr.pdf (mvlwb.com)

SRK. 2016. Giant Mine Freeze Program – Design Basis Report. Prepared for Indigenous and Northern Affairs Canada in 2016.

APPENDIX A Conformity Tables

Type A Water Licence

Conditions of the Type A Water Licence MV2007L8-0031 are summarized in Table A-1 along with sections of the Arsenic Trioxide Frozen Shell Management and Monitoring Plan where each condition is addressed.

Table A-1: Water Licence Conditions

Water Licence MV2007L8-0031	Corresponding Section in Management and Monitoring Plan
Part F (15) A minimum of 120 days prior to commencement of Construction of the Arsenic Trioxide Frozen Shell System, the Licensee shall submit to the Board, for approval, an Arsenic Trioxide Frozen Shell Management and Monitoring Plan. The Plan shall be in accordance with Schedule 4, condition 10.	Purpose of the document
Schedule 4, Condition 10: Arsenic Trioxide Frozen Shell Management and Monitoring Plan	
a) Information regarding the long-term operation of the Arsenic Trioxide Frozen Shell system;	Section 4, 5, and 6
b) An explanation of the triggers that will prompt climate model updates and how those will inform the Arsenic Trioxide Frozen Shell Management and Monitoring Plan;	Section 7
c) Information regarding the long-term maintenance and management of the Arsenic Trioxide Frozen Shell system, including: i. A summary, with appropriate maps or diagrams, of the location of the Arsenic Trioxide Frozen Shell and its components;	Figure 2.2-1, Section 2.4 and Figure 2.1-1
ii. A description of the process and facilities intended for the purposes of maintaining the Arsenic Trioxide Frozen Shell in situ, including the minimum number of thermistors required;	Section 2.2, 3 and 4.4
iii. Any other information required to describe how the Arsenic Trioxide Frozen Shell will be managed to continue to meet the Closure Criteria for the structure; and	Section 1.1 and Throughout Plan
iv. Details of the option to convert passive thermosyphons to hybrid units if climate trends are on a path to exceed current expectations;	Section 5.3.8
d) A description of any engagement activities undertaken to inform the Plan;	Section 1.5
e) Information regarding monitoring and inspection of the Arsenic Trioxide Frozen Shell including: i. Details and rationale for monitoring and inspection, for all components of the Arsenic Trioxide Frozen Shell including monitoring locations, types of instrumentation used and frequency of monitoring, including a site map to scale and where data will be reported;	Figure 2-1, Section 3.1, 3.2 and 5.1.1.2
ii. Predicted performance values based on facility design;	Section 4 and 5.1
iii. Details on the intended frequency of thermal model calibrations for temperature sensors that measure ground temperature, as well as factors that would indicate that a change in calibration frequency would be appropriate;	Section 5.1.1.4 and 5.2.1.
iv. Linkages to other Site-Wide Management and Monitoring Plans, the Giant Mine Remediation Project Closure and Reclamation Plan, Design Plans, Construction Plans, and Closure and Reclamation Completion Reports required in this Licence;	Section 1.1

Table A-1: Water Licence Conditions

Water Licence MV2007L8-0031	Corresponding Section in Management and Monitoring Plan
v. Provide a list of relevant Closure Objectives and Closure Criteria; Linkages to any Closure Objectives and Closure Criteria from the approved Giant Mine Remediation Project Closure and Reclamation Plan or Design Plan(s) that are satisfied in whole or in part by the management systems detailed in this Plan; and vi. Any other information about the monitoring that will be performed to verify that Arsenic Trioxide Frozen Shell is being managed to continue to meet the final design criteria for the structure and any approved EA0809-001 measures.	Section 1.1 Section 5
f) A description of maintenance or contingency activities that will be undertaken if monitoring results show that Closure Activities are not meeting Closure Criteria, or are not trending towards meeting Closure Criteria, or not meeting Part F, condition 1 of this Licence. The contingencies section of the Arsenic Trioxide Frozen Shell Management and Monitoring Plan will include: i. Identified risks related to management of the Arsenic Trioxide Frozen Shell;	Section 5.3
ii. Contingencies to address climate change uncertainties;	Section 5.3.8
iii. Details on the option to convert passive thermosyphons to hybrid units if climate trends are on a path to exceed current estimates;	Section 7
iv. A threshold or Action Level to define the point at which monitoring indicates a response is necessary;	Section 5.4 and 7
v. Details about action response timing following a deviation between predicted and actual temperature;	Section 5.1.1.4, 5.2.1, and 7
vi. Details about model update timing following a deviation between predicted temperature and temperature; and,	Section 5.4
vii. Proposed response and possible contingency actions to be implemented if threshold is exceeded.	Section 7

Commitments on Arsenic Trioxide Frozen Shell Management and Monitoring Plan

In Undertaking 5 from the Water Licence Application Public Hearing, the GMRP committed to administrative and content updates to the Management and Monitoring Plans, these are summarized in Table A-2 along with sections of the Arsenic Trioxide Frozen Shell MMP where each condition is addressed.

Table A-2: Commitments on Arsenic Trioxide Frozen Shell Management and Monitoring Plan

Commitment Number	Commitment	Corresponding Section in Management Plan
4a.	The GMRP commits to revising and clarifying language related to Engineered Components (from Engineered Structures).	N/A
4b.	The GMRP will use the predefined term of Action Levels in the next versions of Site-wide management and monitoring plans.	Section 7
4c.	The GMRP will verify that the Site-Wide Management and Monitoring Plans include all applicable Federal and Territorial legislation.	Section 1.4
4d.	The findings of the QRA will be incorporated into the contingency sections of the next versions of Site-wide management plans and monitoring plans and elsewhere in Project documentation, as appropriate.	N/A
4e.	The GMRP commits to pre-engagement on the next versions of Site-wide management plans, including the Borrow and Explosives Management and Monitoring Plan and the Arsenic Trioxide Frozen Shell Management and Monitoring Plan.	Section 1.5
14a.	Details and steps on thresholds for launching management action and/or model updates when there is deviation between modelled and measured freeze will be incorporated into the Arsenic Trioxide Frozen Shell Management and Monitoring Plan.	Section 5.4 and 7
14b.	Contingencies to address climate change uncertainties will be included.	Section 5.1, 5.3.8, 5.3 and 5.4
14c.	Details on the option to convert passive thermosyphons to hybrid units if climate trends are on a path to exceed current estimates will be included.	Section 5.3.8

APPENDIX B Standard Operating Procedures

This section will be added in a later revision as the documents are prepared by the site management and operations teams.