Gunnar Site Remediation Project – Tailings Remediation Plan (Public Distribution)

August 17, 2015

SASKATCHEWAN RESEARCH COUNCIL

O'Kane Consultants

EcoMetrix INCORPORATED




Integrated Mine Waste Management and Closure Services
Specialists in Geochemistry and Unsaturated Zone Hydrology

Gunnar Site
Remediation Project –
Tailings Remediation Plan
(Public Distribution)

Report No. 963/1-01

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EXECUTIVE SUMMARY

SRC issued a Request for Proposal (RFP) #1415-020 entitled “Engineering Design Services for Gunnar Mine Site Remediation Tailings Cover System and Design Tree Analysis” dated January 7, 2015. SRC awarded a contract to O’Kane Consultants Inc. (OKC) on March 13, 2015 to complete the work scope outlined in the RFP. EcoMetrix Inc. (Ecometrix) is providing technical support related to geochemical aspects of this Project. OKC and Ecometrix are referred to herein as the “Project Team”. This report presents the plan for remediation of the exposed tailings deposits at the Gunnar site (the “Site”) to support an Issue for Tender (IFT) package for execution of the final approved remediation plan.

As recommended in the 2013 Environmental Impact Statement, the preferred option is to remediate the tailings in-place. Given the radiological and geochemical characteristics of the tailings, an earthen or soil cover system, at least 0.5 m thick, is required to remediate the tailings in-place to mitigate ecological and human health risks to acceptable levels post-reclamation. A fundamental component to the long-term integrity and performance of soil cover systems is design of a final landform that takes into consideration the cover system design objectives as well as local conditions of rainfall, soil type, and vegetation cover. This report presents the preferred final landform design for each of the primary tailings deposits as well as the proposed borrow materials and sources. A field investigation was completed at the Site in June 2015, which will confirm the characteristics and volumes of borrow sources for remediation of the tailings deposits. Upon removal of the Phase II Canadian Nuclear Safety Commission licensing hold point, SRC will conduct a public tendering process to select a remediation contractor. The remediation contractor and OKC will prepare final detailed information for the remediation plan prior to implementation of the construction phase of the project.

The following tasks were completed to address the objectives of this report:

- Review of available background information to support a data gaps analysis and recommended actions to reduce uncertainties in the final remediation designs;
- Development and review of various options for remediation of the primary and secondary tailings deposits;
- Review / refinement of existing conceptual models related to geochemical behaviour of the tailings and performance of the base case tailings cover system (a 0.5 to 1.0 m thick layer of local till material);
- Preliminary assessment of loadings for constituents of potential concern (COPC) to Langley Bay for the various tailings remediation options;
- Development of preliminary cost estimates to support a multiple accounts analysis of the various tailings remediation options;
- Selection of the preferred remediation option for each tailings area including identification of key construction elements and potential failure modes as well as an assessment of potential effects of tailings remediation plans on other site aspects; and

- Development of preliminary programs for revegetation, surface water management, and performance monitoring of the remediated tailings areas.

Based on several factors such as environmental impacts, technical feasibility, and cost effectiveness, the preferred remediation designs for the three primary tailings deposits at the Site are as follows:

Gunnar Main:

- Backfill the remnant aquatic portion of Mudford Lake and pump displaced water to the open pit or treat the water before release to Zeemel Bay;
- Create a water-shedding landform by re-contouring the uplands tailings in the south and placing waste rock fill to direct all surface waters towards Beaver Pond;
- Place a minimum 0.6 m thick layer of local till material over the re-countered tailings / waste rock fill surface;
- Construct an armoured drainage channel to direct surface runoff waters to Langley Bay; and
- Revegetate the cover system surface with native plant species.

Gunnar Central:

- Create a water-shedding landform by placing waste rock fill to direct all surface waters towards an armoured drainage channel along the eastern perimeter;
- Place a minimum 0.6 m thick layer of local till material over waste rock fill; and
- Revegetate the cover system surface with native plant species.

Langley Bay (beach area):

- Create a water-shedding landform using local till material or quarried fill that establishes a defined beach area based on the estimated high water level for Langley Bay;
- Place large riprap material along the Back Bay east shoreline and Langley Bay south shoreline to protect the beach tailings cover system from wave action and ice scour;
- Construct an armoured drainage channel across the centre of the beach tailings final landform to provide an outlet for the Back Bay catchment to Langley Bay; and
- Revegetate the cover system surface with native plant species.

Waste rock is preferred over local till material for creating the proposed final landforms for Gunnar Main and Gunnar Central for the following reasons:

- The Gunnar waste rock is a competent, coarser-textured material that will provide an excellent working platform for construction equipment to place the final till cover system;
- The coarser-textured nature of the Gunnar waste rock will limit the capillary rise of COPCs in the tailings pore-waters into the cover system rooting zone; and
- Using stockpiled waste rock results in less disturbance of the natural landscape.

Based on a preliminary assessment of COPC loadings to Langley Bay, the preferred remediation designs likely will reduce loadings compared to current conditions. Site-specific remedial objectives for various COPCs in Langley Bay will be met post-reclamation by an order-of-magnitude.

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LIST OF ACRONYMS

Abbreviation	Full Text
CEAA	Canadian Environmental Assessment Act
CLEANS	Cleanup of Abandoned Northern Sites
CNSC	Canadian Nuclear Safety Commission
COPC	Constituents of potential concern
EcoMetrix	EcoMetrix Inc.
EIS	Environmental Impact Statement
FMEA	Failure Modes and Effects Analysis
GCT	Gunnar Central Tailings
GMT	Gunnar Main Tailings
IDF	Intensity-Duration-Frequency
IFT	Issue for Tender
LLRD	Long-Lived Radioactive Dust
MAA	Multiple Accounts Analysis
masl	Metres above sea level
OKC	O'Kane Consultants Inc.
PM	Particulate Matter
PSD	Particle size distribution
QA/QC	Quality Assurance / Quality Control
RFP	Request for Proposal
SFE	Shake Flask Extraction
SRC	Saskatchewan Research Council
SSRO	Site-Specific Remedial Objectives
WRP	Waste rock pile

LIST OF UNITS

Symbol	Units
cm	Centimetre
cm/s	Centimetre per second
°C	Degree Celsius
dam^3	Cubic decametre (equal to 1,000 cubic metres)
ha	Hectare
kPa	Kilopascal
kg/a	Kilogram per annum
m^3	Cubic metre
Mt	Million tonnes
Mm^3	Million cubic metre
m^3/a	Cubic metre per annum
mg	Milligram
m	Metre
mm	Millimetre
MBq/a	Mega Becquerel per annum
mg/L	Milligram per litre
µg/L	Microgram per litre
$µg/m^3$	Microgram per cubic metre
µm	Micrometre
µSv/h	Microsievert per hour

1 INTRODUCTION

The Gunnar uranium deposit was discovered in July 1952, with commencement of production in September 1955. An on-site milling facility, numerous support buildings, and a town site were constructed to support mine workers and their families, as well as extract and process the ore. Uranium ore was initially mined from an open pit from 1955 to 1961. Underground mining operations, extending over 500 m below the bottom of the pit, began in 1957 and ended in 1963. It is estimated that 5.5 Mt of ore was mined during operation of the Gunnar site (the "Site"). The mine officially closed in 1964 with little decommissioning of the facilities and flooding of the open pit.

The Saskatchewan Research Council (SRC) is acting as project manager for Cleanup of Abandoned Northern Sites (CLEANS) on behalf of the Saskatchewan Ministry of Environment. Project CLEANS is a multi-year project with the objective to remediate the Gunnar site, the Lorado site, as well as 35 satellite sites in northern Saskatchewan. An Environmental Impact Statement (EIS) was completed in 2013 that included site-wide studies to characterize the current conditions and environmental impact of the Gunnar site and its various components. Within the EIS, SRC proposes a plan to remediate and/or manage all areas of concern, including:

- Three main (primary) tailing deposits along with minor (secondary) tailing deposits;
- Two waste rock piles (WRPs);
- Flooded open pit;
- Demolition debris and hazardous materials; and
- Impacted soils and water.

As outlined in the EIS report (SRC, 2013), an analysis of remedial options for the remaining mine components outlined above was undertaken and generally agreed upon with local stakeholders and provincial regulatory authorities. An initial options analysis was completed using the Environment Canada alternatives assessment process. To ensure the final remediation options included the results of continuing studies and the interaction between different aspects, 'decision trees' were developed for each of the listed mine components. Mitigation of ecological and human health risks were the key objectives for the remediation alternatives for each of the mine components. For example, the decision tree analysis determined that an earthen cover system was the recommended option for mitigating ecological and human health risks related to contaminants remaining in the three tailings deposits.

SRC issued a Request for Proposal (RFP) #1415-020 entitled "Engineering Design Services for Gunnar Mine Site Remediation Tailings Cover System and Design Tree Analysis" dated January 7, 2015. SRC awarded a contract to O'Kane Consultants Inc. (OKC) on March 13, 2015 to complete the work scope outlined in the RFP. OKC engaged EcoMetrix Inc. (EcoMetrix) to provide technical support related to geochemical aspects of this Project. OKC and EcoMetrix are hereinafter referred to as the 'Project Team'. This report presents the plan for remediation of the exposed tailings deposits at the Site to support an Issue for Tender (IFT) package for execution of the final approved remediation plan.

1.1 Project Location and Site Features

The Site is located on the shores of Lake Athabasca in Northern Saskatchewan, approximately 25 km southwest of Uranium City (**Dwg. No. 963/1-000**). The Site is isolated from other communities and is accessible by boat/barge in the summer or via ice road or snowmobile in the winter. A small gravel airstrip provides year-round access by light aircraft; weather and runway conditions permitting.

Several bays and channels that form part of the Crackingstone Peninsula on the northern shores of Lake Athabasca are directly adjacent to areas of the Site. The Site is dominated by Precambrian bedrock outcrops, with ridges / hills outcrops showing topographic relief to 10's of metres. Elevation at the Site ranges from 210 to 305 metres above sea level (masl). Low lying areas are infilled with glacial deposits consisting of silty-fine sand to coarse sand-cobble units. These areas are often thickly forested with black spruce dominating the wetter, poorly-drained areas. Pine stands are attributed to the coarser, drier areas as well as some of the basement outcrops.

The location of remaining Site features are shown in **Dwg. No. 963/1-001**. Waste rock was placed in two WRPs adjacent to the open pit and partially submerged into Zeemel Bay. Mine infrastructure such as the acid plant is located north and west of the pit. The Gunnar mill released approximately 4.4 Mt of tailings during mining operations. Tailings were deposited into Mudford Lake located about 500 m north of the mill. This area is known as the Gunnar Main tailings (GMT) deposit. Once Mudford Lake had essentially been filled, tailings flowed towards a small depression to the northeast within a narrow channel blasted in the bedrock sometime prior to 1955 (SRC, 2013). Once this depression had been filled, forming the Gunnar Central tailings (GCT) deposit, tailings proceeded to flow in a westerly direction, to an area of lower elevation, eventually entering Langley Bay and Lake Athabasca. The Site catchments and surface water flowpaths are shown in **Dwg. No. 963/1-002**. Further details are provided below on the primary or major tailings deposits as well as a few secondary or minor deposits.

<u>Primary Tailings Deposits:</u>

Gunnar Main:

Tailings were discharged along the eastern portions of Gunnar Main towards the west. A dam was constructed along the south-eastern margins of Gunnar Main to contain tailings from flowing south towards St Mary's channel. The dam structure no longer functions as a containment facility for saturated tailings or water. This is based on piezometric data for the area where the water table is approximately 10 m below the surface and in the underlying geology. The coarsest tailings are located along this dam and the eastern margins of Gunnar Main where the spigots discharged. A large tailings beach is currently located along the south and eastern areas of Gunnar Main, with tailings getting progressively finer towards the west and north. Remnants of Mudford Lake are currently contained in the western half of the area. Historical investigations indicate that the tailings in Gunnar Main are about 14 m thick at the deepest part of the deposit (SRC, 2013). The GMT footprint is ~45 ha with an estimated tailings volume of ~2.8 Mm^3 based on an assumed average depth of 8 m (SRC, 2013).

Gunnar Central:

Gunnar Central is located approximately 500 m north of Gunnar Main. The area has low relief; hence, finer-textured tailings material were deposited in a delta-like landform. The Gunnar Central footprint is ~11 ha with an estimated tailings volume of ~0.45 Mm^3 based on an assumed average depth of 3.2 m (SRC, 2013). The majority of the tailings deposit is saturated throughout the year. Vegetation has developed over approximately half of the exposed tailings area and is dominated by shrubs and grasses.

Langley Bay:

The Langley Bay tailings deposit lies at the outlet of the channel leading from Gunnar Main to Langley Bay and consists of sub-aerially exposed tailings and an unknown volume of tailings submerged in Langley Bay. Tailings are comprised of the finest fractions and slimes, which have divided the Bay into two areas: Langley Bay is connected to Lake Athabasca and Back Bay, which is west of the exposed tailings and disconnected from Langley Bay when water levels are low. Exposed tailings in Langley Bay exhibit relatively little relief; therefore, as the Langley Bay water levels fluctuate, the areal extent of the exposed tailings fluctuate. Exposed tailings comprise a footprint of ~14 ha when a low water level exists in Langley Bay. The estimated tailings volume is ~0.45 Mm^3 based on an assumed average depth of 3.5 m (SRC, 2013).

Secondary Tailings Deposits:

Catchment 3 – Back Release:

Tailings have been re-deposited along the Catchment 3 flowpath adjacent to Gunnar Main. The tailings are thought to have migrated through a berm breach and subsequent redistribution through surface water movement as well as through windblown erosion. The current Catchment 3 'back release' is largely saturated and covers a footprint of ~18 ha. Tailings depth ranges from approximately 1.3 m immediately east of an earthen berm down to 0.1 m in the dispersed tailings further down-catchment (SRC, 2013). Surface water from this areas flows to the WRP and discharges to Zeemel Bay.

Beaver Pond:

The Beaver Pond area is located immediately north of Gunnar Main. The area is currently impounded to the north by a series of three beaver dams, which have resulted in ponded water upstream in the Beaver Pond area. Tailings from Gunnar Main have deposited within the ponded area. In addition, till overburden was excavated from the current dammed channel in 1954, creating a surface water flowpath from the beaver dams to Gunnar Central. The current footprint of the tailings area in Beaver Pond is approximately 2.7 ha.

1.2 Regulatory and Project Context

The Site has been under the responsibility of the Saskatchewan Provincial Government since operations ceased. The Federal Government oversaw regulation of abandoned uranium mines under the Nuclear Safety and Control Act since 2000. Subsequently the Provincial and Federal Governments signed a memorandum of agreement, where responsibility for the site fell to the Provincial Government, with regulatory over-site from the Canadian Nuclear Safety commission (CNSC). The Saskatchewan Ministry of Economy contracted SRC to manage remediation of the abandoned uranium mines in Northern Saskatchewan. The Gunnar Remediation Project commenced in 2006 when the Saskatchewan Ministry of Economy engaged SRC to manage the CLEANS project. The objective of the Project is to reduce the risks the Site poses, in its current state, to the health and safety of the public and environment, and ultimately, transfer the Site to the Provincial Government's Institutional Control program for monitoring and maintenance.

As a result of the potential risk to public safety associated with the deterioration of buildings and structures on the Site since site abandonment, the CNSC issued *Order 10-1* to secure on-site hazardous substances and materials, and to take down buildings and facilities that failed a structural safety assessment. Following the order, most of the buildings and structures on the Site were abated from asbestos and successfully demolished between 2010 and 2012. Most of the hazardous materials had been transported off-site by winter ice road in 2012 for disposal in approved facilities. The non-hazardous demolition debris are temporary piled on-site and do not pose immediate environmental and public risks.

A revised EIS for the Site was issued to the regulatory agencies in November 2013. A comprehensive effects assessment has been conducted for the Project to support approvals for it from the Provincial and Federal regulators under the *Saskatchewan Environmental Assessment Act* and *Canadian Environmental Assessment Act* (CEAA), respectively. The Gunnar EIS was approved by the Saskatchewan Ministry of Environment in August 2014. The Site is currently operated under CNSC License WNSL-W5-3151.00/2024 to possess, manage, and store nuclear substances. The current (Phase 1 Waste Nuclear Substance License) license is valid from January 14, 2015 to November 30, 2024, and allows for continued activities that are related to the Gunnar mine, mill and tailings site. In addition, activities associated with ongoing care and maintenance are included under the current license. Remediation works are anticipated to commence in 2016, upon obtaining by SRC the Phase 2 Licence allowing for remediation of the numerous components of the Gunnar Site.

1.3 Report Objectives and Scope

The primary objective of this report is to present remediation designs for the exposed tailings deposits at the Site. As recommended in SRC (2013), the preferred option is to remediate the tailings in-place. Given the radiological and geochemical characteristics of the tailings, an earthen or soil cover system, at least 0.6 m thick, is required to remediate the tailings in-place to mitigate ecological and human

health risks to acceptable levels post-reclamation. A fundamental component to the long-term integrity and performance of soil cover systems is design of a final landform that takes into consideration the cover system design objectives as well as local conditions of rainfall, soil type, and vegetation cover. This report presents the preferred final landform design for each of the primary tailings deposits as well as the proposed borrow materials and sources. A field investigation was completed at the Site in June 2015, which will confirm the characteristics and volumes of borrow sources for remediation of the tailings deposits. Final detailed design information as well as a construction plan for remediation of the tailings deposits will be documented in a report prior to the construction phase of the project.

The following tasks were completed to address the objectives of this report:

- Review of available background information to support a data gaps analysis and recommended actions to reduce uncertainties in the final remediation designs;
- Development and review of various options for remediation of the primary and secondary tailings deposits;
- Review / refinement of existing conceptual models related to geochemical behaviour of the tailings and performance of the base case tailings cover system (a 0.5 to 1.0 m thick layer of local till material);
- Preliminary assessment of loadings for constituents of potential concern (COPC) to Langley Bay for the various tailings remediation options;
- Development of preliminary cost estimates to support a multiple accounts analysis (MAA) of the various tailings remediation options;
- Selection of the preferred remediation option for each tailings area including identification of key construction elements and potential failure modes as well as an assessment of potential effects of tailings remediation plans on other site aspects; and
- Development of preliminary plans for revegetation, surface water management, and performance monitoring of the remediated tailings areas.

For convenient reference, this report has been subdivided into the following sections:

- Section 2 – provides background information relevant to this project, data gaps, and recommended actions to reduce uncertainties;
- Section 3 – presents the conceptual models for geochemistry as well as cover system and landform performance;
- Section 4 – details the options analysis of landform and cover system designs considered for the remediation plan;
- Section 5 – summarizes the preferred cover system and landform designs for each of the tailings deposits;
- Section 6 – provides the work plan for completion of final detailed design information and construction plan; and
- Section 7 – describes stakeholder consultation that will be completed as part of this project.

2 REVIEW OF EXISTING INFORMATION

A considerable body of knowledge has been assembled by SRC throughout the process of preparing the EIS for the Site. Data were reviewed and compiled to assist in developing a cover system that incorporates past learnings at the Site to the fullest extent possible. The information will be used to develop a well thought out conceptual model that will be used to tightly define design objectives and criteria. The conceptual model and a set of well-defined objectives and criteria will be critical in ensuring success of the project.

2.1 Documentation Reviewed

The information contained in the EIS represents a comprehensive collection of all information pertinent to the effects of the reclamation project on the environment. A brief summary of pertinent background information is provided below. A detailed data review focused on information that directly pertained to the design of final landforms and cover systems for the three main tailings areas (see **Table 2.1**). The data review that was conducted to support development of remediation plans focused on the following areas:

- Borrow material volumes and locations;
- Physical and hydraulic properties of borrow materials, tailings, and waste rock;
- Geochemical properties of the tailings and waste rock; and
- Surface and groundwater hydrology.

Table 2.1
Summary of documents and data reviewed to support Gunnar tailings remediation plan development.

File Name	Period	Source	Comments
General			
CEAA EA Report	2013	CNSC	
EIS Appendix T:Raw Monitoring Data	1958-2011		Raw data (borrow volumes & properties, (subsurface hydrology, water geochemistry).
EIS Appendix R: 2005 Remedial Options Review	2005	SRC, KHS, WaterMark, CanNorth	Summary of work to date, including BBT,1986.
Borrow Volumes and Material Properties			
Geotechnical Investigation - Gunnar Field Study	2014	SNC Lavalin	Detailed geotechnical assessment of tailings
EIS Appendix Q: 2009 – 2012 Field Surveys	2009-2012	AECOM	Borrow volume estimates lack rationale or methodology.
EIS Appendix H: 2012 Borrow Survey	2012	Golder	High confidence in Golder borrow investigation.

Table 2.1 cont'
Summary of documents and data reviewed to support Gunnar tailings remediation plan development.

File Name	Period	Source	Comments
Miscellaneous			
EIS Appendix I.1: 2009 Field Report: Vegetation and Soils	2009	AECOM	
EIS Appendix I.3: Vegetation and Wildlife Field Report	2012	SRC	
EIS Appendix N: Gunnar Monitoring Data	2011-2012	SRC	Monitoring data only (surface and subsurface hydrology, climate, water geochemistry)
Weather Data 2012-2014 Excel spreadsheet	2012-2014	SRC	
National Uranium Tailings Program Gunnar Field Study	1986	BBT	Document is included in EIS work, targeted physical waste rock properties in particular.
Geochemistry			
EIS Appendix G	2011-2013	Ecometrix	
EIS Site-wide quantitative loadings model of existing conditions	2013	Ecometrix	
Geotechnical Investigation -Gunnar Field Study	2014	SNC Lavalin	Reviewed for geochemical information
Gunnar submerged tailings pore-water extraction dataset	Oct 2014	SRC	Raw data
Waste rock leachability test raw and refined dataset	Fall 2014	SRC	
2014 Hydrological monitoring near the former Gunnar mine	Dec 2014	McElhanney	
"Old and New Piesometer_July_Aug_Oct_2014.xlsx"	2014	SRC	
"2013 GW analysis.xlsx"	2013	SRC	
"2011-2013 Surface Water Monitoring for 2013 report.xlsx"	2011-2013	SRC	
"Surface Water May 2014.xlsx"	2014	SRC	
"Surface Water June 2014.xlsx"	2014	SRC	
"Surface Water August 2014.xlsx"	2014	SRC	

Table 2.1 cont'
Summary of documents and data reviewed to support Gunnar tailings remediation plan development.

File Name	Period	Source	Comments
Surface and Groundwater Hydrology			
EIS Appendix D: Subsurface Hydrogeological Characterization for the Gunnar Site	2012	MDH Engineered Solutions	
EIS Appendix E: Water Quantities	2012	AECOM, McElhanney	Subsurface and surface hydrology
EIS Appendix G.2: Artesian Flow	2012	Ecometrix	
EIS Appendix G.3: Artesian Flow	2011	AECOM	Discussion of artesian conditions at site.
EIS Appendix J.7: Surface Water Quality Objectives	2010	AECOM	
EIS Appendix J.3: Catchment 3 Diversion	2013	SENES Consulting	
EIS Appendix S: Groundwater Flow and Mass Transport Model for the Former Gunnar Mine	2010	AECOM	
2013 Hydrological Monitoring near Former Gunnar Mine	2013	McElhanney	Surface hydrology
Seepage Analysis at Former Gunnar Mine	2013	McElhanney	Subsurface hydrology

2.2 Remediation Design Objectives and Criteria

2.2.1 Design Objectives

The purpose of remediating the Gunnar site is to reduce the risks that the site poses to human health, safety of the public, and integrity of the environment (SRC, 2013). The overall remediation objectives for the site as a whole are to:

- Contain and stabilize unconfined tailings and WRPs to minimize human health risks posed by gamma dose rates;
- Minimize contaminant releases from the tailings and waste rock to Lake Athabasca;
- Permanently dispose of demolition wastes and hazardous materials in a manner that is environmentally sound and meets regulatory requirements;
- Remediate and contour the landscape in a manner that is compatible with the natural surroundings and future use of the site; and
- Take measures to ensure conventional health and safety.

2.2.2 Design Criteria

Remedial action for the Gunnar tailings deposits is driven by human and ecological health risk posed by exposure to gamma radiation (SRC, 2013). As identified in the EIS, the highest priority risk management needs relate to the control of human gamma radiation exposure, and reductions in the contaminant and radionuclide loadings from the tailings deposits to waters frequented by fish. Design criteria proposed for remediation of the Gunnar tailings deposits are summarized in **Table 2.2**.

Table 2.2
Gunnar tailings remediation design criteria.

Parameter	Criteria
External radiation exposure	Reduce gamma dose rate radiation to 1.14 µSv/h (1 µSv/h above the local natural background) for the average of measurements taken over a 1 ha area and 2.64 µSv/h (2.5 µSv/h above the local natural background) as a maximum spot measurement.
Surface water quality	Meet site-specific remedial objectives (SSROs) in St. Mary's Channel and Langley Bay (see Section 2.2.2.1).
Groundwater quality	Groundwater quality to be compared to 2010 interim Tier 2 commercial / industrial guidelines developed on behalf of Environment Canada. Radionuclides to be compared to 2010 Alberta Tier 1 Soil and Groundwater Remediation Guidelines.
Air quality	Keep concentrations of particulate matter (PM) emissions during closure phase to <10 µm below the 24-hour criteria of 50 µg/m^3 and PM ≤2.5 µm below the Canada Wide Standard of 28 µg/m^3.
Land use	Ensure traditional land uses can occur adjacent to the site. Prevent the construction or operation of permanent or temporary residences on remediated mine waste deposits.
Landform	Design landform to be water-shedding and increase the distance between the rooting zone and water table / capillary fringe to prevent COPC efflorescence and limit the effects of solute uptake.
Surface water management	Design surface water management system to handle peak flows from the 1 in 200 year event (see Section 2.3.1).
Vegetation	Establish a self-sustaining community of plant species native to the region.

2.2.2.1 Surface Water Quality Criteria

Surface water quality criteria are based on laboratory toxicity data for aquatic life and led to the development of SSROs (**Table 2.3**). Aquatic life protection levels of 80 or 90% are considered conservative, and will protect a majority of aquatic species at the site.

Table 2.3
Gunnar surface water quality SSROs (from SRC, 2013).

Constituent of Potential Concern	SSRO for St. Mary's Channel /Langley Bay (µg/L)	SSRO for Zeemel Bay (µg/L)
Arsenic	100	390
Cadmium	0.30	0.85

Copper	5	12
Lead	13	35
Uranium	90	200

2.3 Site Climate

Climate is the ultimate driver of reclamation cover system performance. A long-term climate database is indispensable when designing a cover system to meet remediation objectives. Long-term averages of key parameters, such as precipitation, air temperature, and potential evaporation will be fundamental to the design of a cover system for the tailings deposits (**Table 2.4**).

Table 2.4
Average monthly climate normals for the Gunnar site.

Month	Precipitation (mm)	Potential Evaporation (mm)	Air Temperature (°C)
January	22	0	-26
February	15	0	-21
March	20	0	-15
April	19	2	-3
May	22	58	6
June	36	97	13
July	49	103	16
August	52	69	14
September	43	25	7
October	34	3	0
November	33	0	-11
December	24	0	-21
Total	*369*	*357*	-

2.3.1 Intensity-Duration-Frequency Storm Data

Precipitation data are used by Environment Canada to develop intensity-duration-frequency (IDF) tables. Information contained in an IDF table is generated from an extreme value statistical analysis of at least 10 years of rate-of-rainfall observations. IDF data are required for sizing and design of hydraulic structures such as drainage channels and weirs. **Table 2.5** summarizes 24-hour duration design storm values for three different return periods based on IDF data available for three stations nearest the Site.