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
$\mu g/m^3$	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).

<u>Secondary Tailings Deposits:</u>

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.

Table 2.5
24-hour design storm values for three Environment Canada stations nearest the Site.

Station	Elevation (masl)	Distance from Gunnar Site (km)	IDF Climate Record	No. of Years	24-hour Event (mm)		
					1:100 yr	1:200 yr	1:1000 yr
Uranium City, SK	318	25	1965 - 1985	20	55.0	62.0	71.6
Fort Chipewyan, AB	232	150	1969 - 1991	23	80.6	89.5	108.8
Stoney Rapids, SK	245	175	1986 - 2008	22	84.9	94.5	115.3

2.4 Vegetation

The Gunnar site is situated in the Tazin Lake Upland ecoregion, and is characterized by black spruce and jack pine dominated tree species. Soils are dominated by sandy textured soils of the Brunisolic order, as well as poorly developed Regosols on upland locations. Dominant vegetation species are summarized in **Table 2.6**.

Table 2.6
Vegetation species native to Gunnar site and their characteristics.

Common Name	Type	Characteristics
Black spruce	Tree	Found in poorly drained areas; flat root system; dominant upland species;
Jack pine	Tree	Found in well drained sandy soils; tap root system; dominant upland species
Blueberry	Shrub	Understory species; tolerant of low fertility soils
Bearberry	Shrub	Understory species; tolerant of low fertility soils
Reindeer lichen	Lichen	Common ground cover
Labrador tea	Shrub	Understory species; found in low, wet depressions

2.5 Surface Hydrology

Movement of surface water at the site will be a major determinant in the success of a tailings cover system. Properly routing surface water will both minimize contact between fresh water and tailings, as well as maximizing cover system integrity. Understanding surface flows will also ensure that landform contouring takes advantage of natural topography to the fullest extent possible.

Surface water quantities and qualities are very well characterized at the Site. The EIS contains extensive information relating to surface flows and watersheds, hydrographs, gauge station locations, channel cross sections, and seeps among others. Surface water flows and proposed diversions will be of particular use. Site catchments and surface water flows are shown in **Dwg. No. 963/1-002**.

Gunnar site is divided into five catchments: Catchments 1 and 2 convey water north, releasing into Langley Bay, while Catchments 3, 4, and 5 convey water to the south and release into Zeemel Bay and St. Mary's Channel. Calculated annual net water volumes to Langley Bay and St. Mary's Channel were reported to average 527 and 9059 dam^3, respectively (SRC, 2013).

Surface water drainage on the three primary tailings deposits will be configured to direct water northward to Langley Bay in a controlled manner so as to minimize contact between fresh water and tailings, minimize erosion, and avoid re-suspending tailings.

2.6 Hydrogeology

Subsurface and groundwater hydrology is comprehensively measured at the Site and is summarized in the EIS. Appendix D, Subsurface Hydrogeological Characterization, provides a useful and comprehensive summary of the hydrogeology of the Site. A total of 84 standpipe piezometers have been installed at Gunnar Pit, the Mill Site, Acid Plant, Gunnar West, Tailings and Waste Rock Areas, as well as in overburden in Catchment 3. Groundwater flow generally mirrors topography and flows from GMT north towards GCT, east into Catchment 3, and south towards Lake Athabasca.

A comprehensive three-dimensional groundwater model was developed by AECOM to estimate mass loadings at Site. From a groundwater perspective, the results of the model are consistent with other results reported at site that groundwater flow closely mirrors surficial topography. The EIS appendix covering the groundwater model has good documentation of material properties, model mesh, cross sections, assumptions made, and results reporting.

2.7 Geochemistry

Proposed remedial measures, by definition, should result in lower or similar risks to human and ecological receptors. Based on experiences at other northern Saskatchewan uranium mine sites, risks are typically proportional to the rates of transfer or COPC loadings rates from sources to receiving waters, at specific locations. All geochemical related risks identified in the 2013 EIS were related to aquatic pathways; therefore, only water-based sources and hydrologic pathways were considered in the loadings model.

In order to evaluate the ability of proposed remedial options to lower the risks to human and ecological receptors, a thorough understanding of the geochemical behaviour of the tailings deposits is required. A substantial amount of work was completed as part of the EIS to develop a conceptual COPC loadings model for geochemistry of the Gunnar tailings. The model was based on new and historical assessments of the tailings pore-water and solids as well as chemistry of downstream aquatic receiving environments, such as Langley Bay. The tailings conceptual loadings model completed for the EIS showed that there are substantial soluble masses of COPCs in pore-waters associated with tailings exposed to the surface. These soluble COPCs are being mobilized as a result of shallow flushing (i.e. runoff) generated by seasonal rainfall events (EcoMetrix, 2013a; 2013b). This tailings conceptual loadings model, which is supported by direct measurements at the Site, can then be used to evaluate the potential effects of different remedial options on overall loadings of COPCs to Langley Bay and other key receptors.

2.7.1 Tailings

The tailings geochemistry conceptual model, outlined in the EIS, focused on the interaction between rainfall and, to a lesser extent, snowmelt with shallow tailings pore-waters. Shake flask extraction (SFE) test results for GMT solids formed the basis for estimating loading rates from tailings to contact water for each tailings area. Loading rates estimated for tailings were assumed to represent flushing of all soluble products from the tailings. It was hypothesized that runoff generated from rainfall events interacts with the upper 10 cm of the tailings profile resulting in flushing of COPCs. This e depth was estimated by back-calculating the required tailings thickness to generate current COPC concentrations in Langley Bay using shallow tailings pore-water concentrations measured from field samples. The tailings have been in-place for approximately 50 years; therefore, production pore-water has been flushed and weathering processes have occurred. It is assumed that the shallow pore-water in the tailings is at steady-state and that flushing from the top portion of the tailings (runoff) results in removal of the resident soluble load annually.

A substantially smaller portion of the COPCs are mobilized to the groundwater system and eventually discharged to surface water by infiltrating rainwater and snowmelt migrating into the deeper tailings. Groundwater source terms used for the loadings model completed for the EIS for Gunnar Main, Central and Langley Bay exposed tailings deposits were developed from groundwater flow rates (m^3/a)

estimated from the tailings to various receptors and the measured concentrations from the wells completed within the tailings. The flow rates were determined from a numerical model of groundwater flow previously developed for the Gunnar site (AECOM, 2011) and tailings pore-water concentrations from water samples from piezometers within each tailings body. Three different groundwater flow paths were hypothesized to originate from GMT with only one eventually reporting to Langley Bay, representing approximately 17 % of groundwater flow from GMT. The remaining flow paths report to Catchment 3 and to St. Mary's Channel. Individual groundwater flow paths were hypothesized for the Gunnar Central and Langley Bay tailings areas which eventually report to Langley Bay.

The total amount of radium-226 measured in the Langley Bay water column was substantially greater than total estimated loadings possible runoff and groundwater flow, which suggests another mechanism was present. It was hypothesized by EcoMetrix (2013b) that radium-226 and uranium were also being mobilized through the upward flux from the submerged tailings present in the Back Bay and Langley Bay basins into the overlying water columns. Therefore, source terms were developed to represent this source of COPCs to Langley Bay based on historic observations and datasets. However, the source of additional radium-226 measured in Langley Bay must be confirmed through additional investigation to rule out deeper pore-water (i.e. groundwater discharge) as a potential source.

2.7.2 Waste Rock

Estimated COPC loadings from waste rock are a function of soluble concentrations in the WRP pore-water and the amount of net percolation that flushes pore-water through the WRP. Most COPC concentrations in pore-water are kinetically controlled by the oxidation or leaching rates of their host solid phases. However, shake flask test results conducted for the EIS indicate that uranium concentrations in waste rock pore-waters are likely solubility controlled; therefore, this mechanism was built into the loadings model. Additionally, loadings from waste rock were demonstrated to be dependent on the waste rock grain size. Results of particle size controlled shake flask tests indicate that ratios of soluble masses between finer textured (less than 5 cm) and coarser textured (greater than 5 cm) waste rock were COPC specific. Overall, the finer fraction contained larger soluble masses for all COPCs but these ratios were typically less than a factor of 5. Therefore, particle-size based adjustment factors were experimentally determined for each COPC.

Median waste rock pore-water concentrations and loading rates for each COPC are summarized in **Table 2.7**. The pore-water concentrations were calculated for finer textured samples collected from both the south and east WRPs for the 2013 EIS. These concentrations will be used in conjunction with the grain-size adjustment factors also summarized in **Table 2.7**. Together, the values outlined in **Table 2.7** were used to estimate waste rock loadings from the tailings remediation options that include use of waste rock as fill material or at the base of proposed cover systems.

Table 2.7
Waste rock geochemical pore-water concentrations and loadings rates (from SRC, 2013).

Constituent	Correction Factors	Pore-Water Concentrations[1] (mg/L)	Waste Rock Loading Rate (mg/kg/a)
Sulphate (SO_4)	3.6	1,924	18.5
Arsenic (As)	5.8	1.22	0.012
Cadmium (Cd)	1.9	0.02	0.0002
Lead (Pb)	5.5	1.91	0.018
Uranium (U)	1.0	8.95	0.086
Radium 226 (Ra-226)	2.3	134 (Bq/L)	1.29

2.7.3 COPC Loadings to Aquatic Receiving Environment from 2013 EIS

In the 2013 EIS, COPC loadings to Langley Bay, Catchment 3 and St. Mary's Channel from the GMT were estimated from physical and hydrogeological parameters of the Gunnar Main, Central and Langley Bay tailings areas and groundwater flow rates. These loadings include contributions from shallow pore water flushing (runoff) and groundwater that has infiltrated through the tailings. The total loadings to Langley Bay, Catchment 3 and St. Mary's Channel are summarized in **Table 2.8**. It is assumed that loadings from the tailings shallow pore water flushing (runoff) report only to Langley Bay. Therefore, only groundwater discharge from the GMT accounts for the loadings calculated for Catchment 3 and St. Mary's Channel.

Table 2.8
Tailings geochemical loadings to Langley Bay, Catchment 3 and St. Mary's Channel (from SRC, 2013).

Source Area	Sulphate kg/a	Arsenic kg/a	Cadmium kg/a	Lead kg/a	Uranium kg/a	Radium-226 MBq/a
Langley Bay	375,844	4.28	0.19	1.01	94.4	10,679
Catchment 3	5,349	0.10	0.06	0.31	1.14	4.95
St. Mary's Channel	56,243	1.02	0.67	3.26	12.0	52.0

COPC loadings to Langley Bay also include the contribution from submerged tailings in Langley Bay. However, it should be noted that Beaver Pond was not included. Uranium and radium-226 loadings from the submerged Langley Bay tailings were the only COPCs considered in this assessment as they were the only COPCs considered in a report by BBT (1986) that investigated the flux of pore-waters from the submerged tailings into the Langley Bay water column. In addition, EcoMetrix (2013b) indicate that a substantial amount of COPC loadings measured in Langley Bay can be attributed to background concentrations, mainly from the large exchange flow with Lake Athabasca.

2.8 Gamma Radiation Sources

A remediation performance criterion for gamma radiation was established as part of the EIS. The criterion specified that areas of the Site with average gamma dose rates greater than 1 μSv/h above background (averaged over a 1 ha surface area), or with a maximum spot dose in excess of 2.5 μSv/h above background, must be remediated.

2.8.1 Tailings

A gamma survey of all three tailings areas was conducted by SRC in 2004 (SRC, 2005). The average gamma level, measured at 1 m above the ground, for all tailings areas was approximately 4 μSv/h with a maximum value of 9.86 μSv/h. The average levels measured for the GMT, Central Tailings, and Langley Bay Tailings were 4.21, 3.90, and 4.30 μSv/h, respectively (SRC, 2005).

Through the decision tree analysis process, it was identified that remedial action for the exposed tailings is primarily driven by human and ecological health risks posed by exposure to gamma radiation. A gamma shield must be constructed on the surface of exposed tailings; it was assumed in the EIS that the shield would be a 0.5 m to 1.0 m thick layer of local borrow materials.

2.8.2 Waste Rock

A gamma survey of the East and South WRPs were undertaken as part of the assessment program for the 2013 EIS. Gamma dose rates ranged from 0.3 to 6.0 μSv/h with an average value of 1.2 μSv/h. Gamma dose rates were variable with depth in the waste rock with no obvious spatial trends.

A gamma survey was also conducted by SRC in 2004 of the WRPs (SRC, 2005). The piles were surveyed on a 2 m grid, consisting of 3,000 separate measurements. The average gamma level, measured 1 m above the ground, was 0.95 μSv/h for the South WRP and 1.07 μSv/h for the East WRP. The maximum value measured on either WRP was 4.88 μSv/h. Areas that measured above 2.5 μSv/h were almost all associated with materials that had been hauled to the WRPs and were not actually waste rock material.

2.9 Geotechnical Characteristics

Geotechnical characteristics of both the tailings and cover system borrow materials exert a key physical control on the performance of the cover system. Physical characteristics will influence the construction of the cover system, fate and transport of COPCs, and the amount of water and nutrients stored for vegetation, among myriad other processes. A proper understanding of material physical properties will be essential in ensuring project success.

Tailings at the site contain varying amounts of silt and sand size particles, with less than 10% of the particle size distribution (PSD) consisting of clays. GMT are composed primarily of sand sized particles, while Gunnar Central and Langley Bay tailings are dominated by silt-sized fractions. All three tailings areas demonstrated a reduction in the percent sand fraction with depth.

Sand and gravel deposits make up greater than 85% of the surficial material at the site (SRC, 2013). However, finer textured materials do exist at the site. Local borrow materials were most extensively characterized in Investigation Areas 6 and 13 (Borrow Area Drawing) and are generally grouped into silts and clays, sands and silts, and sands and gravels. Material textures in Investigation Area 6 trend from finer materials in the southwestern corner to coarser textured materials in the northeastern corner. A higher percentage of finer-textured materials are found in Investigation Area 13.

Waste rock is abundant at the site, and can potentially be used as a material for cover system construction. Previous investigations of waste rock reported that the material is generally well-graded from a medium sand to boulder sized.

A general summary of key geotechnical characteristics of important materials on site is given in **Table 2.9**.

Table 2.9
Tailings and borrow material key geotechnical characteristics.

Material	Porosity	Saturated Hydraulic Conductivity (cm/s)	Air Entry Value (kPa)
Finer-textured Tailings	45%	1×10^{-5}	8 – 10 kPa
Coarser-textured Tailings	35%	1×10^{-3}	3 – 5 kPa
Till Borrow Cover Material	30%	2×10^{-4}	1 – 2 kPa
Waste Rock	28%	1×10^{-1}	0.1 kPa

2.10 Cover Material Borrow Sources and Volumes

2.10.1 Borrow Sources

Physical properties of the borrow materials will be the primary determinant of final cover system performance. Physical and hydraulic properties are key inputs for numerical modelling of preferred cover system options. Furthermore, the properties and quantities of available borrow material will determine the extent to which alternatives to a 1 m monolithic cover system can be employed at the Site.

Primary sources for the data review of borrow material properties were the AECOM and Golder Associates (Golder) field investigations from 2009 – 2011 (**Dwg. No. 963/1-003**). Investigations conducted by AECOM produced a limited amount of laboratory testing results. Golder conducted a more thorough investigation of Areas 6 and 13 in 2011. A total of 28 test pits were dug in Area 6 using the pre-defined limits from the AECOM report. Laboratory analysis included 28 PSDs, nine Atterberg limits, and three composite Proctor analyses. The most common materials found were silt and clay, sand and silt, and sand and gravel, with the finer material generally being located in the southwest corner. Coarser materials were generally found in the northeastern corner of the area. An area of potential concern was the preponderance of seepage and sloughing found in the coarser material areas. Seepage and sloughing depths ranged from 2 to 6 m.

Twelve test pits were excavated in Area 13 using the pre-defined limits from the AECOM report. Laboratory analysis included seven PSDs, six Atterberg limits, and one Proctor analysis. Textures in Area 13 consisted primarily of silts and clays with a small area of sand and gravel. Results of the laboratory analyses from both Areas 6 and 13 will be digitized and reviewed. Upon first inspection these data appear to be complete and of good quality.

Waste rock was investigated as a potential cover system borrow source as part of the Gunnar Site Characterization (SRC, 2013; Appendix R). Waste rock was found to be generally well graded from a medium sand to boulder size. A blended gradation from nine sieve analyses reported a gradation of 8% cobble, 86% gravel, and 6% sand, silt, clay (BBT, 1986). It was reported that most of the waste rock was suitably graded for easy handling by loaders and shaping with dozers with no special preparation by crushing or screening being anticipated. A limited amount of physical property information for the waste rock exists.

2.10.2 Borrow Volumes

A key constraint in the design and construction of tailings area cover systems will be the quantity and quality of borrow materials. Previous field investigations were conducted in 2009 and 2010 (AECOM) as well as in 2011 (Golder, 2013). The primary source of uncertainty with borrow materials is an accurate estimation of volumes and a conflict in the reporting of available borrow volumes. Total borrow volume requirements for a 1 m tailings cover system has been reported as either 820,000 m^3 (CNSC, 2014) or 764,000 (SRC, 2013; CNSC, 2014). Borrow volumes required for construction of roads, riprap armouring, and channel lining has been reported as 1 M m^3 (SRC, 2013) and (CNSC, 2014). Therefore, final borrow requirements range from 2.0 M m^3 if the WRP is to be remediated in situ (1.76 Mm^3 + 0.27 Mm^3 = 2.03 Mm^3) to 3.7 Mm^3, if the open pit is to be backfilled with waste rock and covered (1.76 Mm^3 + 1.90 Mm^3 = 3.66 Mm^3).

Estimates of confirmed borrow volumes range from 3.3 to 3.5 Mm^3 (CNSC, 2014). However, confusion arises due to conflicting values, often in the same report. The 2009 and 2010 field investigations conducted by AECOM estimated total borrow volumes to be 7.3 Mm^3, primarily sourced from Investigation Areas 6 and 13, but also including Areas 1 and 11. Estimation methods used by AECOM were not reported. The subsequent 2011 investigation by Golder focused on Areas 6 and 13 resulting in revised borrow volume estimates reduced to 3.3 Mm^3. Methods used to estimate volumes were explicitly stated in the Golder report.

An estimate of 3.3 Mm^3 of confirmed borrow volumes would seem to indicate that close to all volume requirements could be satisfied with only two borrow areas. However, although the estimation methods were sound, it is not likely that all of the identified volumes would be accessible. For instance, the volumes reported for Investigation Areas 6 and 13 included materials that were both saturated and unsaturated. Large volumes of organic material were also included. The total unsaturated volumes that do not include organic material from Areas 6 and 13 total 1.76 Mm^3. Furthermore, a large portion of Area 6 includes the existing airstrip, which may be partially preserved for future use.

2.11 Data Gaps or Uncertainties

Based on the review completed for this project, **Table 2.10** summarizes the data gaps or uncertainties pertaining to development of a remediation plan for the Gunnar tailings deposits.

Table 2.10
Data gaps / uncertainties in support of developing a remediation plan for Gunnar tailings deposits.

Data Theme	Data Gap / Uncertainty

Borrow Volumes	• Surface data and locations from Golder 2011 borrow investigation;
	• Accessible fraction of identified borrow sources in Areas 6 and 13;
	  ○ What are the current water table elevations and how much of the borrow material can reasonably be excavated without supplemental de-watering?
	• Extent of buffer areas around the airstrip; and
	  ○ If the airstrip is to be preserved, how much of the surrounding borrow areas will be excluded?
	• Volume available from Areas 1, 3, 11, and 14.
	  ○ Areas that may be targeted in field campaign
	  ○ Are the areas accessible?
	  ○ Does SRC have any supplemental information?

Borrow Material Properties	• Physical properties of materials in Areas 1, 3, 11, and 14;
	  ○ Will be addressed during field campaign
	• Further details on the physical properties of waste rock; and,
	  ○ Will be addressed during field campaign
	• Hydraulic properties have not been extensively characterized.
	  ○ Narrow range in properties would not require many samples to adequately characterize.

Geochemistry	• Mass loading from groundwater to Langley Bay from tailings deposits:
	  ○ Attenuation processes along flowpath not well understood
	  ○ Contribution of groundwater from Gunnar Main to Langley Bay must be constrained.

2.12 Recommended Actions to Reduce Uncertainties

Data gaps and uncertainties that became clear during the data review process generally pertain to physical properties and volumes of potential borrow materials. Uncertainties related to borrow material volumes were used to guide the June 2015 field investigation program. Any remaining gaps in material property data will be targeted with a laboratory investigation.

Uncertainties regarding mass loadings from groundwater to Langley Bay will also be addressed during the final detailed design information and construction plan phase. These generally relate amounts of groundwater flow from GMT deposit to Langley Bay as well as COPC attenuation along the flowpath.

3 CONCEPTUAL MODEL REVIEW AND REFINEMENT

Conceptual models of the geochemical behaviour of the Gunnar tailings and performance of a 0.5 to 1.0 m thick layer of local till over exposed tailings, referred to as the base case remediation cover system, were presented in SRC (2013). These models were reviewed and refined where necessary for this project to form the basis for development of remediation designs for the Gunnar tailings deposits, to mitigate ecological and human health risks to acceptable levels post-reclamation.

3.1 Geochemical Behaviour of Tailings

Under current conditions, COPC loadings to Langley Bay from Gunnar Main, Gunnar Central, and Langley Bay exposed tailings deposits are largely controlled by flushing of shallow tailings pore-waters during rainfall events (i.e. runoff). Flushing to groundwater of deeper pore-waters in the Gunnar Main, Gunnar Central, and Langley Bay tailings deposits also represents a minor source of loadings to Langley Bay. The conceptual model for the loadings mechanisms was developed in the 2013 EIS (EcoMetrix, 2013b) and is briefly summarized in Section 2.7.1 of this report.

Average yearly loadings to Langley Bay, Catchment 3, and St. Mary's Channel from the tailings deposits under current conditions were recalculated, incorporating revised surface area estimates provided for this study, as they differed slightly from those presented in **Table 2.7** (and the 2013 EIS). In addition, the GMT groundwater flow rates and loadings calculations were revised to reflect the estimated infiltration rates for bare tailings presented in this report. The revised current condition COPC loadings estimates are summarized in **Table 3.1**. Average aqueous concentrations measured in Langley Bay for the current conditions are presented in **Table 3.2**.

3.2 Base Case Cover System Performance

A conceptual model of cover system performance has been developed as it relates to four critical aspects of performance; namely, radiation exposure protection, water balance fluxes, propensity for solute uptake, and anticipated reduction in COPC loadings to the aquatic receiving environment. The conceptual model is based on the 'base case' cover system outlined in SRC (2013) (i.e. 0.5 to 1.0 m till cover system).

3.2.1 Radiation Exposure Protection

Three potential pathways exist for human radiation exposure at the Gunnar tailings deposits. The first is inhalation of radon daughters; Radon-222 produced from Radium-226 present in the tailings emanates from the surface of exposed tailings. The extent of emanation is dependent on the concentration of Radium-226 in the tailings and *in situ* water content. The second pathway is inhalation of long-lived radioactive dust (LLRD). The third and final pathway for occupational radiation exposure at the Site is external irradiation by gamma rays.

Table 3.1
COPC loadings to the Langley Bay, Catchment 3 and St. Mary's Channel aquatic receiving environments for current conditions.

Source Area	Sulphate kg/a	Arsenic kg/a	Cadmium kg/a	Lead kg/a	Uranium kg/a	Radium-226 MBq/a
Langley Bay	537,278	9.93	1.29	6.52	117	13,178
Catchment 3	45,944	0.83	0.54	2.67	9.78	42.5
St. Mary's Channel	6,892	0.13	0.08	0.40	1.47	6.38

Table 3.2
Predicted aqueous concentrations of COPCs in Langley Bay for current conditions (SRC, 2013).

Constituent	SSRO (mg/L)	Langley Bay Current Conditions
Sulphate (SO_4)	-	7.13 mg/L
Arsenic (As)	0.1	0.00024 mg/L
Cadmium (Cd)	0.0003	0.0001 mg/L
Lead (Pb)	0.013	0.0028 mg/L
Uranium (U)	0.09	0.0012 mg/L
Radium-226 (Ra-226)	-	0.11 Bq/L

Gamma shielding, or attenuation, occurs when gamma radiation interacts with matter resulting in adsorption and scattering of the radiation. Gamma shield efficiency is dependent on material thickness, density, and the amount of pore-space as well as the energy of the gamma radiation (McAlister, 2013). The common benchmark for the propensity of a material to attenuate gamma radiation is the half-value layer, where the energy or radiation is attenuated by half or a 2-fold reduction (European Nuclear Society, 2003). The Cluff Lake Project Comprehensive Study Report, authored by COGEMA Resources Inc. (COGEMA) in 2001 (CNSC, 2003), stated that every 100 mm of till cover material placed on the tailings surface would result in a two-fold reduction in gamma emissions. The 2013 EIS report proposed a 1.14 μSv/h target for the average of measurements taken over a 1 ha area and 2.64 μSv/h as a maximum spot measurement. SRC (2013) provided measurements of gamma radiation measured on the GMT deposit. The mean gamma radiation was 4.1 μSv/h with a maximum spot measurement of 12 μSv/h. Based on the stated gamma exposure reduction rate with cover thickness, 0.3 m of cover material will be sufficient to bring the average gamma radiation below the 1.14 μSv/h target and the maximum value below the 2.64 μSv/h target. The presence of a minimum 0.5 m thick till cover system over the tailings surface is expected to provide adequate protection from gamma rays as well as radon gas and LLRD emissions.

Based on site-specific monitoring completed from 2004 to 2010, radon concentrations at all tailings monitoring locations at site were substantially below the Health Canada indoor air quality criteria of 200

Bq/m^3 (SRC, 2013). The mean radon concentrations for the tailings was 114 Bq/m^3. Cover system placement will further reduce these concentrations by greater than factor of 2 based on a 0.5m thick cover system (COGEMA, 2001). The cover system will eliminate LLRD emissions by providing a permanent barrier to windblown erosion of the tailings surface.

3.2.2 Surface Water Balance Fluxes

Surface water balance fluxes will be driven by the interaction of climatic forcing, most notably precipitation and potential evaporation, with the constructed cover system and supported vegetation. The average annual precipitation at the Gunnar site is ~370 mm with a similar value of potential evaporation (~360 mm). It is expected that net infiltration into the cover system (and ultimately net percolation from the base of the cover system) will be greatest during the spring snowmelt period as well as autumnal rainfall events. Air temperatures and evaporative conditions are low during these periods and, coupled with mostly dormant vegetation, lead to infiltration into the cover system and percolation into the waste material below. The potential for net percolation is lessened during the summer period when increased evaporative demand from long, sunshine days and active vegetation increase evapotranspiration, producing more storage capacity within the cover system to accommodate summer rainfall events. Several factors including the texture of the tailings mass, the location of the local water table, and the thickness and texture of the cover system materials influence performance of the cover system. **Table 3.3** summarizes the anticipated water balance fluxes for the 0.5 to 1.0 m base case cover system design.

Table 3.3
Mean annual water balance fluxes conceptualized for the tailings cover system base case design.

Water Balance Parameter	0.5 m to 1.0 m Till Cover
Precipitation	370 mm
Potential Evaporation	360 mm
Actual Evapotranspiration	200 mm
Runoff	45 mm
Sublimation	25 mm
Net Percolation	100 mm

3.2.3 Phreatic Surface and Groundwater Flow Estimates for Gunnar Main

Landform water balance fluxes will be affected by surface water balance fluxes, local groundwater conditions and local lithology. The Gunnar Main landform was evaluated to estimate seepage volumes and flow directions both in the current condition and following placement of the cover systems discussed in **Table 3.3**. The phreatic surface within Gunnar Main (**Figure 3.1**) was estimated based on cone penetration testing (SNC-Lavalin, 2014) and piezometer readings (MDH, 2012) completed in 2012.

Three separate groundwater areas are delineated based on the groundwater contours. Seepage from the north-west area is expected to flow west and north, eventually reporting to Langley Bay. Seepage from the north-east and south areas are expected to flow through zones of high permeability found within the bedrock and report to the open pit and St. Mary's Channel respectively. Seepage from Gunnar Main under current conditions is estimated to be approximately 78 m^3/day towards Langley Bay, 19 m^3/day towards the Gunnar open pit, and 12 m^3/day towards St. Mary's Channel. Partitioning of seepage and seepage volumes are also estimated for the post-closure condition. The effect of anticipated closure measures, including cover system placement and draining of Beaver Pond, on the groundwater divides was estimated using a simplified Dupuit two dimensional analysis. Refer to **Appendix C** for further details.

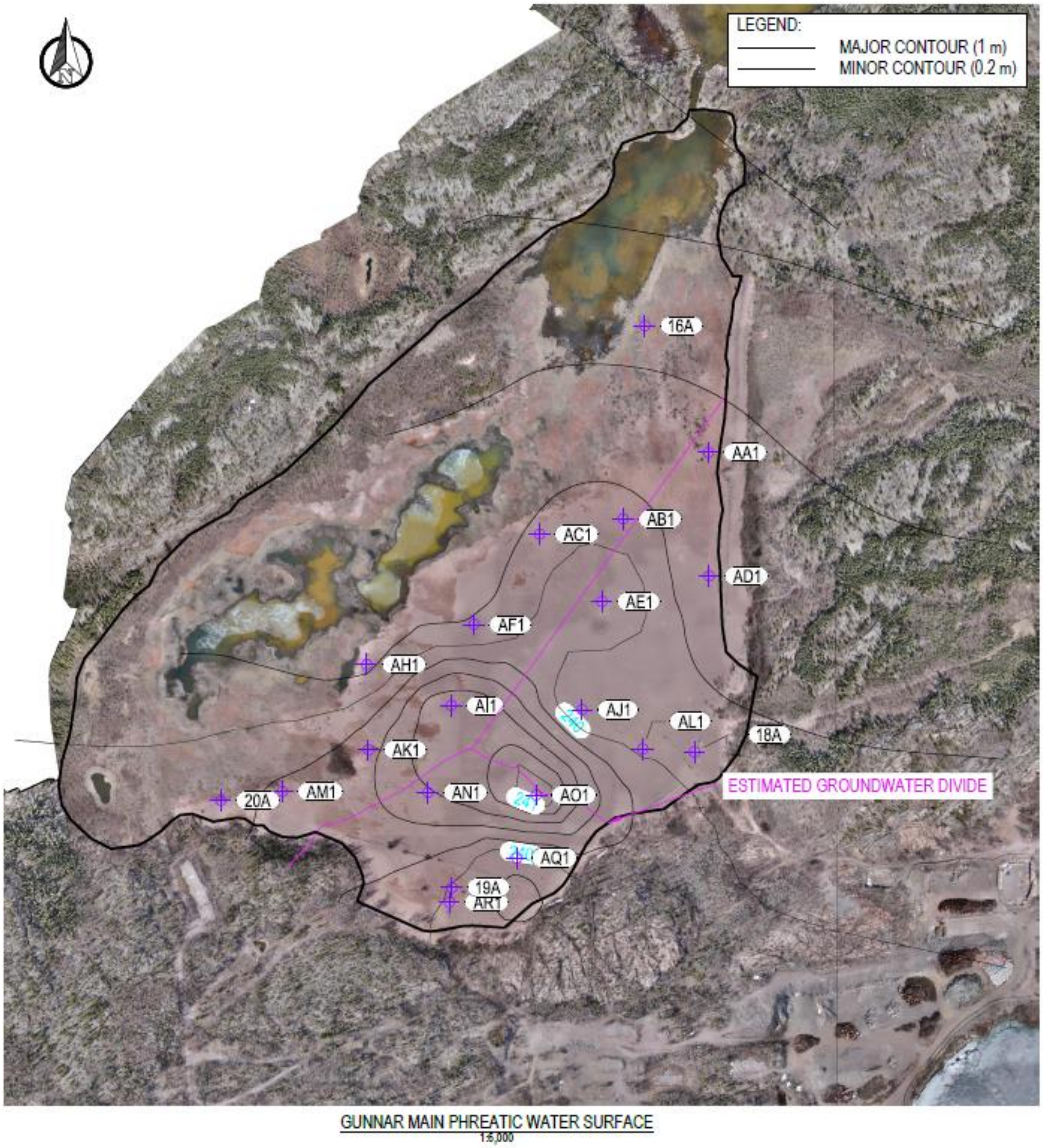


Figure 3-1 Estimated 2012 phreatic surface contours within GMT.

3.2.4 Capillary Rise of Solutes and COPCs

Upward migration of solutes can occur by diffusion when the tailings and cover material at the interface are near saturation, and by advective transport when evapotranspiration conditions produce an upward movement of water. The upward migration of salts into a reclamation cover profile can hinder the development of the desired vegetation community, while the potential uptake of metals and/or radionuclides by various vegetation species may lead to detrimental effects on fauna that eat the vegetation. In a worst case scenario, tailings solutes may reach the cover surface, potentially resulting in contamination of incident meteoric waters that would have otherwise remained free of contamination.

The extent of potential contamination of a till cover placed on the Gunnar tailings by both diffusion and advection will depend on the concentration of solutes in the upper tailings profile at the time of cover system construction. The Gunnar tailings areas have been inactive for >50 years and thus have had numerous oxidation and flushing events. Therefore, it is surmised that the concentration of leachable COPCs in the upper tailings profile at the time of cover construction is substantially lower than in the deeper layers.

The propensity for upward movement of water or 'wicking' to occur is a function of the capillarity of materials and depth to the water table. Finer-textured materials with increased capillarity will maintain an unsaturated area above the water table where water and potential contaminants can interact with cover system materials. If the water table is close to the cover system / tailings interface, water and potential contaminants will migrate upward. Capillarity is reduced in coarser-textured materials; therefore, the probability of a hydraulic and contaminant 'connection' between the tailings mass and cover system is decreased. The upward migration of contaminants can be reversed by downward movement of net percolation.

Capillary rise in potential borrow materials as well as tailings was evaluated using both analytical and numerical methods. Capillary rise can be analytically examined as it is a function of the effective pore diameter of a given material. Using an analytical method provides a conservative maximum height of upwards movement of COPCs as climatic conditions, such as seasonal evaporative conditions and flushing due to infiltration of rain or snow melt, are not considered. Given PSD curves for both tailings and potential cover system materials, the theoretical capillary rise of each material was computed based on equations [3-1] and [3-2] (Hotlz and Kovacs, 1981):

$$h_c = \frac{-4T}{\rho_w g d} \qquad [3\text{-}1]$$

where:

h_c = capillary rise (m),

T = surface tension (73 mN/m),

ρ_w = density of water (1,000 kg/m^3),

g = gravity (9.81 m/s^2),

d = effective pore diameter (equivalent to 20% of d_{10} in mm),

and

$$u_c = h_c \rho_w g \quad [3\text{-}2]$$

where:

u_c = capillary pressure (Pa).

Estimation of capillary rise in tailings and potential cover system materials was also completed using a numerical model (VADOSE/W) under site-specific climatic conditions. This numerical model takes into account the effect of seasonal flushing of solutes downwards from meteoric infiltration and provides a more reasonable estimate of the maximum upwards movement of COPCs possible. **Table 3.4** summarizes the results of analytical and numerical modelling. The analytical model estimates maximum capillary rise based on material properties alone while the numerical model estimates theoretical maximum capillary rise under constant average evaporative conditions. Both models and are highly conservative when considering the possible accumulation of solutes and COPCs at surface from capillary rise. However, based on these preliminary results, finer textured material should not be used as a fill or cover system material near the shallow water table.

Table 3.4
Summary of theoretical maximum capillary rise for tailings and cover system materials at Gunnar.

Material	**Effective Grain Size, d_{10} (mm)**	**Analytical Theoretical Capillary Rise, h_c (m)**	**Numerical Theoretical Capillary Rise (m)**
Finer Textured Material – Silty Clay	0.006	25	8
Finer-Textured Tailings	0.024	6	4.5
Tailings	0.064	2.3	2.4
Medium Textured Material – Fine to medium Sand	0.080	1.9	2.3
Coarser Textured Material – Sand and Gravel	0.200	0.7	1.0
Waste Rock	0.950	0.2	0.2

A properly designed cover system will maintain the summer season drying front within its profile, limiting the upward movement of water and potential contaminants. It is expected that a minimum of 0.5 m of cover material will be required on areas of coarser-textured tailings with a deeper water table whereas a minimum of 1.0 m cover material will be required on finer-textured tailings areas with a near surface water table. Potentially, some wicking from the underlying tailings will occur but will remain within the bottom of the cover system layer below the bulk of the vegetation rooting mass. It is expected that flushing from net infiltration events will seasonally push accumulated contaminants downward and prevent the buildup of contaminants at the base of the cover system. Upward movement of COPCs from the tailings into the cover system will be further assessed using contaminant transport modelling coupled with soil-plant-atmosphere modelling during the final detailed design phase. Based on this assessment, refinements to cover system thicknesses may result.

Tailings pore water quality was measured for each primary tailings deposit in 2013 (SRC, 2013) and compared to Agriculture and Agrifood Canada Guidelines for irrigation water quality (Ag Canada, 2000). Average concentrations of plant affecting ions such as TDS, chloride and sodium in Gunnar Main, Gunnar Central and Langley Bay tailings deposits ranged from no required irrigation restriction to moderate restrictions. None of the solutes were within the severe category. Calcium and sulphate within the pore water may result in precipitation of gypsum, which often used to ameliorate saline and sodic soil conditions. Tailings pore water quality will form the basis of the solute transport modelling that will be completed to determine if tailings salts will accumulated in the cover system profile or if flushing during spring freshet will result in negligible salt accumulation.

3.2.5 Anticipated Reduction in COPC Concentrations in the Receiving Environment

Placement of the base case cover system over each of the exposed tailings deposits is expected to remove the shallow pore-water flushing (i.e. runoff) mechanism, which would result in substantial COPC loadings (and corresponding concentrations) reduction to Langley Bay. The potential for an increase in loadings to Langley Bay through groundwater flow is unlikely; however, more robust evaluation of loadings through this mechanism is required. Loadings from shallow pore-water flushing (runoff) greatly exceed those from groundwater; therefore, a cover system is expected to substantially reduce the total COPC loadings from the tailings deposits to Langley Bay thereby reducing COPC concentrations in the bay.

Incorporating these assumptions into the existing conceptual model for movement of COPCs from the tailings deposits, the reduction in loadings from tailings can be estimated for the Gunnar Main, Gunnar Central, and Langley Bay tailings that eventually discharge to Langley Bay. The estimated changes in COPC concentrations in Langley Bay, compared to current conditions, are summarized in **Table 3.5**. Estimated COPC concentration reductions are mainly attributed to the removal of shallow pore-water flushing mechanism (runoff), with contributions from groundwater flow and submerged Langley Bay tailings accounting for the remaining loadings.

Currently, arsenic, cadmium and lead loadings reporting to Langley Bay are associated with measured background concentrations within the water column. Additionally, radium-226 is predominantly mobilized to Langley Bay through the upward flux from the submerged tailings. Therefore, under the Base Case scenario, where the reduction in loadings is from removal of shallow flushing of tailings pore-waters (runoff), the amount of these COPCs in Langley Bay will remain relatively unchanged.

Table 3.5
Predicted COPC aqueous concentrations in Langley Bay for base case cover system.

Constituent	SSRO	Langley Bay Current Conditions	Base Case Cover System
Sulphate (SO4) – mg/L	-	713	3.5
Arsenic (As) – mg/L	1.0	0.00024	0.00021
Cadmium (Cd) – mg/L	0.0003	0.0001	0.0001
Lead (Pb) – mg/L	0.013	0.0028	0.0028
Uranium (U) – mg/L	0.09	0.0012	0.003
Radium-226 (Ra-226) – Bq/L	-	0.11	0.11

4 TAILINGS REMEDIATION OPTIONS ANALYSIS

Several options were considered for remediation of the primary or major tailings deposits as well as the various secondary or minor tailings deposits at Gunnar. The primary tailings deposits include Gunnar Main, Gunnar Central, and Langley Bay. The secondary tailings deposits include the Gunnar Main back release, commonly referenced as the "Catchment 3 tailings", and the area immediately downstream of Gunnar Main surface release known as "Beaver Pond". All of the remediation options considered in this study were previously identified in the 2013 EIS. Remediation of the tailings deposits includes both design of a final landform and cover system, with a key consideration being covering the tailings in-place or relocation to another disposal area prior to covering. The preferred remediation option for each tailings deposit was selected based on the results of a COPC loadings assessment, preliminary remediation cost analysis, and a MAA. The results of these analyses are presented below, with the preferred remediation option described in Section 5.

4.1 Landform Design Options

4.1.1 Gunnar Main Tailings Deposit

Studies completed for the 2013 EIS determined the preferred remedial approach for Gunnar Main is to remediate the tailings in-place; hence, no consideration was given to relocating the tailings to another location for final disposal. The primary consideration for remediation of Gunnar Main was possible options for release of surface waters from the reclaimed catchment. Currently, Gunnar Main surface waters release to Beaver Pond and ultimately to Gunnar Central and Langley Bay. However, given the size of the Gunnar Main catchment, a smaller and thus more cost-effective drainage channel could be constructed between Beaver Pond and Langley Bay if Gunnar Main surface waters were routed in a different direction. The various landform design options for Gunnar Main are shown in **Dwg. Nos. 963/1-004 to -008**, inclusive. **Table 4.1** outlines the advantages and disadvantages of the various final landform design options for Gunnar Main.

Irrespective of the surface water discharge point, it is recommended that the following remediation activities occur at Gunnar Main:

- Backfill the remnant aquatic portion of Mudford Lake using tailings and either waste rock or till materials;
- Pump displaced water to the open pit and/or treat the water before release to St. Mary's Channel;
- Create a water-shedding landform using tailings or waste rock;
- Place a minimum 0.6 m thick layer of local till material over tailings or waste rock backfill;
- Construct armoured drainage channels to handle peak flows from the design storm event; and,
- Revegetate the cover system surface with native plant species.

Table 4.1
Remediation options considered for GMT deposit.

Option	Remedial Description	Advantages	Disadvantages	Uncertainties / Potential Risks	MMA Score
1)	**Single Outlet to Beaver Pond**	• Follows current route for surface drainage • Additional volume of cleaner water entering Langley Bay for dilution purposes	• Larger channels / riprap needed to convey runoff waters to Langley Bay	• Reliance on a single outlet to drain the GMT deposit (more susceptible to failure modes such as beaver dams and channel glaciation) • Sourcing sufficient volume of large stones for channel armouring	2.6
2)	**Single Outlet to Catchment 3**	• Removal of Main catchment runoff from Beaver Pond / GCT area, thus smaller channel / riprap needed for channel to Langley Bay	• Potential higher volume of surface water entering base of WRPs, thus higher COPC leaching and loadings to Zeemel Bay • Armoured channel needed from outlet to Zeemel Bay	• Potential delays due to unknown remediation plans for WRPs • Reliance on a single outlet to drain the GMT deposit (more susceptible to failure modes such as beaver dams and channel glaciation)	2.0
3)	**Single Outlet to Southwest**	• Removal of Main catchment runoff from Beaver Pond / GCT area, thus smaller channel / riprap needed for channel to Langley Bay • Outlet will have negligible effect on other site aspects that could increase COPC loadings to aquatic receptors (e.g. no additional water flowing through WRPs) • Direct, relatively short armoured channel required to reach St. Mary's Channel	• Highest fill volume to create landform compared to all options • Armoured channel needed from outlet to St. Mary's Channel	• Reliance on a single outlet to drain the GMT deposit (more susceptible to failure modes such as beaver dams and channel glaciation) • Potential delays with regulatory approval due to introduction of new drainage path	1.9

Table 4.1 (cont')
Remediation options considered for GMT deposit.

Option	Remedial Description	Advantages	Disadvantages	Uncertainties / Potential Risks	MMA Score
4)	**Double Outlet – Catchment 3 and Southwest**	• Less risk of failure of entire drainage system due to presence of two outlets • Removal of Main catchment runoff from Beaver Pond / GCT area, thus smaller channel / riprap needed for channel to Langley Bay • Smaller riprap needed for catchment channels due to runoff flows split between two catchments	• Potential higher volume of surface water entering base of WRPs, thus higher COPC loadings to Zeemel Bay • Armoured channel needed from outlet to St. Mary's Channel • Armoured channel needed from outlet to Zeemel Bay	• Potential delays due to unknown remediation plans for WRPs • Potential delays with regulatory approval due to introduction of new drainage path	2.0
5)	**Double Outlet – Beaver Pond and Southwest**	• Less risk of failure of entire drainage system due to presence of two outlets • Smaller riprap needed for catchment channels due to runoff flows split between two catchments • Most cost-effective landform design of all the options	• Armoured channel needed from outlet to St. Mary's Channel • Higher runoff flows reporting to GCT / Langley Bay compared to Options 2, 3, and 4	• Potential delays with regulatory approval due to introduction of new drainage path	2.0

A key design objective for each of the Gunnar tailings deposit final landforms is to minimize the ponding of meteoric waters, which will reduce net percolation and thus seepage rates through the tailings deposits over the long term. Given the footprint and current topography of Gunnar Main, a considerable volume of earth fill is required to create a final landform with minimum 0.75% gradient drainage channels and hillslopes. It is presumed that smaller construction equipment will be able to work on the southern half of the tailings mass to relocate the upper tailings material to the remnant aquatic portion of Mudford Lake. Based on preliminary final grading design work, the estimated volume of tailings that would be relocated ranges from approximately 265,000 m^3 for Option 1 to about 75,000 m^3 for Option 3. The estimated volume of additional earth fill needed to create a water-shedding landform, less a 0.5 m thick layer of suitable local till to support the growth of native plants, ranges from about 600,000 m^3 for Options 1 and 5 to about 1,800,000 m^3 for Option 3. The majority of fill material is required in the northern half of Gunnar Main, where the tailings will be relatively wet given their closer proximity to the local water table elevation. The preferred fill material for Gunnar Main to support an overlying 0.6 m thick till cover system is waste rock borrowed from the nearby WRPs, given its relatively close proximity to Gunnar Main and coarser-texture. Coarser-textured, competent fill material will create the best possible working platform for construction equipment, and will also limit the capillary rise of COPCs in tailings pore-waters into the cover system rooting zone over the long term.

4.1.2 Gunnar Central Tailings Deposit

Consideration was given to remediating the GCT in-place as well as relocating the tailings to Gunnar Main or Back Bay for final disposal under a till cover system. Gunnar Main was suggested in the 2013 EIS as a possible final disposal location for GCT, which is understandable given the estimated fill required to backfill the remnant aquatic portion of Mudford Lake and create a water-shedding landform for Gunnar Main. Back Bay was considered as another possible final disposal location for both Gunnar Central and exposed or beach tailings at Langley Bay. Back Bay contains submerged tailings and is not known to support a fish population given its isolation from Langley Bay. The bathymetry of Back Bay is unknown, but it is believed to be 2 to 3 m deep at its deepest part. Back Bay does not have sufficient volumetric capacity to store the estimated volume of tailings at Gunnar Central (~454,000 m^3) below its NWL elevation. Hence, a new mounded landform would be created that would require a till cover system for final remediation.

It can be more cost-effective to relocate tailings at several locations to a single final repository with a reduced overall footprint for cover system construction. However, given the GCT are near saturation year-round, tailings relocation would involve a dredging operation during the summer construction season, or a conventional load-and-haul operation during the winter months when tailings are frozen. Either method would incur considerable costs as well as logistical challenges. **Table 4.2** outlines the advantages and disadvantages of remediation options considered for the GCT deposit. **Dwg. No. 963/1-009** shows the preferred landform design for Option 1.

Table 4.2
Remediation options considered for GCT deposit.

Option	Remedial Description	Advantages	Disadvantages	Uncertainties / Potential Risks	MMA Score
1)	**Cover Tailings In-place with Till Cover (min. 0.6 m thick working platform layer overlain by 0.5 m thick growth medium layer)**	• Minimal disturbance to tailings mass, thus minimal increase in COPC loadings to Langley Bay during construction • Higher cost effectiveness compared to Options 2 and 3	• Higher volume of cover system borrow material required compared to Options 2 & 3	• Having sufficient volume of suitable borrow material for reclaiming tailings in-place	2.8
2)	**Re-locate Tailings to Gunnar Main**	• Reduced cover system borrow material compared to Option 1	• Excavation of tailings will likely result in short-term increase in COPC loadings to Langley Bay • Current assessment predicts long-term COPC loadings to Langley Bay will not change compared to leaving tailings in-place • Much higher remediation cost compared to leaving tailings in-place	• Technical challenges associated with relocating a near-saturated tailings mass	1.6
3)	**Re-locate Tailings to Back Bay**	• Reduced cover system borrow material compared to Option 1	• Excavation of tailings will likely result in short-term increase in COPC loadings to Langley Bay • Current assessment predicts long-term COPC loadings to Langley Bay will not change compared to leaving tailings in-place • Much higher remediation cost compared to leaving tailings in-place	• Technical challenges associated with relocating a near-saturated tailings mass	1.6

4.1.3 Langley Bay Tailings Deposit

The tailings deposit at Langley Bay includes dry or beach tailings as well as submerged tailings. Submerged tailings are considered to be tailings that are below the NWL elevation in Langley Bay. As proposed in the 2013 EIS, it is recommended that the submerged tailings be left as-is. The exception is the submerged tailings along the shoreline, which will need to be covered in the event the water level in Langley Bay drops due to a drought condition and/or climate change. In addition, the surface of a till cover system placed over the Langley Bay beach tailings will need to be protected (i.e. rock armoured) from wave action and ice scour.

A total of five options were considered for remediation of the Langley Bay beach tailings (see **Table 4.3**). Two options are remediating the tailings in-place, two options are relocating the tailings to another disposal location, and the final option involves relocating the western half of the tailings mass to the eastern half. Besides the reduced cover system footprint and thus remediation cost savings, this option has the advantage of re-establishing a surface water connection between Back Bay and Langley Bay, which existed pre-mining. **Dwg. Nos. 963/1-010 to -012** inclusive show the preferred landform design for Options 1 and 2.

Table 4.3
Remediation options considered for Langley Bay tailings deposit.

Option	Remedial Description	Advantages	Disadvantages	Uncertainties / Potential Risks	MMA Score
1)	**Cover Tailings In-place with 0.6 m Till Cover overlain by 0.5 m Riprap Layer**	• Minimal disturbance to tailings mass, thus minimal increase in COPC loadings to Langley Bay during construction • Riprap will prevent damage to cover system due to wave action and ice scour	• High water level condition in Langley Bay will result in connection with Back Bay	• Having sufficient volume of suitable borrow material for reclaiming tailings in-place • Challenges in sourcing sufficient volume of non- or low-contaminated riprap	2.8
2)	**Cover Tailings In-place and Raise Central Portion (till overlain by riprap) to Create a Defined Beach Area for Langley Bay**	• Minimal disturbance to tailings mass, thus minimal increase in COPC loadings to Langley Bay during construction • Raised landform will result in defined beach area for Langley Bay, thus less riprap needed compared to Opt. 2 • Riprap will prevent damage to cover system due to wave action and ice scour • Raised landform will isolate Back Bay from Langley Bay		• Having sufficient volume of suitable borrow material for reclaiming tailings in-place	2.8
3)	**Re-locate Tailings to Gunnar Main**	• Reduced cover system borrow material compared to leaving tailings in-place	• Excavation of tailings will more than likely result in short-term increase in COPC loadings to Langley Bay • Current assessment predicts long-term COPC loadings to Langley Bay will not change compared to leaving tailings in-place • Much higher remediation cost compared to leaving tailings in-place	• Technical challenges associated with relocating a near-saturated tailings mass	1.8

Table 4.3 (cont')
Remediation options considered for Langley Bay tailings deposit.

Option	Remedial Description	Advantages	Disadvantages	Uncertainties / Potential Risks	MMA Score
4)	**Re-locate Tailings to Back Bay**	• Reduced cover system borrow material compared to leaving tailings in-place	• Excavation of tailings will more than likely result in short-term increase in COPC loadings to Langley Bay • Predicted long-term COPC loadings to Langley Bay will not change compared to leaving tailings in-place • Much higher remediation cost compared to leaving tailings in-place	• Technical challenges associated with relocating a near-saturated tailings mass	1.8
5)	**Re-locate West-half of Tailings Mass to East-half, then Grade and Cover In-place**	• Reduced cover system borrow material compared to leaving tailings in-place • Re-establish pre-mining connection between Back Bay and Langley Bay	• Excavation of tailings will more than likely result in short-term increase in COPC loadings to Langley Bay • Current assessment predicts long-term COPC loadings to Langley Bay will not change compared to leaving tailings in-place • Much higher remediation cost compared to leaving tailings in-place	• Technical challenges associated with relocating a near-saturated tailings mass	2.1

4.1.4 Secondary Tailings Deposits

Remediation options considered for the secondary tailings deposits (Catchment 3 and Beaver Pond) included covering the tailings in place and relocating the tailings to another location for final disposal. The advantages of remediating the tailings in place with a Till cover system include minimal disturbance of the tailings mass, thus causing a minimal increase in COPC loadings during construction, as well as the cost effectiveness of the remediation measure compared to tailings relocation. However, construction of a cover system will require additional sourcing and placement of borrow material. The largest potential risk for the remediation option is having sufficient volume of suitable borrow material for reclamation.

Re-location of tailings in the Catchment 3 and Beaver Pond areas to Gunnar Main and Back Bay was considered. Given that Beaver Pond and Catchment 3 are immediately adjacent to Gunnar Main and Gunnar Main requires additional fill volume to create a water-shedding landform, relocation to Back Bay was discounted as a viable option. Relocation to Gunnar Main reduces the required volume of borrow material compared to remediating the tailings in-place. The disadvantages of tailings relocation include a likely increase in short-term COPC loadings in Langley Bay (for Beaver Pond) and/or Zeemel Bay (for Catchment 3), due to disturbance of the tailings mass, and a higher remediation cost compared to covering in-place. The largest potential risk for this option is technical challenges associated with relocating a near-saturated tailings mass.

4.1.5 Preliminary Assessment of Langley Bay Water Quality Post-Reclamation

As outlined in Section 3.2.4, the base case cover system would remove the shallow pore-water flushing mechanism (runoff) that currently contributes the majority of COPC loadings to Langley Bay from the tailings deposits. COPC loadings from deeper groundwater flow from each tailings deposit and fluxes from the submerged Langley Bay tailings would continue to report to Langley Bay. Concentrations in Langley Bay were predicted using estimated loadings from the tailings areas as well as the outflow rate to Athabasca Basin coupled with resident COPC concentrations within Langley Bay.

Waste rock is proposed as the fill material required to construct a water-shedding landform for Gunnar Main and Beaver Pond. Utilizing waste rock as fill material will contribute COPC loadings to Langley Bay through leaching of waste rock pore-waters. COPC loadings to Langley Bay are dependent on the volume of waste rock used with the exception of uranium loadings, which are dependent on the surface area of the constructed waste rock layer and net percolation. The mechanism controlling loadings from waste rock fill in Gunnar Main, Beaver Pond, and Gunnar Central landforms is not fully understood, but it is assumed that infiltrated meteoric waters carrying the loadings will report to the tailings groundwater system. MDH (2012) noted that an upward gradient is measured at Gunnar Central, indicating a groundwater discharge area. It is hypothesized that minimal amounts of COPCs from the GCT are reporting to Langley Bay through groundwater.

Groundwater Pathways

In the 2013 EIS, three separate groundwater flow paths were identified for Gunnar Main from previous field groundwater investigations (BBT, 1986; AECOM, 2011; MDH, 2012). Only one of the flow paths (MT-GW-4) within Gunnar Main reports to the creek draining to Langley Bay (EcoMetrix, 2013b). The remaining flow paths were assumed to report to St. Mary's Channel (MT-GW-1), the Gunnar Pit (MT-GW-2), and Catchment 3 (MT-GW-3). These groundwater flow paths have since been revised to include individual pathways reporting to Langley Bay, Catchment 3 and St. Mary's Channel. The flow rates of these new pathways have also been determined. For the purposes of the loadings assessment, groundwater pathways were assumed to exist between Beaver Pond, Central and Langley Bay tailings and Langley Bay. Flow rates for these pathways were determined by pro-rating, on a tailings area basis, the GMT flow path reporting to Langley Bay (**Table 4.4**).

Table 4.4
Calculated flow rates for the tailings deposit flow paths.

Flow path	Flow Rate (m^3/d)	Flow Rate (m^3/a)	Percent of Flow (%)
GMT (Langley Bay)	92	33,603	66.7
GMT (Catchment 3)	40	14,610	29.0
GMT (St. Mary's Channel)	6	2,192	4.3
GCT	34	12,481	100
Langley Bay Tailings	42	15,336	100
Beaver Pond	8	2,958	100

For the 2013 EIS, the type of groundwater pathways involved in the transportation mechanism was assumed to be represented only by a long pathway through the underlying till/clay and/or bedrock to Back Bay and Langley Bay. As a refinement to the original model, two pathways are considered, a short or shallow groundwater pathway with local discharge to the creek and channel downstream from the GMT and a long or deeper groundwater pathway from the tailings to Back and Langley Bays.

Based on previous work, the hydraulic conductivity values of the tailings, till/clay and bedrock can be estimated to be on the order of 10^{-4}, 10^{-5} and 10^{-6} cm/s, respectively (BBT, 1996; AECOM, 2011). The differences between the tailings and underlying till/clay and bedrock layers suggests that at least some groundwater flow will occur within the tailings. Groundwater flow within the tailings will likely discharge to the surface water system closer to the Gunnar Main and Central tailings. The remaining seepage would migrate through the till/clay and upper bedrock groundwater flow paths. Transport via these pathways (deep pathways) will occur over a longer timescale based on their length and relatively lower velocities. The time required for COPCs to travel the shallow and deep pathways can be roughly estimated based on few assumptions. The hydraulic conductivity of the tailings and till/clay were estimated to be approximately 1.0×10^{-3} and 3.6×10^{-5} cm/s (AECOM, 2011). Based on an estimation using the contour map provided by MDH (2012) in the 2013 EIS, the deep groundwater pathway has vertical and horizontal gradients of 45 and 2,250 m, between GMT and Langley Bay. Similarly, the shallow groundwater pathway vertical and horizontal gradients are 10 and 500 m, between the GMT and Beaver Pond. The estimated porosity values for the till and tailings are 0.3 and 0.35 (AECOM, 2010). Therefore, the average velocities along the deep and the shallow pathways are approximately 0.22 and 6.3 m/a, respectively. These equate to a travel times of approximately 10,000 and 100 years, respectively. Due to the short distance between the GMT, Catchment 3 and St. Mary's Channel, only a single groundwater flow pathway was considered.

COPC Depletion

In the 2013 EIS, a majority of COPC loadings were demonstrated to originate from the fine-grained (less than 5 cm) waste rock (EcoMetrix, 2013b). Therefore, the COPCs available to leach from the waste rock can be assumed to be associated with the fine-grained fraction. Grain-sized distribution results suggest that the fine-grained fraction represents between 30 and 40 wt% of the waste rock (SRC, 2013). Therefore, the time required to fully deplete the waste rock COPC content can be estimated based on the solids concentrations and estimated leaching rates determined in the 2013 EIS (**Table 2.7**).

For example, the mean content of uranium was determined to be 53 mg/kg (EcoMetrix, 2013b). Assuming an average waste rock depth of 1.52 m, a density of 1,500 kg/m^3, an infiltration rate of 111 mm/a, a fine-grained content of 30 wt% and a leach concentration of 8.95 mg/L, the time to deplete the available uranium can be determined. Based on these values, a uranium content of 36.2 g/m^2 and a leaching rate of 0.99 g/m^2/a can be calculated. Therefore, it is estimated that all of the available uranium would be leached from the waste rock in approximately 40 years. The waste rock is a finite source of COPC loadings to the underlying deep and shallow groundwater pathways.

Groundwater Transport of COPCs

For the shallow pathway, it would take approximately 90 years (50 years travel and 40 years to leach all the uranium from the waste rock) for the uranium loadings to be transported from the GMT to Beaver Pond. Therefore, it can be assumed that shallow groundwater originating from Beaver Pond, GCT or the Langley Bay tailings would take less time, based on their relatively smaller areas.

Conversely, uranium loadings that migrate through the deep groundwater pathway will require more than approximately 10,000 years to arrive at Langley Bay. In addition, because of the long travel time, the concentration peaks associated with the 40 year pulse of uranium leaching from the waste rock would be substantially reduced as the pulse is dispersed along the groundwater pathway.

The migration of a 40 year pulse was simulated using a simple one-dimensional (1-D) numerical model (Papadopulos, 2014). A 250 m column was used to simulate the shallow groundwater flow path and a 2,000 m column was used to simulate the deep groundwater flow path. The transport parameters used for both simulations are summarized in **Table 4.5**. For both pathways, the Darcy flux was calculated from the hydraulic conductivity, porosity and hydraulic gradient. The shallow pathway used the hydraulic conductivity of the tailings (1.0 x 10^{-5} m/s) and the deep pathway the value for the underlying till (3.6 x 10^{-7} m/s). The porosity and dispersivity values were assumed, while the value for water at 25 ºC was assumed for the diffusion coefficient. The initial concentration within the column was set to zero and a unitless concentration of 1 was used to represent an undefined COPC. The transport model results for the theoretical migration of a COPC along the shallow and deep flow paths are illustrated in **Figure 4.1.** Approximately 50 years would be required for the majority of the COPC to migrate 250 m and over 2,500 years to travel 2,000 m. The effect on the peak concentration at each location due to dispersion within the groundwater environment is illustrated by the concentration profiles.

Because of the differences in arrival times at Langley Bay resulting from the two groundwater pathways, there will be no overlap in loadings and, therefore; the loadings are not cumulative at any instant in time. Moreover, because of the time required for loadings to migrate along the deep groundwater pathway, the incremental loadings to Langley Bay are effectively limited to those from the shallow groundwater pathways from the tailings areas. In practical terms, this means that the loadings migrating along the deep groundwater pathway are removed or displaced so far in the future that they will represent significantly smaller incremental loadings to Langley Bay relative to the shallow groundwater pathway loadings.

Table 4.5
Transport parameters for 1D model of groundwater flow paths.

Transport Parameter	Units	Shallow Pathway	Deep Pathway
Darcy Flux	m/a	0.23	6.31
Porosity	-	0.35	0.30
Longitudinal Dispersivity	m	50	50
Molecular Diffusion Coefficient	m2/a	0.073	0.073
Retardation Factor	-	1	1
Initial Concentration	-	0	0

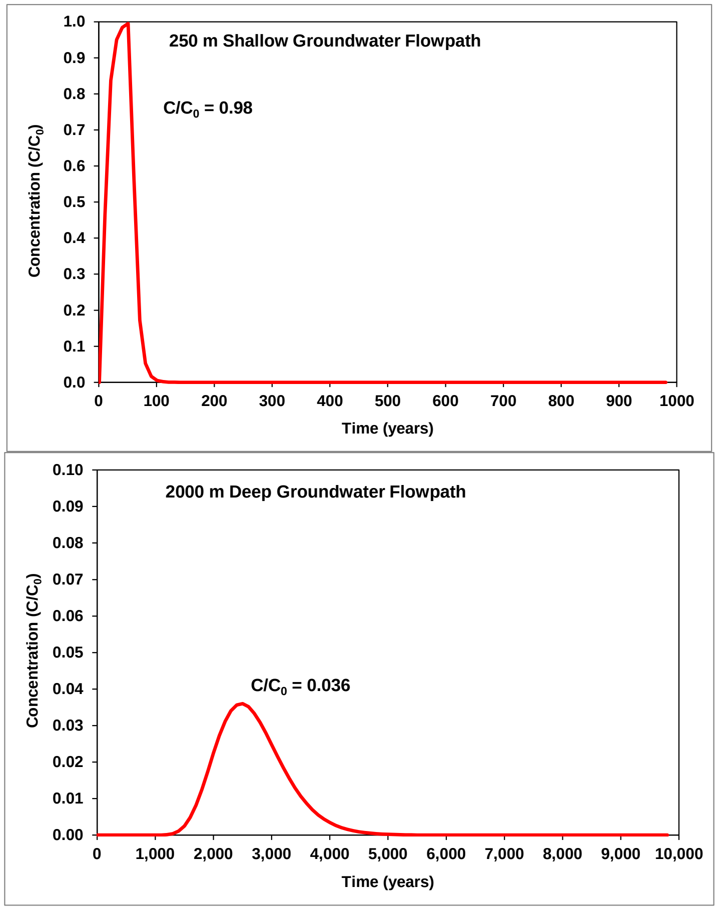


Figure 4-1 1D model of groundwater flow paths.

<u>Sensitivity Analysis</u>

Currently, the relative loadings associated with the deep and shallow ground water pathways cannot be precisely determined from the currently available hydrogeological data. The groundwater flow rates determined in this report assume all groundwater flow is present within the deep pathways. However, a sensitivity analyses was developed for the loadings assessment that investigated the estimated loadings to Langley Bay based on variations in the proportion of these flowrates that were assigned to the shallow groundwater flow paths. For the purposes of this report, shallow groundwater flows representing 10 and 25 % of the total groundwater flows were investigated.

<u>Assessment Results</u>

The amount of COPC loadings from the waste rock cover and tailings reporting to the shallow and deep groundwater flow paths were estimated for the two sensitivity analyses, based on the flowrates and percentage assigned to the deep and shallow flow paths (**Table 4.4**). The COPC loadings for the 10 and 25 % groundwater reporting to the shallow and deep flow paths are summarized in **Appendix G**.

In both sensitivity scenarios, the majority of loadings contributed by the leaching of the waste rock present in the cover system were assigned to the deep groundwater pathway; thereby effectively removing them from the estimate of COPC concentrations in Langley Bay. The estimated COPC concentrations in Langley Bay, compared to current conditions and base case are summarized for the two sensitivity analyses in **Table 4.6**.

Table 4.6
COPC concentrations estimated in Langley Bay for each sensitivity analysis.

Constituent	SSROs	Current Conditions	Base Case	10 % Shallow Flow	25 % Shallow Flow
Sulphate (mg/L)	-	7.13	3.53	1.90	2.20
Arsenic (mg/L)	0.1	0.00024	0.00021	0.00015	0.00017
Cadmium (mg/L)	0.0003	0.00010	0.00010	0.00009	0.00009
Lead (mg/L)	0.013	0.0028	0.0028	0.0027	0.0027
Uranium (mg/L)	0.09	0.0012	0.0003	0.0004	0.001
Radium-226 (Bq/L)	-	0.11	0.11	0.09	0.09

The observed reduction in COPC concentrations in the sensitivity scenarios, compared to current conditions, is mainly attributed to removal of the shallow pore-water flushing mechanism (i.e. bare tailings surface runoff), with contributions from groundwater flow and submerged Langley Bay tailings accounting for remaining loadings. Increases in COPC concentrations, compared to the base case cover system, are attributed to use of waste rock as landform fill. Variations in COPC concentrations between the two scenarios indicate that uranium is most sensitive to the amount of groundwater flow attributed to the shallow groundwater flow path.

Based on the simple 1D transport model results, peak uranium loadings from the waste rock cover would take approximately 50 years to migrate to Langley Bay from the GMT along the shallow flow path, and likely less time from Beaver Pond and GCT shallow flow paths. However, because the available uranium will be depleted within 40 years, these peak loadings will rapidly decrease to near zero by year 100. Moreover, the assessment does not take into account the potential effects of attenuation on the migration of uranium, and other COPCs, along the shallow groundwater flow path. Using the simple 1-D transport model and incorporating a diffusion coefficient of only 1 L/kg results in a 40 % decrease in peak values and an additional 20 years to migrate along the 250 m flow path.

As previously discussed, the proportion of COPC loadings reporting to the deep groundwater pathways will not contribute to an increase in the concentrations observed in Langley Bay, or other receptors. The significant increase in travel time associated with this pathway, illustrated in **Figure 4.1**, is estimated to reduce peak loadings to less than a percent of those calculated in **Table 4.7**. Therefore, the concentrations estimated for Langley Bay in **Table 4.6** represent fairly conservative COPC values.

Predicted radium-226 loadings from waste rock are conservatively based on the SFE data presented in EcoMetrix (2013a). However, the radium-226 loadings for SP-1 and Zeemel Bay predicted in EcoMetrix (2013b) from these laboratory estimates were substantially higher than the actual values measured in samples collected directly from both sources. Therefore, the radium-226 loadings predicted to report to Langley Bay from waste rock used as fill in the tailings area may be over-estimated.

4.1.6 Risk Assessment

The proposed cover systems for the tailings deposits will achieve the primary objectives of providing a gamma shield that limits radiation to an average of 1.14 μSv/h per ha. In addition, the cover systems will limit radon gas and LLRD emissions to background levels.

Combined, the estimated loadings calculations for the base case and the preferred design option indicate that the placement of a cover system will substantially reduce COPC loadings to Langley Bay that are mobilized from the tailings. This will result in a reduction of COPC concentrations in Langley Bay. The use of waste rock as fill material will contribute incremental COPC loadings to Langley Bay. However, these loadings may represent a decrease in the COPC loadings currently reporting to Langley Bay. In addition, the loadings model did not account for COPC attenuation along the groundwater flow path, which would reduce loadings to Langley Bay compared to those presented. In all cases examined in this report, the estimated COPC concentrations in Langley Bay were substantially lower than the SSROs determined in the EIS.

The estimated COPC concentrations in Langley Bay determined for the preferred remediation option decreased from the current conditions. While some COPCs, in particular uranium, demonstrated sensitivity to the amount of loadings reporting through the proposed shallow groundwater flow path, for the analyses conducted the estimated concentrations in Langley Bay remained well below the SSROs (Appendix G). These results suggest, it is likely that COPC loadings risk to Langley Bay compared to current conditions will decrease.

4.1.7 Remediation Option Preliminary Cost Estimates

Preliminary costs were developed to provide relative costs for evaluation of the remediation options within a MAA. The MAA required roughly estimated costs for relative scoring of economic feasibility of each option. Material quantities and unit costs were developed to capture the total cost of construction tasks required to develop each landform and closure cover system. Examples of costs not included in the cost estimate include, but are not limited to, equipment mobilization/demobilization, project management, and construction supervision. The main drivers to total cost for Gunnar Main are the quantity and placement of fill material required to produce a water-shedding landform and the quantity and placement of a till cover system across the 45 ha footprint.

The main drivers for cost at Gunnar Central were the required quantity and placement of materials for landform development and till cover system construction. Costs for the Langley Bay options were driven by the required quantity and placement of till cover system construction and production and placement of riprap for shoreline protection.

4.1.8 Multiple Accounts Analysis of Options

A high-level MAA of the remediation design options for each tailings deposits was completed. The MAA was adapted from the process completed for the 2013 EIS. Given that the current design process does not include options that were already removed during the previous MAA (and decision tree analysis), accounts were adjusted or added to reflect further refinement of the design process. For example, performance indicators such as Impacts to Human Health were considered to be similar for many options (because options that did not provide this had already been removed in previous options assessments. Economic feasibility, borrow disturbance, and site-wide impacts were included in this MAA, which were impacts that were not considered in the MAA conducted for the EIS. **Table 4.9** shows the accounts and indicators used in this MAA.

Sub-accounts under the MAA were rated from 0 to 3 with 3 being the highest performing standard. Indicators were provided as weighted percentages based on perceived importance. Weighting percentages were distributed as follows: Borrow disturbance – 20%, Technical Feasibility – 30%, Economic Feasibility – 30%, and Site-wide Impacts – 20%. The MAA ratings given to each of the designs are presented in **Table 4.10** with the preferred option shown in bold in the bottom row.

Table 4.7
Characterization criteria, accounts and indicators used in the MAA.

Characterization Criteria / Accounts	Sub-Accounts	Indicators
Constructability	Borrow Disturbance	Increased disturbed area required to be remediated
	Technical Feasibility	As per Table 5-2 of EIS (2013)
Economic Feasibility	Cost to complete remediation works	Estimated cost
Site Wide Impacts[1]	Aquatic Life and Vegetation	As per Table 5-2 of EIS (2013)

[1] Human health risks and terrestrial wild life and vegetation were not considered as each option had the same ranking.

Table 4.8
MAA ratings for the various tailings remediation design options.

Characterization Criteria/Accounts	*Sub-Accounts*	GMT-Opt 1	*GMT-Opt 2*	*GMT-Opt 3*	*GMT-Opt 4*	*GMT-Opt 5*	*GMT BR-Opt 1*	*GMT BR-Opt 2*	*GBP-Opt 1a*	*GBP-Opt 1b*	*GCT-Opt 1a*	*GCT-Opt 1b*	*GCT-Opt 2*	*GCT-Opt 3*	*LB-Opt 1*	*LB-Opt 2*	*LB-Opt 3*	*LB-Opt 4*	*LB-Opt 5*	*Weight*
Constructability	Borrow Disturbance	2	2	2	2	2	2	3	3	2	2.5	2	3	3	2	2	3	3	3	**20%**
	Technical Feasibility	3	2	2	2	2	3	2	3	2	3	3	1	1	3	3	1	1	1	**30%**
Economic Feasibility	Cost to complete construction*	3	2	1	2	2	3	1	3	2	3	3	1	1	3	3	1	1	2	**30%**
Site Wide Impacts & HHERA	Aquatic life & veg	2	2	3	2	2	3	3	2	3	2	3	2	2	3	3	3	3	3	**20%**
Total MAA Rating		**2.6**	2.0	1.9	2.0	2.0	**2.8**	2.1	**2.8**	2.2	2.7	**2.8**	1.6	1.6	2.8	**2.8**	1.8	1.8	2.1	**100%**

4.2 Cover System Design Options

The cover system design options developed for the Gunnar tailings areas complement the landform design options, creating a 'water-shedding' surface promoting surface runoff to keep meteoric waters clean by isolating the tailings material from the atmosphere. The primary design objectives of the cover systems are to provide a gamma radiation shield and eliminate dust emissions from the tailings surface. Secondary objectives include development and sustenance of a vegetation cover as well as reduction of net percolation to the tailings mass. The latter objective will be achieved through increased runoff volumes as a result of the water-shedding landforms, as well as increased removal of incident meteoric waters as a result of transpiration and canopy interception provided by the eventual native vegetation ecosystem. Establishing a sustainable vegetation cover on the reclaimed tailings landforms also has the benefits of improved aesthetics, erosion protection, and wildlife habitat.

4.2.1 Monolithic Layer of Till

A monolithic layer of local till material was the preferred cover system identified in the 2013 EIS. The till material would be placed directly onto tailings with a thicker cover system (up to 1.0 m) constructed in areas with a higher water table condition and finer-textured tailings, and a thinner cover system (minimum 0.5 m) placed on coarser-textured tailings with a deeper water table. The minimum 0.5 m layer will provide an adequate growth medium to develop and sustain vegetation on the remediated areas.

Advantages:

- Ease of constructability for sourcing and placing a single layer of material; and
- Reduced quality assurance / quality control (QA/QC) requirements during construction compared to more complex multi-layer cover systems.

Disadvantages:

- Higher potential for upward movement of tailings pore-water and solutes during dry periods;
- Direct placement onto tailings might not be feasible in areas that are not sufficiently dewatered; and
- Potential large footprint of natural landscape will have to be disturbed to meet required borrow volumes.

4.2.2 Multi-Layer using Waste Rock

The anticipated configuration of this multi-layer cover system would include a 0.5 m (nominal) thick layer of waste rock overlain by a 0.6 m (nominal) thick layer of local till material. The waste rock material would be borrowed from both the East and South WRP.

Advantages:

- Additional material available for shaping and improving surface water drainage;
- Waste rock provides a working platform allowing easier placement of growth medium materials in areas where the tailings are not sufficiently dewatered;
- Reduced potential for upward movement of COPCs in tailings pore-waters during dry periods due to waste rock being coarser-textured compared to the local till materials;
- Reduced volume of local till borrow, which means a smaller natural landscape disturbed footprint; and
- Use of waste rock reduces the WRP footprint and allows re-contouring of current angle-of-repose slopes for the WRPs.

Disadvantages:

- Potential for higher COPC loading to Langley Bay due to relocation of waste rock;
- Increased complexity and cost of construction for a multi-layer cover system; and
- Greater QA/QC requirements compared to single layer cover system.

4.2.3 Multi-Layer using a Capillary Break Layer

A capillary break cover system at the Site would utilize relatively coarser-textured material to ‘break’ or ‘stop’ the upward wicking of tailings pore-waters into the cover system. The tailings and potential cover system material must have substantially different textures to ensure the occurrence and longevity of the capillary break. If sufficiently different till borrow materials exist, the cover system could potentially incorporate two different layers, thereby creating a capillary break of a finer-textured material overlying a coarser-textured material. The upper capillary break would increase the water storage capacity of the near surface till layer, benefitting vegetation and potentially improving cover system performance.

Advantages:

- Reduced potential for upward movement of COPCs in tailings pore-waters during dry periods; and
- Capillary break layer results in additional water being stored in the growth medium layer, which will aid with revegetation efforts.

Disadvantages:

- Requires identification and procurement of materials with a distinct textural difference to tailings and overlying growth medium materials;
- Increased complexity and cost of construction for a multi-layer cover system;
- Requires additional QA/QC during construction to verify capillary break material meets specifications;
- Capillary break action will be lost in areas where the tailings do not drain sufficiently; and
- A working platform or separation medium (e.g. geotextile) more than likely required in finer-textured / high water table tailings areas to prevent void spaces in the capillary break material from being infilled with tailings.

5 TAILINGS REMEDIATION PREFERRED DESIGN

The preferred remediation plan for each of the primary and secondary tailings deposits include landform and cover system design elements. The primary areas are discussed first followed by the secondary areas. Considerations for revegetation, surface water management, construction, and performance monitoring of the remediated tailings areas are also detailed in this section.

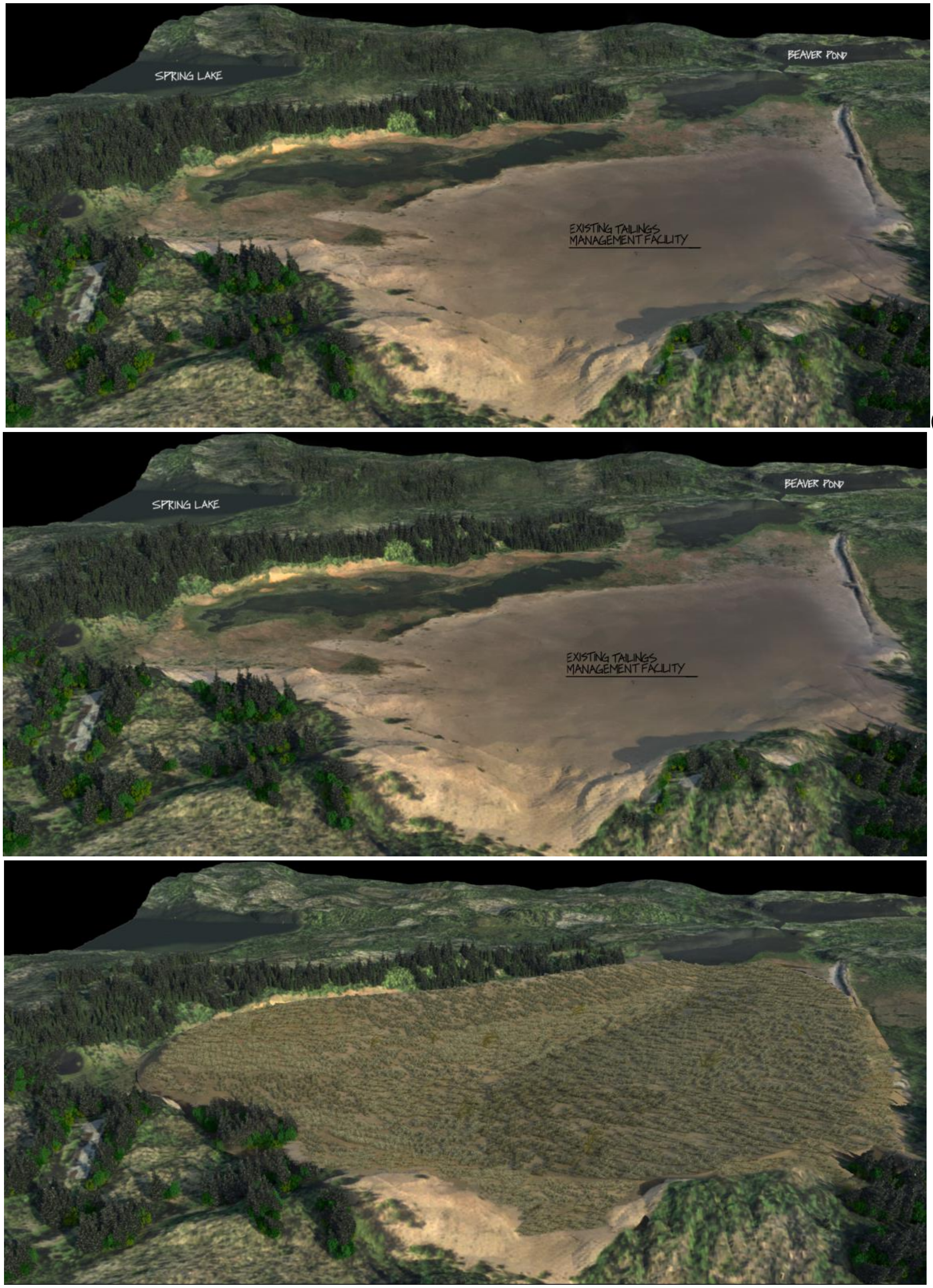
5.1 Primary Tailings Deposits

The preferred remediation design for the GMT area is Option 1 from **Table 4.1** (see **Dwg. No. 963/1-004**). The preferred option is to produce a water-shedding landform draining to the northern outlet leading to Gunnar Central (**Figure 5.1**). This continues the current surface drainage pattern at the Site and will eliminate standing bodies of water within the area. A surface drainage swale with an average 0.75% slope gradient is proposed through the middle of the landform to collect surface waters from the reclaimed tailings and natural catchment area, routing surface waters to the northern outlet leading to Gunnar Central.

The anticipated post-reclamation depth to water table will be used as a guide to determine the type and/or thickness of the cover system for the Gunnar Main area. The preferred landform and cover system design will require some re-grading of the current tailings surface including the southern dam. This dam is no longer function to contain saturated tailings and water. **Dwg. No. 963-1-013** shows the anticipated extent of the re-graded area. A 0.5 m till cover system will be placed directly on the tailings to the east of the re-grading extent in areas with a minimum of 2 m depth from the re-graded tailings surface to the water table. This is expected to provide a minimum 2 m separation between the base of the vegetation rooting zone and the water table. In areas with less than 2 m depth from tailings surface to water table, a minimum 1.0 m thick cover system will be constructed, comprising a 1.0 m layer of till material or a combination of 0.5 m waste rock fill and overlying 0.5 m till material. Following completion of geotechnical index testing of available borrow materials, estimates of capillary rise of tailings salts, and associated COPCs, into the cover system will be completed as part of the final detailed design information and construction plan phase. This may result in refinement of design cover system thicknesses.

The preferred remediation design for Gunnar Main was selected based on advantages outlined below:

- The 2013 EIS recommended the creation of a water-shedding landform with positive surface drainage to eliminate standing bodies of water on Gunnar Main.
- Due to the large area of Gunnar Main, substantial amounts of fill will be required. Sufficient waste rock is available within close proximity and will be more easily sourced than local till material.
- Use of the northern outlet continues the current surface water drainage pattern. The northern outlet represents the lowest available outlet elevation, which minimizes the required fill to produce a water-shedding landform.



(a) (b) (c)

Figure 5-1 Rendering of existing (a) and preferred final landform design (without (b) and with vegetation (c)) for GMT deposit.

- A working platform of waste rock creates a coarser-textured material over the finer-textured tailings material creating a capillary break and limiting the upward migration of tailings pore-waters and COPCs.
- A 0.5 m till cover system will provide an adequate radiation shield and vegetation growth medium and is relatively easy to construct.
- Limiting the till cover system to 0.5 m over the majority of the landform greatly decreases till borrow requirements and reduces land disturbance from creating new borrow areas.

A possible option for remediation of demolition and/or contaminated waste materials at the Site is burial within the backfill material required to infill the remnant portion of Mudford Lake. During the final detailed design information and construction plan phase, the Project Team will engage SRC's consultant that has been retained to develop remediation plans for all other aspects at the Site. At this time potential detrimental effects or possible failure modes associated with disposal of demolition and/or contaminated waste materials in Gunnar Main will be examined. At this stage of analysis two possible failure modes are considered; namely, localized differential settlement and preferential flow of infiltrated meteoric waters. Provided the waste materials are compacted to the greatest extent possible and till placed as required to fill larger voids, the likelihood of these two failure modes is very low. Further analysis of this disposal option will be conducted during the final detailed design information and construction plan phase. This will include applying results of cone penetration testing completed in 2012 (MDH, 2012) to an analytic settlement model to estimate vertical change in tailings height due to cover system and fill placement.

Gunnar Central incorporates the same design principle of creating a water-shedding landform as proposed for Gunnar Main. **Figure 5.2** presents the reclamation landform, which slopes with a surface gradient range of 0.7% to 1.0% towards the drainage channel proposed between Gunnar Main and Langley Bay (see **Dwg. No. 963/1-009**). Waste rock is the preferred material to create the water-shedding landform. A cover system consisting of 0.5 to 1.0 m of till will be constructed on the landform. Minimum till thickness is 0.5 m, the minimum total waste rock and till thickness is 1.0 m.

The preferred remediation design for Gunnar Central was selected based on advantages outlined below:

- The 2013 EIS recommended the creation of a water-shedding landform with positive surface drainage for Gunnar Central.
- Waste rock is the preferred fill material to create the Gunnar Central landform. It is anticipated that natural till will be located in closer proximity to Gunnar Central than waste rock; however, due to the ease of access to waste rock and the cost and environmental impact of developing large till borrow areas, till is not recommended as the landform fill material. While outside the scope of this study, there are environmental benefits to re-locating waste rock from its current position immediately adjacent to Zeemel Bay.

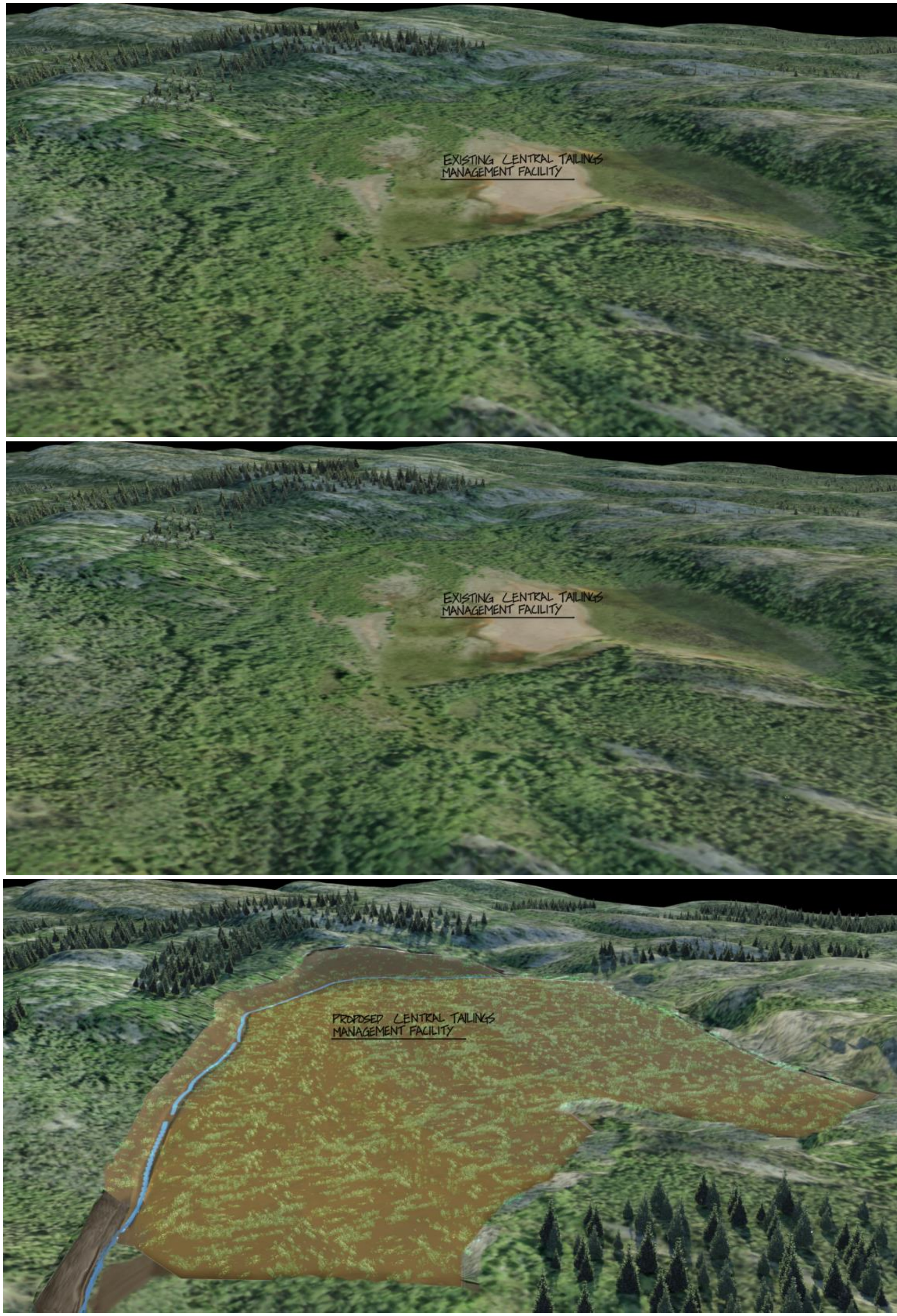


Figure 5-2 Rendering of existing (a) and preferred final landform design (without (b) and with vegetation (c)) for GCT deposit.

- A working platform of waste rock creates a coarser-textured material over the finer-textured tailings material creating a capillary break and limiting the upward migration of tailings pore-waters and COPCs. The tailings within Gunnar Central are finer-textured than tailings in Gunnar Main, elevating the importance of having design measures in place to limit the upward movement of tailings pore-waters and COPCs.
- A 0.5 m to 1.0 m till cover system will provide an adequate radiation shield and vegetation growth medium and is relatively easy to construct.

The tailings mass within the Langley Bay area is saturated and presents a challenging remediation design. The preferred remediation alternative leaves the tailings in-place and includes a minimum of 1.0 m till cover system and defined shorelines in both Back Bay and Langley Bay with rock armour protection (Option 2; see **Figure 5.3** and **Dwg. Nos. 963/1-011 and -012**). Till borrow and till deposit stones are the preferred construction materials. Waste rock is not recommended for the Langley Bay area given the proximity of the beach tailings to Langley Bay and potential additional contaminant source associated with Gunnar waste rock material.

The water level in Langley Bay has ranged from a minimum elevation of 207.2 masl to a maximum elevation of 210.6 masl since the onset of daily measurement in 1955. Till material will create a defined shoreline in Langley Bay covering the deposited tailings from an elevation of 205.2 masl (2 m below the low water level to accommodate the estimated effects of scouring from wind action and ice thrusting) up to 210.8 masl. The tailings landform is graded with a ~0.3% slope from the Back Bay end down towards Langley Bay. A channel to hydraulically connect Back Bay and Langley Bay runs across the middle of the landform, the inlet elevation of the channel is higher at Back Bay ensuring one way flow from Back Bay to Langley Bay. The cover system is thicker near Back Bay (>2 m) and gradually thins to a minimum of 1 m near Langley Bay.

The preferred remediation design for Langley Bay was selected based on advantages outlined below:

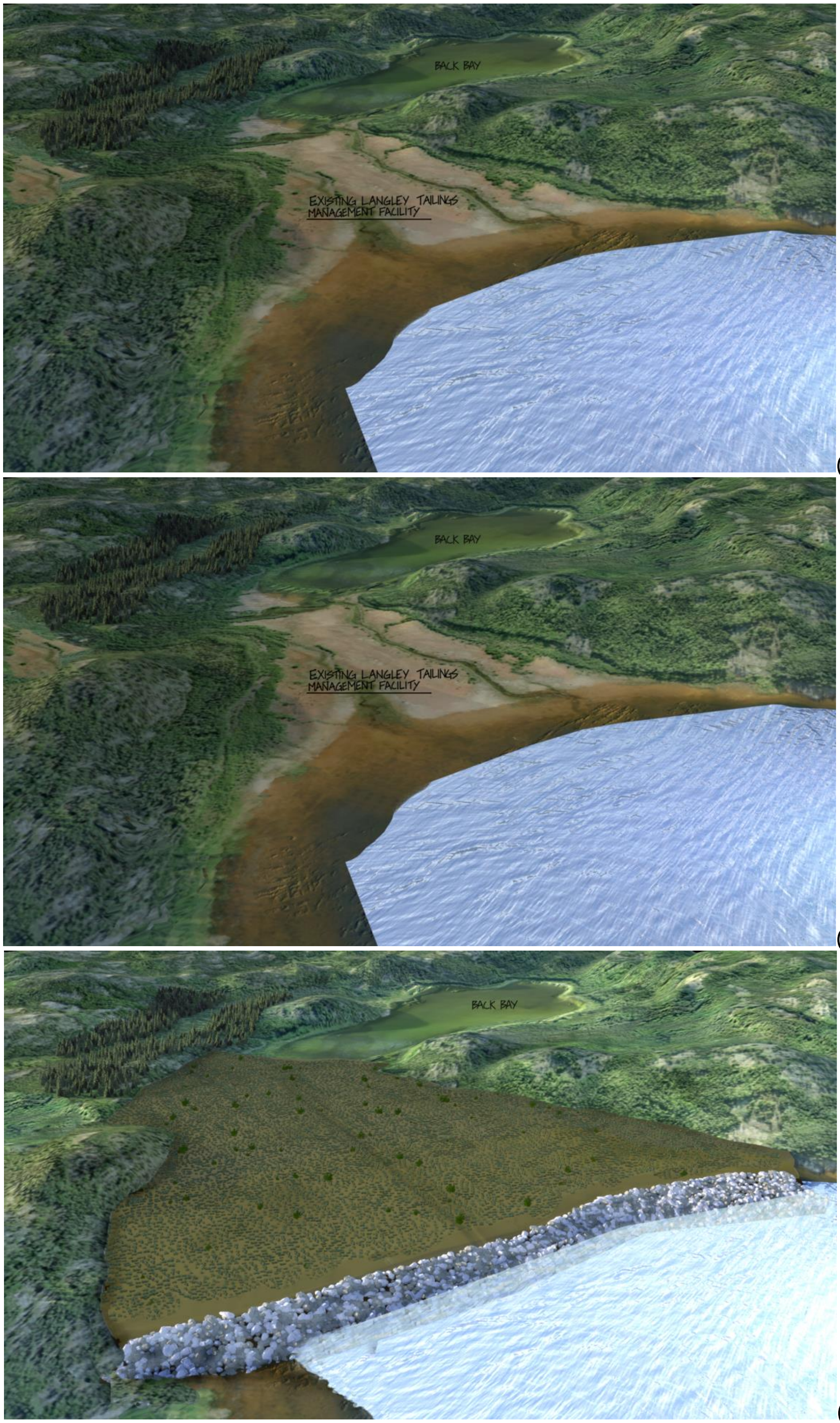
- A minimum 1 m till cover system provides adequate protection of the saturated tailings mass. Final elevation of surface is a minimum of 0.2 m above the maximum historical water level greatly diminishing the probability of flooding the entire landform.
- The use of till, compared to waste rock, does not introduce an additional source of potential contaminants adjacent to Langley Bay.
- Creation of defined shorelines with riprap in Back Bay and Langley Bay allow protection of the tailings deposit across the entire range of historical lake water levels.
- Hydraulic connection between Back Bay and Langley Bay provides long-term management of Back Bay waterbody.

5.2 Secondary Tailings Deposits

Preferred remediation designs for the Gunnar Main Back Release and Beaver Pond tailings areas were developed. The Back Release area is a portion of the tailings originally intended for disposal in Gunnar

Main that migrated into a lower elevation pathway heading eastward away from the facility. The preferred remediation method is to cover the tailings in-place with a 1.0 m till cover system. It is anticipated that a 0.5 m thick cover system will not be adequate for this area given the wetter conditions and need to create additional separation between the rooting zone and local water table.

North of the GMT is surface waterbody resulting from historically located beaver dams. It is likely that an unknown quantity of tailings underlies the waterbody. As part of the preferred remediation plan, the impounded water will be removed and waste rock fill added to match the surface elevation of the area to the outlet elevation of Gunnar Main. A drainage channel will be constructed that will extend through Gunnar Central to Langley Bay. A minimum of 0.5 m of till will be added within the area outside the extents of the channel to provide a radiation shield and a growth medium for vegetation.



(a)

(b)

(c)

Figure 5-3 Rendering of existing (a) and preferred final landform design (without (b) and with vegetation (c)) for Langley Bay tailings deposit.

5.3 Revegetation Plan

The primary task in developing a revegetation plan is to identify an optimal approach and techniques for vegetation establishment over the completed engineered cover system. A dense and sustainable vegetation canopy is necessary to ensure effective erosion control and high transpiration capacity of the final tailings cover system. Another important task is re-establishment of natural vegetation at the borrow excavation footprint and other areas disturbed during remediation activities.

The borrow material available around the Site has acceptable physical-mechanical properties to serve as a growing medium and generally sufficient calcium and potassium content, but low in nitrogen and phosphorus. Field trials were established along the periphery of the Gunnar Mine airstrip in mid-June 2012, after the research area was cleared of vegetation (Petelina et al, 2014). Seven wooden box frames were constructed measuring 0.3 m x 4 m x 6 m and were divided into 12 cells. Cells were filled with four replicates of different combinations of borrow material, two soil organic amendments using three rates, and mineral fertilizer using two rates. The cells were seeded by hand with a native species seed mix comprised of eight grasses, five forbes, and one shrub. Further detailed information regarding methods used for the field trials is found in the SRC Gunnar Revegetation Research Field trials report (Petelina, 2012). Details of the revegetation plan for Gunnar tailings cover systems are based upon the preliminary findings of the field trials.

A native legume/grass seed mixture is recommended to be applied to the tailings cover systems at Gunnar Mine. Based upon the preliminary results of the field trials and the availability of native boreal herb seeds on the Canadian market, the seed mixture shown in **Table 5.1** is proposed for the tailings cover systems.

Table 5.1
Seed mixture proposed for Gunnar Mine tailings remediation revegetation plan.

Plant species	PLS dry weight (%)
Rocky Mountain Fescue (Festuca saximontana)	20
American Vetch (Vicia Americana)	20
Slender Wheat Grass (Elymus trachycaulus)	15
Rough Hair Grass (Agrostis scabra)	10
White Bluegrass (Poa glauca)	10
Fowl Bluegrass (Poa palustris)	10
Tufted Hairgrass (Deschampsia caespitosa)	7
Canada Milkvetch (Astragalus Canadensis)	5
Marsh Reed Grass (Calamagrostis Canadensis)	3

The proposed seeding rates of the seed mixture in **Table 5.1** vary from 4,000 pure live seeds/m^2 (approximately 16 kg bulk seed mixture/ha) on steep slopes with poor soil to 1,000 pure live seeds/m^2

(approximately 2 kg of bulk seed mixture/ha) on flat areas with good topsoil quality. Seeding rates were determined based upon the field trials and recommendations of the Yukon Revegetation Manual (Matheus and Omtzigt, 2012). The following factors were taken into account when determining seeding rates:

- Poor growth medium quality,
- Risk of erosion,
- Soil treatment,
- Seeding methods, and
- Intent to encourage establishment of woody species on the site.

Seeding will be performed during early frost conditions in the fall to ensure that seeds remain dormant until spring. Seeding will not take place if there is snow cover on the ground to prevent loss via spring melt.

The revegetation trails showed that application of mineral fertilizer boosts establishment of seeded plants and natural volunteers. However, due to the high cost of shipping organic amendments to site, fertilization will be limited to the application of a mineral fertilizer. Mineral fertilizer will be applied before seeding, at the recommended rate of 50 N kg/ha, 70 P_2O_5 kg /ha, 60 K_2O kg/ha, and 20 S kg/ha. To avoid eutrophication of water bodies, fertilizer application will not occur within 30 m of water bodies.

Rooting depths of the species in **Table 5.1** are based on site specific conditions. Gunnar Mine is located in a northern environment with a short growing season, poor soils, and limited water supply; therefore approximately 90% of the roots of the species in **Table 5.1** would be within the top 20 to 30 cm of the cover system. Therefore, it is unlikely that the roots would interact with tailings if planted on the tailings cover system.

Natural recovery is the primary suggested strategy for revegetation of borrow areas. Topsoil in the borrow areas will be stripped and stockpiled along with natural vegetation debris prior to excavation activities. Upon completion of the excavation, the topsoil and organic debris will be spread back across the disturbed areas to promote natural recovery. With a shallow or lack of topsoil, natural recovery at selected areas can be amended by low-rate seeding and/or fertilizer application.

Based on the above-described approach, further details of the revegetation plan for the remediated Gunnar tailings and borrow areas will be developed by SRC during the final detailed design information and construction plan phase of this project.

5.4 Surface Water Management

Proper management of surface waters incident to and upgradient of the Gunnar tailings deposits is vitally important to the long-term integrity and performance of the reclaimed areas. A key aspect of proper surface water management is design of a robust landform design that takes into consideration local conditions of climate, vegetation, and soils (MEND, 2007). A mature stand of native forest species will eventually colonize the reclaimed tailings areas, given a suitable cover system design is in place to combat the detrimental effects of upwards migration of tailings solutes. However, for an area such as Gunnar Main, which has a relatively large catchment size, rock armoured drainage channels will be required to provide resistance to soil erosion during higher flow events. Improper management of surface waters may result in gully formation, potentially exposing buried tailings, but also increased suspended sediments in surface water and higher rates of seepage from the tailings deposits.

It is recommended that a design storm event with a recurrence interval of 200 years be used to calculate peak flows for design of drainage channels required for the tailings remediation design. This is the same recurrence interval that was used to design drainage channels for the nearby Lorado tailings cover system. The failure modes, potential risks, and consequences of failure of the surface water management systems for the Gunnar and Lorado tailings areas are considered to be similar. However, two additional factors will be taken into consideration during final detailed design information and construction plan phase of the Gunnar tailings remediation drainage channels that will result in a more conservative estimation of peak flows. IDF data from Stoney Rapids will be used instead of those available for Uranium City given the more recent climate record and higher design IDF values (refer to **Table 2.5**). In addition, the Stoney Rapids IDF data, which are based on historical rainfall data, will be adjusted to account for a reasonable climate change scenario for the Site. The duration of the design storm event will be based on the time of concentration calculated for each catchment.

Soil loss rates from the remediated tailings deposits are expected to be low over the medium and long terms due to the following:

- Lower surface gradients for the final landforms;
- Erosion resistance provided by the coarser-textured nature of the local till materials; and
- The anticipated success with establishing self-sustaining vegetation covers.

Surface runoff waters will contain elevated levels of suspended sediments until the cover surfaces stabilize and the seeded revegetation mixture adequately develops, which should occur within 2 to 3 years. A potential concern is waters with higher total suspended solids entering nearby streams or lakes and in particular, waterbodies that contain a fish population. Where necessary, wire-backed silt fences or an equivalent product will be used to limit sedimentation of fish-bearing waterbodies.

The following five areas will require rock armouring to provide adequate protection against unacceptable erosion of areas remediated with a till cover system:

- Lower portion of the swale on the GMT final landform (length of ~400 m);
- Drainage channel from Beaver Pond to the south shore of Langley Bay (length of ~2,200 m);
- Drainage channel to the north of the Langley Bay beach tailings to provide an outlet for Back Bay to Langley Bay (length of ~500 m); and
- Cover system along the southwest shoreline of Langley Bay; and

- Cover system along the east shoreline of Back Bay.

5.4.1 Design Storm Peak Flow Calculation

The Soil Conservation Services (SCS) method was selected for calculating peak flow from the design storm event for preliminary channel and riprap sizing for the tailings remediation plan. *It should be noted these estimates do not incorporate climate change into the climate database and resulting IDF curves.* This will be completed as part of the detailed design phase. As such, peak flow estimates and resulting riprap and channel specifications are provided as placeholders for the preliminary design.

The SCS method has replaced the rational method in the United States to a significant degree because of its wider database and the manner in which physical characteristics are considered in its application (Maidment, 1993). The United States Department of Agriculture (USDA) developed a model based on the SCS method called Technical Release 55 (TR-55) (USDA, 1986). The MS-Windows version WinTR-55 v1.00.10, released in 2011, was used for calculating the design storm peak flow for each of the tailings deposit remediation plans.

The TR-55 model begins with a rainfall amount uniformly imposed on the watershed with a specified time distribution. Mass of rainfall is converted to mass of runoff by using a runoff curve number (CN). CN is based on soil properties, plant cover, impervious area, interception by vegetation, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed. The peak runoff rate is based on the selected distribution of the 24-hour design storm and the calculated time of concentration (t_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed.

Each tailings deposit landform was simulated in the TR-55 model. The peak flow calculated for the outlet of each landform/catchment was used as the design basis for sizing drainage channels and estimating median riprap size.

Design storm peak flows were calculated assuming a 'good' and 'fair' vegetation cover or hydrologic condition. SCS developed CN values for urban, cultivated agricultural, other agricultural, and arid and semi-arid range land uses. The woods cover type in the other agricultural lands category most closely approximates the expected cover type for the remediated tailings deposits. SCS also classifies all soils into four hydrologic soil groups (A, B, C, and D); the proposed surficial material for the covered tailings deposits (mixture of mineral soil and organics) falls into Group B, which are soils with a k_{sat} in the range of 1×10^{-4} to 2×10^{-4} cm/s. The CN value for the selected wood cover type with a 'good' hydrologic condition (litter and brush adequately covers the soil) is 55, while the CN value for the same cover type with a 'fair' hydrologic condition (some forest litter covers the soil) is 60.

Table 5.2 presents design storm peak flows calculated by the TR-55 model for each catchment of the tailings remediation plan. In general, peak flows for a 'fair' vegetation or hydrologic condition are at least double those calculated for a 'good' hydrologic condition for each catchment.

Table 5.2
Preliminary Peak Flows Calculated using TR-55 for Drainage Areas Used to Estimate Rip Rap Size

Drainage Area	Area (ha)	Peak Flows (m^3/s) - CN of 60	
		1:200 Yr Event	1:1000 Yr Event
GMT	77.2	1.54	2.88
Beaver Pond	25.1	0.57	1.06
GCT - South	18.8	0.44	0.83
GCT - North	28.5	0.63	1.18

5.4.2 Drainage Channel Design Calculation

Preliminary drainage channel designs completed were based on the tractive force method as documented in Smith (1995). In principle, the method is used to evaluate the adequacy of a designed channel from comparison of the shear stress generated by the flow to the shear resistance of the channel lining material. That is, the shear resistance of the lining material (grass, gravel, riprap, etc.) must be greater than the shear stress generated by the flow to produce a stable channel. Spreadsheets developed by the Project Team were used to calculate the maximum allowable flow in a channel based on Manning's equation for various channel geometries and linings, and evaluate the hydraulic condition (i.e. stability) of channel flow based on the Froude number. A conservative design approach will be taken to account for icing or glaciation of drainage channels, a failure mode that is common for sites in a cold region (MEND, 2012).

Preliminary assessment shows a median stone diameter (D_{50}) of 75 mm will be required to line drainage channels with a smaller contributing area, while a D_{50} of 150 mm may be required to line drainage channels with a larger contributing area. The channel bottom widths will likely range between 3 m and 6 m with side-slopes of approximately 3H:1V. **Table 5.3** shows the preliminary channel and ripraps sizes.

A graded riprap material is preferred over a uniform material of the same median diameter as a result of greater interlocking effect between particles (giving increased shear strength) and decreased porosity (giving a better filter effect between flowing waters and base material under the stone) (Smith, 1995). Filter layers are typically required beneath coarser riprap materials to prevent foundation material from being washed out or sucked through voids in the riprap layer. A natural granular material or a non-woven, needle-punched geotextile can be used for this application. It is anticipated that a local soil material will not be available that would meet the required gradation limits for a filter medium unless the material was screened; from a cost-effectiveness perspective, a non-woven, needle-punched geotextile will likely be recommended for this application.

Table 5.3
Preliminary Channel and Riprap Sizes

Peak Flow (m3/s) Range	Channel Bottom Width (m)	Channel Depth (mm)*	Riprap D50 (mm)
0 to 0.6	3	300	75
0.6 to 1.6	3	430	75
1.6 to 2.6	6	400	75
2.6 to 4.0	6	510	150
4.0 to 6.0	6	620	150

* Assumes 100 mm freeboard.

Rock armouring will be required along the southwest shoreline of Langley Bay and east shoreline of Back Bay to protect the beach tailings cover system from ice scour and wave action. Based on analyses completed for the Lorado beach tailings cover system, it is anticipated that the median stone diameter will be approximately 500 mm with a total layer thickness of about 1,000 mm. The appropriate analyses will be completed for Gunnar during the final detailed design information and construction plan phase to determine the required riprap size and footprint for armouring. In addition, drainage channel designs will be confirmed during the detailed design phase of the project.

5.5 Decision Tree Analysis of Preferred Remediation Plan

As described in the Gunnar EIS (SRC, 2013), an alternatives assessment process (following the process recommended by Environment Canada (EC, 2011)), was used to develop the optimum remediation alternative for each site aspect. However, upon review of the assessment results, it was determined that the following factors still needed to be considered in the decision:

- Ongoing site investigation activities would generate new or improved information that might change some of the scores used in the assessment; and
- Interaction between the site aspects might change the assessment results (i.e. the best alternative for one aspect negatively impacting another site aspect).

Therefore, a decision tree analysis was completed for each aspect to address these considerations.

A decision tree is a visual, documented representation of a decision-making process, where all factors influencing a decision are represented as branches. Different decisions at various points in the process lead to a different path and therefore to a different final outcome.

The key factors that were included in the Gunnar Decision Trees for each aspect were consideration of the risks to human and ecological health posed by:

1) the source of contaminants,
2) the pathway of contaminants, and
3) the receiving environment.

In some cases, like for the waste rock, the source of contaminants generated a different decision for remediation compared to the receiving environment. Based solely on the source, the waste rock decision tree only generated a decision to remediate portions of the WRP; however, based on the risks to the receiving environments, the decision tree generated a decision to remediate the entire WRP.

The preferred remediation plans affect the decision trees for the tailings deposits. The decision points for each of the tailings Decision Trees were included in the development of the preferred option and will not be further discussed here. However, the preferred remediation plans for the tailings areas affect some of the other decision trees for the Gunnar site and these are discussed below:

- *Pit Decision Tree:* The preferred tailings remediation plans will use a substantial portion of the waste rock for fill to create water-shedding landforms. Additionally, because waste rock will be used as fill instead of till, there will likely be sufficient till to cover the remaining waste rock, if required. Therefore, it is unlikely that the preferred remediation option for the waste rock will be pit back fill, which would have led to the pit lake requiring full treatment/evacuation. Potentially, this would preclude the need for an additional risk assessment on the pit lake as there would be no contaminant stream directed to the pit resulting from direct placement of waste rock. However, during remediation of Gunnar Main, Gunnar Central and secondary tailings deposits, the current plan is to pump excess surface water into the pit lake. Therefore, this may constitute an additional contaminant stream and may trigger additional risk assessment based on the Pit Decision Tree.
- *Mill Complex Decision Tree:* Some of the uncertainty in the decision points for the various source materials are based on whether or not fill is needed elsewhere on-site and whether or not there will be till and waste rock available as potential construction materials for an engineered landfill or covering the material in place. The preferred remediation plans for the tailings deposits do not use all of the waste rock or, most likely, all of the till borrow materials. Therefore, some of the uncertainty on whether these materials will be available has been removed from this decision tree.
- *Waterfront Decision Tree:* As with the Mill Complex Decision Tree, some of the uncertainty in the decision points can be removed because both waste rock and till materials will be available for remediation.
- *Waste Rock Decision Tree:* The preferred tailings remediation plans will use a substantial portion of the waste rock for fill to create water-shedding landforms. This reduces some of the uncertainty in the decision points. From the source branch, this addresses both the question of covering (still possible given cover material will be available) and relocation (some will be relocated). The increased mass flux to Langley Bay and other groundwater areas by placing the waste rock on the tailings has been assessed and therefore the uncertainty in this has been addressed. Removing

some of the source will also reduce some of the loading and therefore will influence the appropriate remedial action. However, as with the Mill Complex and Waterfront Decision Trees, the tailings remediation actions do not preclude the feasibility of any of the available remediation actions for the waste rock.

5.6 Estimated Volumes and Borrow Sources for Cover Materials

The in-place volume of materials required for construction of the preferred remediation design for each tailings deposit was estimated (**Table 5.1**). Total till borrow material requirements for the tailings preferred remediation plans is estimated to be ~675,000 m^3. The total volume of waste rock and riprap are estimated at 910,000 m^3 and 26,300 m^3, respectively.

5.6.1 Borrow Material Selection Criteria

Borrow material required for the tailings remediation designs falls into three categories: till cover material, waste rock fill or working platform material, and riprap. The volume of each category required for each remediation aspect is shown in **Table 5.4**. The majority of local till materials are comprised of silt and clay sized material. Areas 1, 2, 11, 12 and 14 are entirely comprised of these materials. These materials are not recommended to be used as cover material near the surface due to the propensity for frost heaving and erosion.

The most suitable material for use a cover system material is found in Areas 5 and 6. These areas are comprised primarily of clay to sand sized materials however large amounts of sand and gravel were found in both areas. Borrow materials from Areas 5 and 6 have sufficient fines content to support plant growth as well as a relatively high gravel and cobble content to limit the effects of soil erosion. It is recommended the coarser material from Areas 5 and 6 as well as the airstrip be used for the surface layer of the cover system for the tailings remediation plan. The advantage of using airstrip material is reduced disturbance of the natural landscape for borrow excavation.

The clay and silt material is currently being assessed for suitably for use as fill in the Langley Bay landform. These assessments include estimates of capillary rise and COPC uptake into the cover system profile. A detailed assessment of borrow material suitability as well as material balance can be found in **Appendix D**.

Table 5.4
Estimated material volumes and borrow sources to construct the tailings remediation designs.

Area	Till Borrow Volume (m^3)	Waste Rock Volume (m^3)	Riprap Volume (m^3)	Anticipated Till Borrow Source
Gunnar Main	240,000	700,000	1,600 d_{50}=75 mm	Area 6, 11 or 13
Beaver Pond	15,000	90,000	1,100 d_{50}=75 mm	Area 6, 12 or 13
Catchment 3	50,000	0	300 d_{50}=75 mm	Area 6, 12 or 13
Gunnar Central	60,000	110,000	1,700 d_{50}=150 mm	Area 5, 12 or 13
Langley Bay	310,000	0	600 / 21,000 d_{50}= 75 / 500 mm	Area 5 and 6
Total Borrow Required	***675,000***	***910,000***	***26,300***	

Waste rock material will be sourced from both East and South WRPs. Detailed PSD assessment of waste rock material shows the waste rock is coarser-textured material with approximately 80% of particle greater than 4.75 mm. Material possessing higher gamma radiation levels, would be placed in the deeper parts of Mudford Lake or Beaver Pond.

It is anticipated riprap material will be sourced by blasting a suitable bedrock outcrop and screening to specifications. Riprap stone must be hard, durable, and chemically acceptable (i.e. non-acid and/or COPC generating). Riprap stone material must be resistant to weathering, and be substantially free of overburden, spoil, shale, and organic material. It should be generally cubic in shape; if possible, angular or sub-angular material is preferred. The WRP material is not considered a viable source of riprap material given associated risks with potentially unacceptable gamma radiation levels and COPC concentrations. Riprap requirements for the drainage channels include cobble-sized particles that are 75 mm to 150 mm on average, while the Langley and Back Bay shoreline protection riprap is anticipated to be an average size of 500 mm.

5.7 Construction Elements to Address in Final Detailed Design Information and Construction Plan Phase

The following items related to implementation of the tailings remediation design will require careful consideration during the final detailed design information and construction plan phase:

- Construction schedule and logistics for earthworks contractor(s);
- Placement of cover material in areas where vegetation has established;
- Re-contouring of the Gunnar Main uplands / beach tailings;
- Placement of cover material on undrained (soft) tailings material;

- Placement of cover material on submerged tailings along the shoreline of Langley Bay;
- Reduction of tailings or till cover dust emissions to workers and surrounding landscape; and
- Occupational health and safety for persons involved in the remediation works.

It is anticipated that the majority of the planned tailings remediation work will take place during the summer construction season. This is typically early June to the end of September for the Site, which allows for a 4-month construction season. The construction schedule will also need to consider logistics surrounding mobilization of construction equipment to the Site. It is anticipated that the necessary construction equipment will be mobilized / demobilized to Site via the Provincial winter road. Alternatively, heavy equipment can be mobilized / demobilized via barge should winter ice conditions not be favourable; however, this alternative could result in a significant delay to the construction schedule (SRC, 2013).

Some of the tailings areas support a fairly mature stand of volunteer vegetation including grass, shrub and woody species. It would be acceptable to place cover material over areas that support only grass and shrub species; however, areas that support woody species will need to be cleared prior to placing till cover material. This is to minimize the potential for large voids or preferential pathways to form in and around the trunks of woody species. The cleared organic matter can be used to create ‘organic piles’ at random locations on the final reclaimed surface to improve wildlife habitat and add diversity to the relatively flat landscape.

The current plan is to relocate uplands tailings in the south part of Gunnar Main to topographic low areas in the north half of Gunnar Main. It is anticipated that conventional construction methods can be used for this earthmoving operation due to the relatively drained condition of the southern tailings mass. It is surmised that a dozer would be used for the bulk of tailings re-location. Material would be loaded into haul trucks with a hydraulic excavator and re-located to fill areas where the depth of cut or pushing distance is excessive for a dozer.

Some of the tailings areas, particularly the northern half of Gunnar Main and most of Gunnar Central and Langley Bay, are not sufficiently drained to support construction equipment. It is anticipated that sufficient bearing capacity will exist for hauling and spreading equipment provided the equipment travels on fill material already placed. The preferred fill material to create a working platform layer is waste rock given its coarser-textured, competent nature. The current plan, however, is not to use waste rock as fill material over the Langley Bay beach tailings given its close proximity to Langley Bay. If necessary, a geo-grid or geotextile product can be used to provide additional strength for construction equipment. Traffic compacted areas in the till cover layer will need to be ripped or scarified at the end of construction; these compacted areas, if left intact, could hamper the successful development of revegetation.

Till cover material will need to be placed over submerged tailings in Langley Bay along the shoreline, to an elevation that is below the anticipated minimum water level for Langley Bay. This is to ensure that a radiation shield will be provided over tailings that are currently submerged, but could become exposed in the event of a drought condition and/or climate change. It is anticipated that a hydraulic excavator with a long-reach boom will be the preferred method for this application.

Dust emissions from re-working the Gunnar Main upland tailings and during dry periods of cover material placement will need to be managed and controlled. LLRD is of particular concern when the GMT are being re-contoured, while excessive tailings or till material dust emissions could have detrimental effects on the surrounding aquatic and terrestrial ecosystems. As required, a water truck will be used during drier conditions to control dust emissions during remediation earthworks.

An occupational health and safety plan will be developed for the construction phase of the Gunnar tailings remediation project. In particular, monitoring and measures will be in-place to ensure radiation doses to workers are kept below acceptable levels.

5.8 Potential Failure Modes for the Preferred Remediation Design

5.8.1 Purpose and Approach

A failure modes and effects analysis (FMEA) was completed by the Project Team and SRC on the preferred designs for the tailings remediation. A FMEA is a top-down / expert-system approach to risk identification and quantification, and mitigation-measure identification and prioritization. Its value and effectiveness depends on having experts with the appropriate knowledge and experience participate in the evaluation during which failure modes are identified, risks estimated, and appropriate mitigation measures proposed. The goal is to provide a useful analysis technique that can be used to assess the potential for, or likelihood of, failure of the proposed design and effects of such failures on human health and the surrounding ecosystem. Robertson and Shaw (2006) describe the FMEA approach in greater detail.

An assessment period of 500 years was chosen for the FMEA. This timeframe was chosen to be within a reasonable timeframe over which the group felt they had some confidence in prediction.

The following people were involved in completion of the FMEA (referred to as the FMEA group):

- *Brian Ayres, M.Sc., P.Eng.* – Senior Geotechnical Engineer at OKC with nearly 20 years of experience in mine waste cover system and landform design (project senior technical advisor);
- *Kristie Bonstrom, M.Sc., P.Geo.* – Senior Geoscientist at OKC with over 10 years of experience in mine waste cover system design, monitoring, and performance evaluation (project technical coordinator and has visited the site);
- *Denise Chapman, M.Sc., P.Eng.* – Senior Geo-Environmental Engineer at OKC with over 10 years of experience in mine waste cover system design, monitoring, and performance evaluation (project manager and has visited the site);

- *Bonnie Dobchuk, M.Sc., P.Eng.* – Senior Geo-Environmental Engineer at OKC with over 12 years of experience in mine waste cover system design, monitoring, and performance evaluation (project engineer *and has visited the site);*
- *Dave Christensen, M.Sc., P.Eng.* – Senior Geotechnical Engineer at OKC with over 12 years of experience in mine waste cover system design and numerical modelling (project engineer for cover design and modelling programs);
- *Alexey Klyashtorin, Ph.D.* – Environmental Remediation Specialist at SRC;
- *Chis Reid, B.*Sc., E.I.T. – Associate Geo-Environmental Engineer at SRC;
- *Elizaveta Petelina, M.*Sc., MSEM, AAg – Remediation Specialist; and
- *Sean Shaw, Ph.*D. – Geochemist at EcoMetrix (geochemist leading the solute loadings modelling program).

A total of 23 failure modes were developed for the FMEA as detailed in **Appendix E**. The potential failure modes encompass the key physical, chemical, and biological processes that are relevant to the site and could potentially influence the long-term integrity or performance of the reclaimed tailings facilities. Several of the failure modes include more than one effect and pathway. The FMEA group assessed the risk for each combination of failure mode and effects / pathways (45 combinations in total).

Figure 5.4 shows the risk matrix used for the FMEA. The term 'risk' encompasses the concepts of both the likelihood of failure (the expected frequency of failures) and the severity of the expected consequences if such events were to occur (Robertson and Shaw, 2006). If the likelihood and consequences for a given failure mode and effect(s) results in a low risk rating, then the potential risk is broadly acceptable. If the risk rating is moderate or moderately high, then appropriate mitigation measures should be developed, which may include slight modifications to the design, post-closure monitoring, and/or post-closure maintenance. Once mitigation measures are implemented, the residual risk is considered to be 'as low as reasonably practicable' (ALARP). If the risk rating is high or critical, then the potential failure mode and effects are deemed to be intolerable, and a design modification is recommended.

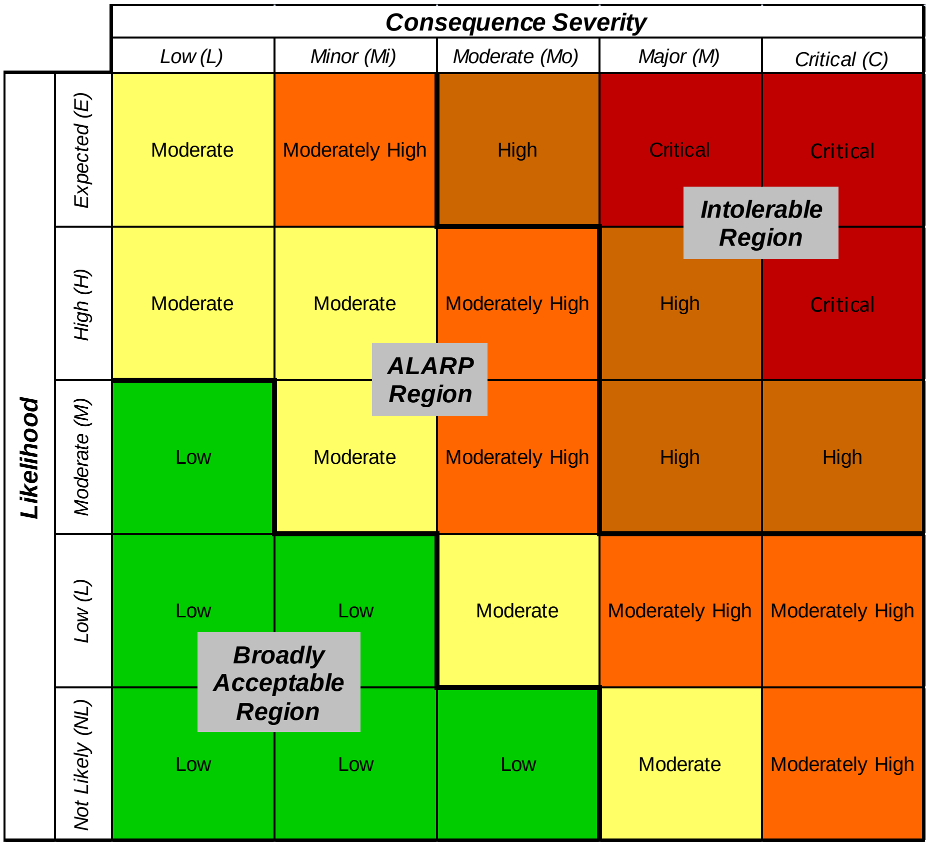


Figure 5-4 Risk matrix used for the FMEA.

5.9 Results of Analysis

Detailed results of the FMEA completed for this study are provided in **Appendix E**, with a synopsis provided herein. Of the 45 combined failure modes and effects / pathways, none were assigned a critical risk rating, 4 were assigned a high risk rating (falling into the intolerable region of **Figure 5.4**), 12 were assigned a moderately high risk rating, 15 were assigned a moderate risk rating, and 14 were assigned a low risk rating. **Table 5.5** shows the failure modes and effects / pathways identified to have a risk rating of high as well as pertinent comments and proposed mitigation measures.

The failure modes that resulted in unacceptable/intolerable risk ratings (those shown in **Table 5.5**) fit into two broad categories: three related to insufficient quantities of coarser textured materials and one related to capillary rise of contaminants. In all cases, the mitigation measures for these failure modes relate to rigorous detailed design that takes into account available quantities of coarser-textured materials such as the waste rock and the medium/coarser-textured till as well as the potential for producing clean coarse-textured materials from an onsite quarry. The confidence in these assessments, and the additional information required for the detailed design, will come from additional modelling that is to be done for the detailed design.

Provided the proposed mitigation measures or alternative measures are implemented to address the potential risks, the Project Team expects the proposed reclamation designs for the Gunnar tailings facilities will be geotechnically stable and minimize effects on the receiving environment to acceptable levels over the long term.

Table 5.5
Potential failure modes identified in the FMEA requiring some form of mitigation.

Failure Mode ID	*Failure Mode Description*	*Effects and Pathways*	*Likelihood*	*Level of Confidence*	*Highest Risk Rating*	*Mitigation / Comments*
2a	Insufficient volume of till material available to complete cover system construction	Modification to the design required due to lack of suitable materials leading to construction delays and/or higher capex costs.	M	M	H	Optimize use of coarse-textured material by using finer-textured till material in lower layer of growth medium layer. Additional surveying, and material sampling to confirm till materials meet specs.
2b		Modification to the design required due to lack of sufficient volumes of fill materials meeting design specs (or due to needs from other site aspects), leading to construction delays and/or higher capex costs.	H	M	H	Optimize use of coarse-textured material by using finer-textured till material in lower layer of growth medium layer. Additional surveying, and material sampling to confirm till materials meet specs. Continuous communication throughout design process to ensure the designs align for the other site aspects. Could add additional waste rock to tailings final landforms to reduce cover material requirements for other site aspects.
3	Insufficient volume of coarse-textured material available to construct access roads	Waste rock used to construct access roads and CNSC requires removal of roads resulting in higher capex costs.	E	H	H	Early discussion with regulator regarding expectations over road construction and removal. Appropriate budgeting to include road removal. Careful alignment of roads and consider using clean material in sensitive areas. Optimize borrow material development to minimize road construction.
23	Capillary rise of water into rooting zone	COPCs from the underlying waste are transported into the cover system leading to loading rates of COPCs to Langley Bay in exceedance of SSROs	E	M	H	Capillary rise is expected to occur into the cover system in areas where there is a shallow water table and fine textured cover/fill materials are used exclusively. Mitigation of this will be to modify the detailed cover design materials to add coarse textured material in the cover or increase the fill thickness (or a combination of both). The waste rock fill will provide this function in the areas where this material is designated to be used. The materials to be used in other areas of the landform will be finalized in the detailed design. Additional confidence in this assessment will be gained following the modelling for the detailed design.

5.10 Cover System Performance Monitoring and Maintenance Programs

5.10.1 Preliminary Performance Monitoring Program

Direct measurement of field performance is the preferred methodology for measuring performance of cover systems reclaimed waste storage areas (MEND, 2004). This is the best method for demonstrating to all stakeholders that the cover system will perform as designed. For a full-scale cover system, a recommended minimum level of monitoring should include climatic conditions (for determination of potential evaporation rates), site-specific precipitation, cover material moisture storage changes, watershed or catchment area surface runoff, vegetation success, and erosion (MEND, 2004).

A 'watershed' approach as opposed to a 'point-scale' approach is preferred when designing performance monitoring systems for reclaimed waste storage areas (O'Kane, 2011). Although most monitoring techniques used in point-scale reclamation monitoring can be applied for macro-scale reclamation monitoring, the extent of performance monitoring for an entire reclaimed mine waste landform is much broader than that for a point-scale (e.g. trial plot) area. Performance monitoring and evaluation of a macro-scale reclaimed landform considers the temporal and spatial variability of field-measured datasets. The monitoring frequency (scale) for obtaining sufficient data, which is associated with spatial instrumentation and temporal data acquisition, must be understood to deploy a cost-effective monitoring system. In short, a watershed approach to designing reclamation monitoring systems allows for thought in regards to interaction of key processes, mechanisms, and characteristics that will be operational over the entire reclamation area, but which can be studied at a manageable size.

It is recommended that a performance monitoring system be designed and installed on the remediated primary tailings deposits at the Site. Details related to monitoring locations, parameters that will be measured and their frequency will be outlined in the final detailed design information and construction plan report. The performance monitoring system will be dependent on the final landform and cover system for each tailings deposit. In addition, recommendations for surface and groundwater monitoring will be provided in the detailed design report.

5.10.2 Preliminary Maintenance Program

The reclamation plan for the tailings cover systems is designed to be stable over the long term, however, maintenance of the landform in addition to the performance monitoring system will be required in the short term. It is recommended that cover system surfaces be inspected for erosional features such as rills and gullies annually after spring melt and prior to the first snowfall, as well as after large rainfall events. Erosion maintenance work would likely consist of infilling of deep rills and gullies with cover system material. Areas showing signs of settlement will also require filling with cover system material.

It is recommended that SRC personnel visit the tailings cover systems once per month to perform data downloads and conduct maintenance of the performance monitoring system. Data should be reduced on a monthly basis to avoid data loss over long periods. A monthly data collection and reduction schedule will ensure high data capture rates, which can substantially increase stakeholder confidence with respect to performance. Further details on the maintenance program will be outlined in the final construction plan report for the tailings remediation plan, as the maintenance program is closely related to the monitoring program.

6 FINAL DETAILED DESIGN INFORMATION AND CONSTRUCTION PLAN WORK PLAN

Detailed analyses to support a final remediation design for the Gunnar tailings deposits will commence following approval by stakeholders and regulators of the plans documented in this report.

6.1 Work Scope and Deliverables

Upon approval of the remediation plans, a series of tasks will be completed to develop the tailings final remediation designs. In addition, the Project Team will provide the necessary documentation for inclusion in an IFT package to facilitate execution of the remediation plans. The major tasks include descriptions and deliverables are include in **Table 6.1**. Each deliverable will be provided to SRC upon task completion. The final detailed design information and construction plan and construction plan report will be submitted to SRC prior to the construction phase of the project.

Table 6.1
Work scope and deliverables for Gunnar tailings remediation final detailed design information and construction plan.

Task	Sub-Task	Deliverables
Cover System and Landform Design	FMEA of Preferred Designs	Memorandum summarizing FMEA
	Surface Water Management Plan	Engineer Design Drawings
	Plan views and cross-sections of final landforms	
Decision Tree	Decision Tree Analysis of remediation options	Memorandum summarizing application of the Decision Tree to the Detailed Design
Construction Plan and Procurement Documentation	Project Specification	Draft Report that also includes Final Detailed Design Information and Decision Tree
	Construction Drawings	
	QA/QC Plan	
	Construction Schedule	
	Cost Estimates and Material Quantities	
	Scope of Work Description	
Detailed Design Report	Compilation of Final Detailed Design Information and Construction Plan to Support IFT Package	Final Report for submission to CNSC

6.2 Field Investigation 2015

Adequate borrow source requirements in terms of volume and geotechnical properties has been identified as a key risk to remediation of the Gunnar tailings deposits. As described in Section 2.10, a previous detailed borrow volume and material property investigation was completed to assess Investigation Areas 6 and 13. Given estimates of borrow volume requirements from these areas are similar to the volumes delineated during previous investigation and include the airstrip, further field investigation was required to ensure suitable borrow sources are available to complete remediation plans. In addition, waste rock has been proposed as a fill material for Gunnar Main and Beaver Pond areas as well as a working platform for a remediation cover system at Gunnar Central. The Project Team completed a field investigation that targeted borrow areas best-situated for accessibility to tailings deposit areas as well as the WRPs.

The field investigation was completed from June 1 to 19, 2015. Rare species and heritage surveys of target borrow areas were completed prior to excavation of test pits to ensure ground disturbance did not occur in sensitive areas. Each investigation was surveyed where GPS survey equipment could obtain a satellite signal. Areal extents and outcrops were marked in order to constrain volume estimations. A total of 83 test pits were excavated in Investigation Areas 1, 2, 5, 11, and 12, as well as 22 test pits completed on the South and East WRPs. **Dwg. No. 963/1-003** shows borrow areas that were targeted during the 2015 field investigation and includes surface areas for each Investigation Area surveyed.

Borrow material ranged from silty clay to medium-fine sand with trace gravel. Investigation Areas 1, 2, 11, and 12 were dominated by finer textured materials including silty clay to clayey silt, with some sand and gravel deposits encountered in Area 1. Area 5 was dominated by medium-fine sand and encompassed the largest surface area of the all the borrow areas investigated. Physical and digital samples from the borrow areas and WRPs were collected totaling 85 and 82 samples, respectively. Laboratory testing to determine PSD is currently being completed on 48 physical samples and 50 digital samples. These data will be used to optimize borrow pit development during construction activities.

It is anticipated that Area 5 in combination with Area 6 and the airstrip will comprise most of the source borrow material for the tailings remediation cover systems. Preliminary volume estimates from these areas coupled with borrow material from Investigation Areas 1, 2, 5, 11, and 13 indicate there is sufficient borrow materials with suitable material properties to implement the proposed remediation plans. Volume estimates will be finalized using standards included in Northern Land Use Guidelines for pit and quarry development and remediation (INAC, 2009).

7 STAKEHOLDER CONSULTATION

The key stakeholders for this project are the federal and provincial governments, the regulators, and the Aboriginal People of the Athabasca Basin. This section briefly outlines the previous efforts for consultation activities and introduces the key methodologies proposed for assisting with consultation activities for the cover system design project.

7.1 Previous Consultation Activities

Consultation activities have occurred with interested Aboriginal communities over the last number of years through the regulatory process and is well-documented in the Gunnar EIS. The Gunnar Project is located within historic Treaty 8 (1988) as well as the traditional territories of a number of Aboriginal communities in northern Saskatchewan and Alberta (SRC, 2013). The Aboriginal people of the Athabasca Basin include First Nations and Metis communities/organizations. Consultation has involved numerous meetings and workshops as well as the studies and interviews conducted as part of the Traditional Knowledge Survey and the Socio-Economic Assessment.

The overall land-use vision for the Athabasca lands is “to manage the use of the land and renewable resources of the Athabasca in an integrated and environmentally sound manner to ensure ecological, economic, social, cultural, and spiritual benefits for present and future generations”. The Gunnar site falls into the Special Management Zone of the Land Use Plan, where the protection of cultural places and wildlife habitat is paramount.

Based on the consultation with the Aboriginal people of the Athabasca Basin, the key message was a desire to see the area put back to a state that reflects what the area looked like prior to the presence of the large-scale development. There was also an emphasis on cleaning up the site as opposed to what is perceived as a “cover-up” type of remediation. Cleaning up the site, to the local Aboriginal communities, means an effort to remove foreign objects and material, to remove and/or contain contamination and to redevelop the natural environment.

For all stakeholders, including the government bodies and regulators, the aim of this remediation Project is to reduce the risks posed by the Gunnar Site to health, safety, and the environment. Proposed site remediation measures are based on the assumption that the site should be returned to a state that supports the safe future use for casual visits to the site and traditional land-use including hunting and fishing in the vicinity of the site. Although the proposed post-remediation land use for the mining facility footprint is suggested as “industrial”, the Gunnar Site Remediation Project is designed to minimize the need for care and maintenance activities, and long-term institutional control taking into consideration socio-economic factors.

An important aspect of Project CLEANS is the engagement of the interested Aboriginal communities, both through providing information on the project as well as receiving feedback and advice. One of the key mechanisms to providing information to the Aboriginal communities and to gain their input for consideration during project planning and implementation is through community engagement. This can be accomplished through community meetings, surveys, and other mechanisms and forums. SRC has successfully communicated project information and gained valuable input from interested Aboriginal community members through more than 120 engagement meetings held in the region. **Table 7.1** provides a summary of the community engagement meetings held in 2014.

Table 7.1
Summary of community engagement meetings in 2014.

Meeting	Meeting Date; Location	Participation / Purpose
January Community Meetings	January 14-16, 2014: Black Lake, Stony Rapids, Uranium City	• Mark Calette, Ian Wilson, Chris Reid, Dianne Allen, Skye Ketilson from SRC attended and presented on Project CLEANS progress. • George Bihun from the Ministry of Environment attended and Ron Stenson and Adam Levine from CNSC presented. • Brent Saive from NUNA logistics presented as the Lorado contractor. • Poor weather kept us from flying to Fond du Lac and a funeral kept us from Hatchet Lake.
Northern Saskatchewan Environmental Quality Committee Meetings	February 25-26, 2014; La Ronge	• Mark Calette and Dianne Allen presented an update to committee members and others on the status of Project CLEANS.
Community Meeting	March 18, 2014; Fond du Lac	• Mark Calette, Ian Wilson, Chris Reid, Dianne Allen, Skye Ketilson from SRC attended and presented. • Trevor Dwyer from NUNA logistics presented. • Mark Calette, Ian Wilson, Chris Reid, Allan Adam and Vice Chief Tsannie met with Chief Lidguerre about potential options for Fond du Lac to clean up Homer Yellow Knife site.
Met with Vice Chief Tsannie of Prince Albert Grand Council	June 5, 2014; PAGC Offices in Prince Albert	• Mark Calette, Ian Wilson and Joe Muldoon gave Vice Chief Tsannie a full report on Project CLEANS and how Lorado was progressing.
Met with Metis Nation - Saskatchewan Representatives from Athabasca and Northern Regions	June 21, 2014; Saskatoon	• In Attendance: Area Director Region 10 Earl Cook, Local President Uranium City and Camsell Portage Allen Augier, Local President Stony Rapids, Curtis Fiss, Area Director from Northern Region 3 Pinehouse Glen McCallum, Full Project Cleans update. • SRC: Mark Calette and Dianne Allen.
Met with PAGC Representatives in Saskatoon about partnering on Northern Training Initiative	June 27, 2014; Saskatoon	• In Attendance: Joan Strong and Rosalie Tsannie Burnseth from PAGC. • Discussed how we could support their training program and the gathering of northern inventory of training needs. • SRC: Mark Calette and Ian Wilson.
Athabasca Sector Gathering	July 2 & 3, 2014;Hatchet Lake and Wollaston	• Ian Wilson attended on behalf of SRC. • SRC also made a financial contribution to gathering to help provide food for delegates.
Signing Ceremony of SRC and PAGC on the Inventory Gathering of Training Needs for the Athabasca Region	July 15, 2014; Saskatoon	• In Attendance: Joan Strong and Rosalie Tsannie Burnseth from PAGC. • SRC contributed $25,000 to partner on the PAGC training initiative. • SRC: Mark Calette, Ian Wilson, Jesse Merilees.

Table 7.1 cont'
Summary of community engagement meetings in 2014.

Meeting	Meeting Date; Location	Participation / Purpose
Meeting with Dianne McDonald, Darryl McDonald and Terri-Lynn Beavereye	July 29, 2014; Saskatoon	• In attendance: Ministry of Economy – Hal Sanders and Richard Turkenheim SRC Attendees: Mark Calette, Ian Wilson, Joe Muldoon and Jesse Merilees
Sent Update Letter to Athabasca Chiefs about Project Cleans. Attendees at the July 29th meeting also recieved a copy of the update.	September 12, 2014	*The letter was sent to:* *Chief Rick Robillard* *Chief Earl Lidguerre* *Chief Bart Tsannie* *Vice Chief Joseph Tsannie – PAGC* *Ministry of Economy – Hal Sanders and Richard Turkenheim* *Mark Calette, Ian Wilson, Joe Muldoon* *Dianne McDonald, Darryl McDonald and Terri-Lynn Beavereye*

7.2 Current Consultation Activities

A critical aspect to successful implementation of a remediation plan is to have all stakeholders, including both governments, the regulators and the Aboriginal people of the Athabasca Basin, fully engaged and supportive. The Project Team understands that communicating the proposed remediation plans in an open and transparent way will be very important in order to create support for the plans.

SRC, with support from the Project Team and SRK Consulting, conducted a Workshop at the Site from June 3 to 5, 2015. Participants included community members and elders from Prince Albert Grand Council, Wollaston Lake, Metis Nation Saskatchewan/Stoney Rapids, Hatchet Lake, Fond du Lac Denesuline First Nation, Athabasca Chipewyan First Nation, and the Saskatchewan Ministry of Environment. SRC and OKC personnel conducted a site tour, completed question-and-answer sessions as well as delivered presentations that gave an overview of the site, disseminated information regarding the proposed design process and proposed endpoints, and discussed challenges to site-wide remediation. In addition, participants contributed information with regards to their observations and historic knowledge of the site. This workshop also allowed free and open dialogue between community members, SRC, and the remediation consultants. The Project Team provided details on the plan for the Tailings Remediation designs, including renderings of the final landforms in the presentation and hard copy for participants to review. The presentations prepared by SRC and the Project Team, in addition to draft workshop minutes, are provided in **Appendix F.**

SRC conducted another Workshop on July 28th, 2015 in Saskatoon. The purpose of this meeting was to review the conceptual designs for all other site aspects as presented by SRK Consulting. OKC participated in this meeting in order to answer questions relating to the plans for tailings remediation. Participants included community members and elders from Prince Albert Grand Council, , Metis Nation

Saskatchewan/Stoney Rapids/Uranium City, Hatchet Lake First nation, Fond du Lac Denesuline First Nation, Black Lake First Nation, Mikisew Cree First Nation, Athabasca Chipewyan First Nation, as well as representatives from the Saskatchewan Ministry of Environment, the Saskatchewan Environmental Society, and the CNSC.

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9 CLOSURE

O'Kane Consultants Inc. (OKC) and Ecometrix Inc. (Ecometrix) prepared this report for the account of Saskatchewan Research Council. The material in it reflects the judgement of the Project Team in light of the information available to the Project Team at the time of report preparation. Any use which a third party makes of this report, or any reliance on decisions to be based on it, is the responsibility of such third parties. OKC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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Yours sincerely,

O'KANE CONSULTANTS INC.
per:

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APPENDIX A

Drawings

APPENDIX C

GMT Phreatic Surface and Groundwater Flow Rate Assessment

APPENDIX D

Borrow Material Suitability and Volume Estimates

APPENDIX E

Failure Modes and Effects Analysis

APPENDIX F

Presentations by SRC and OKC and Draft Meeting Minutes for June 3-5, 2015 Stakeholder Meeting

APPENDIX G

Predicted Loadings to Langley Bay and St Mary's Channel for Sensitivity Scenarios