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

Great Bear Lake Sites Remediation Project

Appendix O Remedial Action Plans

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Affaires autochtones et du Nord Canada

Appendix O-1

Report: Silver Bear Mines Remedial Action Plan with Project Update

Canada

Indigenous and Northern Affairs Canada　Affaires autochtones et du Nord Canada

Appendix O-1

Report: Silver Bear Mines Remedial Action Plan with Project Update – PART 1

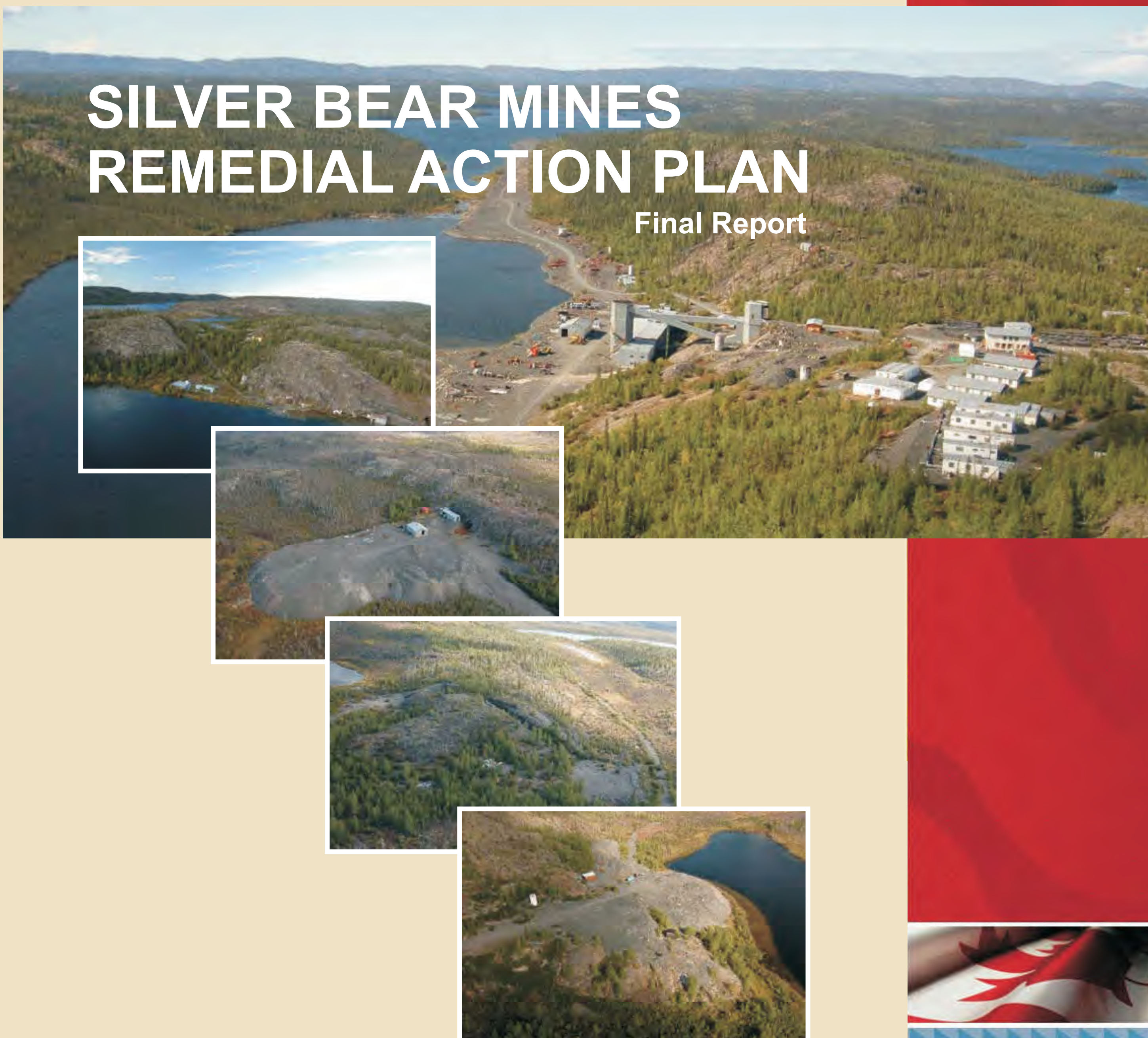
Canada

Public Works and Government Services Canada

Travaux publics et Services gouvernementaux Canada

SILVER BEAR MINES REMEDIAL ACTION PLAN

Final Report



Public Works and Government Services Canada

March 2008

Canada

Public Works and Government Services Canada

FINAL Remedial Action Plan

Silver Bear Mines, NT

March 2008

FINAL Remedial Action Plan

Silver Bear Mines, NT

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Summary

The Silver Bear Mines are five former mining sites located close to the Camsell River, near Great Bear Lake in the Northwest Territories. These include Terra Mine, Northrim Mine, Norex Mine, Graham Vein and Smallwood Mine. While exploration and initial small scale operations were initiated in the 1930s, the time of major activity and production of silver and copper concentrates only occurred between 1969 and 1985, with the most extensive mining and ore processing activities and infrastructure occurring at Terra Mine.

Between 1978 and 1985 the mines were abandoned by their developers and the sites are now the responsibility of Indian and Northern Affairs Canada (INAC). In recent years, INAC has completed intensive monitoring in the mine areas and assessed the need for remediation work to protect human health and the environment in the long term.

Issues relating to remediation of the sites include chemical and physical concerns. The chemical concerns include contaminated water, contaminant sources such as waste rock and tailings, spills of hydrocarbon products, and several types of hazardous materials. The physical hazards include mine openings (e.g. adits, shafts, vents, stopes to surface, and open cuts), an open pit, deteriorating buildings, waste materials and site infrastructure. This Remedial Action Plan (RAP) has been developed to effectively mitigate potential impacts associated with these chemical and physical concerns.

Included in this document are a description of the traditional use of the area and the history of mining activity, a description of current site conditions, a review of the state of the environment around the mines, an assessment of potential human health or ecological risks posed by the mines, a summary of key issues relating to potential remediation, a review of the remediation methods that might be used to address concerns, a description of the preferred remediation methods, a review of monitoring requirements, and a discussion of the anticipated remediation schedule.

A key component in the development of the RAP was consultation with the local Sahtu and Tłı̨chǫ communities. Community representatives toured the sites and participated in a series of meetings that reviewed potential reclamation options and provided input regarding their preferred options, acceptable options and unacceptable options. This input was a key consideration in the development of the final plan which focuses on risk reduction and the remedial actions preferred by the community's representatives. Additional feedback from the communities is expected once the community representatives present the selected preferred options for consideration by the communities as a whole.

The proposed remedial action plan is summarized in Table E.1 at the end of this section. Selected highlights of this plan are discussed in the following sections.

Mine Openings

The mine openings represent serious physical risks to people and animals. Some of these openings are not covered and are readily accessed. Issues include falling hazards for people and animals and potential for poor air quality. The mine openings include:

- 17 vertical shafts that will be reclaimed by placing a concrete cap over the openings. The local communities also considered backfilling of shallow vertical openings with local waste rock as a preferred method;
- 12 portals and adits openings that will be backfilled with local waste rock;
- 7 open stopes and trenches that will be backfilled with waste rock. Contaminated waste rock will not be placed in openings with running water. In some cases, the open stopes and trenches can also be used to dispose of local demolition debris;
- 1 open pit at Terra mine, a portion of which is a candidate site for use as a non-hazardous waste landfill.

Only one portal located at Norex produces any significant quantity of seasonal drainage. The portal discharges across the edge of the Norex waste pile which contributes to additional loadings of contaminants from the waste pile. As discussed below, the drainage will be diverted around the pile to reduce the potential for flushing contaminants from the waste pile.

Waste Rock

Waste rock is located at all the mine sites. Overall, there is more than 450,000 m^3 of waste rock of which about 10-20% has the potential to generate acid. The waste rock has been on surface for 30-40 years and appears to be having minimal effects on local water quality in the lakes and rivers of the area. This is illustrated by the low levels of metals and sulphate in lakes where waste rock has been placed in and beside (SO_4 level is typically <20 mg/L). The proposed plan is to minimize drainage through the piles by diverting surface runoff flows around the sites where appropriate, use of natural attenuation in wetlands to provide ongoing treatment of the drainage, and selective removal and backfilling of problematic waste in open stopes and trenches which will be covered after waste placement.

Tailings and Water Quality

Tailings are located at 3 sites. Tailings are in some cases acid generating and may contain elevated levels of metals. The proposed plan to remediate these areas and reduce risks is indicated below:

- Terra Mine-Ho Hum Lake TCA (Tailings Containment Area) - 2,200 m^2 of exposed tailings. These tailings will be covered with waste rock and/or soil to reduce potential for contact with people and animals. It is believed these tailings have minimal effect on Ho Hum Lake TCA water quality.

- Terra Mine-Ho Hum Lake TCA- ~500,000 t (metric tonne) of submerged tailings. Ho Hum Lake TCA has above background levels of metals (notably arsenic at ~80 µg/L and copper ~9 µg/L). These levels have been stable over the past 5 years. The lake discharges through a wetland to Moose Bay on the Camsell River. Monitoring at Station T-10 in Moose Bay has shown that effects in Moose Bay are only measured in the immediate vicinity of the discharge. Minimal ecological effects are predicted. The plan is to leave the tailings in place and to lower the water level in the lake to restore the former upper wetland which was degraded when the lake level was raised. The existing wetland areas are functioning well to reduce copper and arsenic levels in the lake discharge. The existing dyke near the outlet of the lake will be rebuilt with a low permeability core and provided with a closure spillway. This should stabilize water levels and enhance natural wetland formation and attenuation of arsenic.

- Northrim Mine has 1,600 m^2 of exposed tailings and smelter waste in and around the Leachate Pond. These materials will be covered with till and waste rock and the Leachate Pond will be partially backfilled.

- Northrim Mine also has about 10,000 t submerged tailings. The majority of these tailings were deposited in Hermandy Lake TCA, but a small quantity was also deposited in the Camsell River near the dock. Hermandy Lake TCA water quality is relatively good with only a few parameters exceeding CCME objectives and ecological impacts are projected to be minor. No degradation of water quality is observed in the Camsell River. The proposed plan is to leave the tailings in the river and to restore the drainage to the former outlet of Hermandy Lake TCA. This will be achieved by backfilling a portion of Leachate Pond and removing the dyke at the former outlet of the lake.

- Norex - A portable mill operated at Norex for a brief period and produced perhaps 1,000 t of tailings that were discharged towards the Xeron Pond near Graham Vein. Sampling has failed to identify the tailings in the pond. Given the minor effect on water quality, the proposed plan is to leave Xeron Pond undisturbed.

Buildings and Equipment

The existing buildings are deteriorating and are a safety hazard. Some buildings contain equipment, materials and residual chemicals. The proposed plan is to decontaminate the buildings and equipment as appropriate, salvage or recycle any equipment or material of value, and demolish and dispose of all buildings and structures.

Non-Hazardous Wastes

The Silver Bear sites include a substantial amount of refuse strewn throughout the various sites. This material, along with non-hazardous demolition debris and waste from existing landfills will be disposed in non-hazardous landfill sites. A portion of the former open pit at Terra has been selected as a candidate site for the landfill although other sites could be considered. This site will accept all debris from Terra, Norex, Graham Vein and Smallwood. The Graham Vein may also be considered for disposal of non-hazardous waste from Norex, Graham Vein and Smallwood. At Northrim, the small amount of refuse will either be: transported to the Terra Landfill; disposed in Leachate Pond before backfilling; or disposed in a separate on-site landfill. The total amount of debris identified by Rescan in the demolition report (Rescan 2005a) is about 18,000 m^3. This does not include general refuse dispersed around the sites (~2,000 m^3) and waste from the existing landfill sites (~6,750 m^3).

Hazardous Wastes and Asbestos

There is a substantial inventory of waste materials that include asbestos, lead paint, old lime, residual mill reagents and hydrocarbons. This includes about 140,000 L of waste hydrocarbons stored in drums. While the majority of the hydrocarbons in drums will be incinerated directly, a portion of the waste is oily water that will require pre-treatment before incineration. A central hazardous waste disposal site has been tentatively proposed at the Terra Mine site. This site will be designed with an under-liner and capped with a low permeability cover. The site will store hazardous materials from the demolition activities (approximately 1050 m^3), hydrocarbon contaminated soils which cannot be managed in place (approximately 3,500 m^3), any hazardous material found in the existing surface waste disposal sites (waste batteries identified) and miscellaneous materials such as residual concentrate stored at the site.

Roads

The site has about 18 km of roads. These roads are constructed from local borrow materials and waste rock to varying degrees. Many of the roads have become overgrown with alders and provide browse and cover for local animals. The roads are not hazards to local animals and no environmental effects from the roads have been measured. The RAP (Remedial Action Plan) for the roads is to remove the culverts and to allow the roads to naturally re-vegetate. Many of the roads may also require upgrading as part of the reclamation program. DFO (Federal Department of Fisheries and Oceans) would be consulted to assure any new culverts installed or culverts removed at closure would be done with fisheries approval where appropriate.

Waste Disposal Sites

Terra Mine has 3 surface waste disposal sites. Norex, Graham Vein and Smallwood have no defined disposal areas. The plan for Terra is to excavate the sites and relocate the non-hazardous waste to a new landfill. A preliminary estimate of the waste to be relocated is 6,750 m^3 from the waste disposal sites and 2000 m^3 of general refuse strewn about the sites.

Hydrocarbon Contaminated Soils

There is extensive hydrocarbon contamination, primarily of the waste rock lay-down areas, around the mine sites. EBA, in EBA 2006b, have identified about 30,000 m^3 of hydrocarbon contaminated soils. Observations and water quality monitoring are not detecting any material impacts from the current contaminated soils/waste rock which have been in place for 20-40 years. Hydrocarbon contaminated soils identified by EBA as potential candidates for monitoring and management in-place will be covered to eliminate any exposure to animals and monitored. For those soils/waste which are in sensitive areas not suited to management in-place (2,700 m^3), these soils will be excavated and disposed of in a purpose-built cell within the hazardous waste landfill site.

Airstrips

There are two airstrips at the site: the Terra Mine airstrip currently being used by INAC and local exploration companies, and; the Smallwood mine airstrip which has been abandoned and is partially overgrown with vegetation. The RAP is to leave the Smallwood airstrip as is and to follow Transport Canada requirements for abandonment of the Terra airstrip once it is no longer required to service reclamation activities.

Docks

There are three docks on wooden piers on the Camsell River; one at Terra, one at Northrim and one at Norex. The RAP is to remove the docks, excavate and fill materials and stabilize the shorelines.

This RAP references a series of reports previously referenced as supporting documents (SD A through O). These documents provide details of scientific and engineering studies completed since 2004 and are retained by Indian and Northern Affairs Canada

Table E.1 Summary of Preferred Remedial Plan

Site Component	Terra Mine	Northrim Mine	Norex Mine	Graham Vein	Smallwood Mine
Mine Openings	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill trench with waste rock • Use rock from Smallwood Mine as backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill
Waste Rock	• Improve drainage • Monitor	• Relocate waste by the River to Leachate Pond • Leave main pile as is • Monitor	• Re-direct mine drainage away from waste rock pile with open channel • Monitor	• Leave as is • Monitor	• Relocate some problematic rock to Graham Vein trench • Monitor
Tailings	• Cover exposed tailings with waste rock • Lower Ho-Hum Lake level and outlet dyke; construct spillway • Use natural wetland to reduce arsenic in Ho-Hum Lake discharge	• Cover exposed tailings with waste rock • Cover smelter process waste • Partially backfill Leachate pond and re-direct Hermandy Lake outflow	n.a.	• Leave as is • Monitor	n.a.
Buildings and Equipment	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in new landfill • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons on-site	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in leachate pond , or new landfill • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons on-site, or at Terra Mine	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in new landfill • Dispose of hazardous materials in secure landfill Incinerate most waste hydrocarbons on-site, or at Terra Mine	• Demolish all structures • Dispose of non-hazardous waste at Graham Vein or new landfill	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in landfill at Terra Mine • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons at Terra Mine
Roads	• Construct drainage swales at major drainage crossings on haul road	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary

Table E.1 Continued

Site Component	Terra Mine	Northrim Mine	Norex Mine	Graham Vein	Smallwood Mine
Airstrips	• Remove any markings • Advise Transport Canada of un-maintained status	• No action necessary	• No action necessary	• No action necessary	• No action necessary
Waste Disposal Sites	• General cleanup of all rubbish for disposal in New Landfill	• General cleanup of all rubbish for disposal in leachate pond or New Landfill	• General cleanup of all rubbish for disposal in New Landfill	• General cleanup of all rubbish for disposal in open trench or New Landfill	• General cleanup of all rubbish for disposal in Graham Vein open trench or New Landfill
Docks	• Remove Docks and stabilize banks • Remediate contaminated soil or fill	• Remove Docks and stabilize banks • Remediate contaminated soil or fill	• Remove Docks and stabilize banks • Remediate contaminated soil or fill		
Hydrocarbon Contamination	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the hazardous landfill site	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the hazardous landfill site	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the hazardous landfill site		• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the hazardous landfill site

Table of Contents

List of Tables

List of Figures

Glossary of Terms

Aboriginal land claim: A claim to a specific area of land based on legal concepts of land title and the traditional use and occupancy of that land by aboriginal peoples who did not sign treaties, nor were displaced due to war or other means.

Acid generating: Material capable of or actually producing acidic drainage.

Acid Mine Drainage (**AMD**)**:** Any water draining mine workings or mine wastes which has a pH less than 4.5. It results from the oxidation of exposed sulphide mineralization which produces sulphuric acid and sulphate salts.

Acid Producing Potential (AP or APP): The potential of a material to produce acid, generally stated as kg $CaCO_3$ equivalent per tonne of rock.

Acid Rock Drainage (ARD): Drainage of low pH water from mineral areas as a result of the oxidation of sulphur-bearing materials which may release metals into the environment and result in significant environmental impacts.

Activity: A measurement of the number of becquerels of a radioactive species in a sample.

Adit: A nearly horizontal passage from the surface by which a mine is entered and dewatered. A blind horizontal opening into a mountain, with only one entrance.

Aerial photography: Photographs taken from an aircraft either obliquely or vertically.

Algae: Photosynthetic plants which live and reproduce entirely immersed in water. They range in size from simple, single-celled organisms to huge kelps several metres long.

Alkalinity: The aggregate measure of the concentration of hydroxyl, carbonate and bicarbonate ions, and dissolved CO_2. Therefore, it is a general indicator of the acid-buffering capacity of the water body.

Analytic detection limit: The limit of measurement of a given parameter, below which variations in concentration are indistinguishable from one another.

Asbestos: A naturally occurring soft fibrous mineral commonly used in fireproofing materials and considered to be highly carcinogenic.

Background radiation: The radiation in the natural environment, including cosmic rays and radiation from naturally radioactive elements. It is also called natural radiation.

Baseline: See “Environmental baseline”.

Basement: The undifferentiated rocks (commonly igneous and metamorphic) which underlie the rocks of interest (commonly sedimentary) in a given area. In many regions the basement is of Precambrian age.

Bathymetry: The science of measuring the water depth relative to sea level.

Becquerel or Bq: A standard international unit of radioactivity, equal to one radioactive disintegration per second. The obsolete unit curie or Ci, based upon the amount of radioactivity in a gram of radium, equals 3.7×10^{10} Bq.

Bedrock: The solid rock that underlies gravel, soil or other surficial material.

Benthic: Refers to the bottom of a lake or river and/or the organisms that inhabit it.

Benthos: The whole assemblage of plants or animals living on the lake or river bottom; distinguished from *plankton*.

Best Management Practice (BMP): Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.

Bioaccumulation: The net accumulation of a chemical by an organism as a result of uptake from all routes of exposure.

Bioassay: Any method for quantitatively determining the concentration of a substance in plant or animal tissue.

Bioavailability: Degree of ability to be absorbed and ready to interact in organism metabolism.

Biological diversity (biodiversity): The variety of different species, the genetic variability of each species, and the variety of different ecosystems that they form.

Biological indicator species: See “Indicator species”.

Biomagnification: The tendency of some chemicals to accumulate to higher concentrations at higher levels in the food web through dietary accumulation.

Biosphere: Total of all areas on earth where organisms are found.

Biota: The animal and plant life of a region.

Bog: An acidic, poorly drained, rainwater fed peatland characterized by hummocks or sphagnum spp. Mosses with Labrador tea usually being the dominant shrub. Bogs may be treed with stunted black spruce and tamarack (muskeg) or may be open (open bogs).

Borehole: Hole made with drilling equipment typically to obtain samples.

Buffering capacity: The degree to which a given volume of water or soil is able to neutralize acids.

Carbonate: Any mineral containing CO_3 (carbonate) ions.

Carcinogen: An agent that has the potential to cause cancer.

Carnivore: An animal that eats the flesh of other animals.

Clay: Soil particles which are smaller than silt (less than 0.002 mm in diameter).

Collar: The mount or upper end of a mine shaft or drill hole.

Compliance monitoring: Monitoring of operations to ensure they comply with government regulatory standards and requirements.

Composite sample: A sample for analysis that is made up of two or more samples from the same sample site or a number of sample sites.

Conductivity: A measurement of the electrical conductivity of a water body or sample in order to determine the amount of dissolved material present.

Conservative: As used in the term conservative estimates, this is considered a pessimistic or an overestimate of the level, effect or hazard, as the case may be.

Consumers (primary, secondary, tertiary): Trophic levels in an ecosystem which obtain their energy from trophic levels positioned below them, e.g. primary consumers frequently feed directly on plants (primary producers) and secondary consumers would feed on primary consumers.

Contaminant migration: The movement of contaminants from one location to another.

Contamination: Elements both radioactive and non-radioactive that are present at levels above those normally found (i.e. above background).

Contingency plan: A prearranged plan to be implemented in the event of some unforeseen happening of serious concern.

Country food: Food that is derived from the local countryside and not associated with agricultural products (e.g., moose meat and wild blueberries) purchased through a store.

Crown or surface pillar: A body of rock of variable geometry, which may or may not contain minerals. Located above the underground operations, it supports the surface above stopes.

Decommissioning: The act of removing a regulated facility from operation and operational regulation. This usually entails a certain amount of cleanup (decontamination).

Decontamination: The process of removing contaminants from equipment, personnel, buildings or water.

Delineate: To determine the outer limits and size of something (i.e., an ore body).

Dip: A vertical angle measured downward from the horizontal plane to the level of an inclined plane such as a tilted sedimentary rock unit (see strike).

Discharge: The volume of water passing a given point per unit time, usually expressed as m^3/sec.

Dose: See **Effective dose** (unless otherwise specified).

Dose: A general term used to describe the amount of radiation or chemical absorbed by a person or in some cases a particular organ. The term dose can be used to describe two concepts. The first concept is a physical quantity; for radiation, it is the amount of energy absorbed per unit mass of tissue (see absorbed dose) and for chemicals, it is the concentration in tissue. This EIS uses the term dose to refer to effective dose (a measure of radiation exposure), unless otherwise stated.

Drainage basin: The area of land and water bodies therein, draining to a given point, usually a lake or river.

Ecological Risk Assessment: The application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial hazard identification, exposure and dose response assessments, and risk characterization.

Ecosystem: Any natural system in which there is an interdependence upon and interaction between living organisms and their physical environment. This interdependence is characterized by the transfer of energy between the organisms themselves and their physical environment in a complex series of cycles.

Element: A substance that is comprised of one and only one distinct kind of atom.

Environment: The sum of all external conditions, influences and forces affecting the development and life of organisms.

Environmental baseline: The data collection characterizing the "natural" environment in its pre-development or pre-impact state. This data is used as a base for determining potential and actual impacts in the defined impact area.

Environmental Assessment: An environmental analysis to determine whether a site / facility would significantly affect the environment and thus require a more detailed environmental impact statement.

Environmental Impact: A change in environmental conditions resulting from an action or development, which may be negative, positive, or neutral.

Erosion: The wearing down (weathering) and removal of soil, rock fragments and bedrock through the action of rivers, glaciers, sea and wind.

Evapotranspiration: The total return of water from the land to the atmosphere, including the process of evaporation from the soil surface and transpiration from plants.

Exposure: The amount of radiation or pollutant present in a given environment that represents a potential health threat to living organisms.

Exposure Assessment: Identifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number likely to be exposed.

Exposure Concentration: The concentration of a chemical or other pollutant representing a health threat in a given environment.

Exposure Pathway: The path from sources of pollutants via, soil, water, or food to man and other species or settings.

Fault: A fracture in bedrock along which movement has taken place.

Foot wall: The underlying surface of an inclined fault plane.

Fracture (geological): A crack, joint, fault or other break in rocks.

Rock fracture: The general term given to any non-sedimentary medicinal discontinuity thought to represent a surface or zone of mechanical failure.

Gamma radiation: The greatest penetrating power, but least ionizing, of the three principal forms of radiation from radioactive materials. Gamma radiation can completely penetrate and damage all body organs. Gamma radiation can be shielded effectively by several inches of lead, steel, or concrete, depending upon the shielding material and the energy and intensity of the gamma radiation.

Gauging station: A location where water depth (stage) is recorded.

Geochemistry: Refers to the chemical analysis of surface and subsurface water, rock alluvium, soil and plants.

Grab sample: A single sample taken for analysis purposes in a random manner.

Grade: The relative quantity or percentage of ore mineral content in an ore body (i.e., g/t Au or % U_30_8).

Grading: The process of making a surface level or evenly sloped.

Groundwater: Water beneath the earth's surface, accumulating as a result of infiltration and seepage, and serving as a source of springs and wells.

Habitat: The natural home of a plant or animal.

Hanging wall: The overlying surface of an inclined fault plane.

Hazard: Potential for radiation, a chemical or other pollutant to cause human illness or injury. Hazard identification of a given substances is an informed judgment based on verifiable toxicity data from animal models or human studies.

Hazard Assessment: Evaluating the effects of a contaminant or determining a margin of safety for an organism by comparing the concentration which causes toxic effects with an estimate of exposure to the organism.

Headframe: The structure surmounting the shaft which supports the hoist rope pulley, and often the hoist itself.

Heavy metals: Any metal with a high atomic weight (usually greater than 100). They are poisonous and tend to persist in living tissue once ingested, e.g. mercury, lead, cadmium and chromium.

Health and Safety Monitoring: Monitoring activities associated with the identification and monitoring of potential human health and safety hazards.

Human Health Risk Assessment: The process of quantifying risks and determining the acceptability of those risks to humans.

Hydraulic head: A combined measure of the elevation and the water pressure at a point in an aquifer which represents the total energy of the water; since ground water moves in the direction of lower hydraulic head (i.e. toward lower energy), and hydraulic head is a measure of water pressure, ground water can and often does flow 'uphill'.

Hydrogeology: The study of subsurface waters and related geologic aspects of surface water.

Hydrology: The study of the characteristics, occurrence, movement and utilization of water on or below the earth’s surface and within its atmosphere.

Impervious liner: A layer of clay or manmade material such as High-Density Polyethylene (HDPE), used to seal the bottom of containment structures in order to prevent percolation and migration of potential contaminants.

Indicator species (or biological indicator species): An individual plant or animal species that indicates the quality of the environment.

Incremental: Small increase.

Lay-down area: An open area for storing equipment or materials at a mine site prior to their use.

Leachate: The water which percolates through a porous medium such as soil and transports any salts or other dissolvable materials which may be found in the soil.

Leaching: Washing out of soluble substances by water passing down through rock or soil. In a milling sense, indicates the dissolving of ore minerals from the ground ore.

Limnological: Referring to the scientific study of lakes and their physical, chemical and biological components.

Loadings: Total mass of contaminants to a water body or to the land surface over a specified time.

Lower limit of detection: This is the lowest concentration of radioactive material in a sample that can be detected at the 95% confidence level with a given analytical system.

Macrophytes: Rooted aquatic vascular plants.

Maintenance Activities: Activities undertaken to ensure that conditions remain in the desired state

Manway: Vertical opening that can be used by miners to exit the underground workings. A shaft compartment used to accommodate ladders, pipes and electric cables. Underground usually a small passage used as a travelway for miners, an airway and supply route.

Mean: The average value of the data.

Measurement endpoint: A quantitative summary of the results of a toxicity test, a biological monitoring study, or other activity intended to reveal the effects of a substance.

Mine drift: A horizontal (or near horizontal) passageway in a mine through or parallel to a vein, or a secondary passageway between shafts or tunnels.

Mineral: A naturally occurring inorganic, crystalline solid that has a definite chemical composition and characteristic physical properties.

Mineralization: The process by which a valuable mineral or minerals are introduced into a rock, resulting in a potential or actual ore deposit.

Mitigation: An action or design intended to reduce the severity or extent of an environmental impact.

Modelling: Using mathematical principles, information is arranged in a computer program to model conditions in the environment and to predict the outcome of certain operations.

Monitoring: Sampling, measurement, and/or inspection.

Muskeg: A poorly drained bog composed of peat moss, decayed vegetable matter and black soil.

Muskrat Root: Acorus calamus is the botanical name of the plant more commonly known as calamus. Other common names of calamus include calamus root, flag root, muskrat root, sweet calomel, sweet flag, sweet sedge, and many other names.

Natural radioactivity: The property of radioactivity exhibited by more than 50 naturally occurring radionuclides.

Neutralizing potential (NP): The potential of material to neutralize an acid or a base.

Neutralizing Potential Ratio (NPR): The ratio of neutralizing potential to acid generation potential.

Ore: Naturally occurring rock material from which a mineral or minerals of economic value can be profitably mined.

Ore body: A continuous well-defined mass of material containing enough ore to make extraction economically feasible.

Outcrop: The part of a rock formation that appears at the surface of the earth, uncovered by water or overburden.

Overburden: Unconsolidated soil and rock material overlying bedrock.

Oxidation: The process of combining with oxygen, especially at the atomic level.

Particulate: Consisting of particles.

Pathway: The physical course a chemical or pollutant takes from its source to the exposed organism.

Pathways analysis: A method of estimating the transfer of contaminants (e.g. radionuclides released in water) and subsequently accumulated up the food chain to fish, vegetation, mammals and humans and the resulting radiological dose to humans.

PCB's (polychlorinated biphenyls): A group of manufactured chemicals including 209 different, but closely related, compounds made up of carbon, hydrogen, and chlorine. If released to the environment, they persist for long periods of time and can biomagnify in the food web. They are an organic toxicant suspected of causing cancer, endocrine disruption, and other adverse impacts on organisms.

Permafrost: Thermal conditions remaining below 0 ºC continuously for more than one year.

Permeability: Describes the ability of subsurface features to transport water.

pH: A number expressing the degree of alkalinity or acidity of a substance according to the hydrogen ion concentration. A substance is said to be “neutral” if its pH is 7, acidic if less than 7 and alkaline if greater than 7.

Phosphate ($P0_4$): A plant nutrient which, when present in water, may lead to excessive algal growth.

Phytoplankton: Any microscopic or near microscopic, free-floating autotrophic aquatic plant.

Piezometer: A piezometer is a small slotted standpipe, usually hand-driven into the ground, which is used to measure water pressure, seepage of groundwater, and groundwater movement. It also can be used to sample near–surface groundwater.

Population: A group within a single species, the individuals of which can and do freely interbreed.

Porosity: The relative volume of open spaces within a rock or soil. (Usually expressed as a percentage of the total volume of the material occupied by the open spaces, or interstices.)

Porewater: Water contaminated and trapped within void spaces in soils or rocks.

Potable water: Water that is fit for human consumption and use.

Precipitation: The deposition of atmospheric moisture as rain, sleet, snow, hail, frost or dew.

Prospector: An individual engaged in the search for economic mineral deposits, identifying minerals or mineral properties visually or with the use of portable instruments.

Pyrite: A common yellow mineral with a brilliant metallic lustre often crystallizing into cubes. It is an important sulphur ore and is often associated with gold and copper.

Radiation: The emission and propagation of energy through space or matter in the form of electromagnetic waves (e.g. gamma rays) or fast-moving particles such as alpha and beta particles.

Radioactive: The condition of a material exhibiting the spontaneous decay of an unstable atomic nucleus into a stable or unstable nucleus (e.g. uranium-238 decays into thorium-234 (unstable) and polonium-210 decays into lead-208 (stable)).

Radioactive decay: The spontaneous transformation of a radionuclide into a different nuclide. The transformation 7 results in the emission of ionizing radiation, often an alpha or beta particle. In some cases, gamma radiation is emitted along with the alpha or beta particle.

Radionuclide: An element or isotope which is radioactive as a result of the instability of the nucleus of its atom (e.g. radium or uranium).

Radon: A radioactive element in the U-238 decay chain produced by the radioactive decay of radium-226. Radon occurs as an inert gas. The half-life of Rn-222 is 3.8 days. Short-lived radon decay products or, daughters, are the principal radiation hazard in the underground mine. Decay of radon-222 and short-lived decay products produces lead-210.

Range: The upper and lower limits of a data set.

Reagent: A Substance used to cause a reaction (i.e., chemicals used in milling or water treatment).

Receptor: A human or ecological entity exposed to a contaminant released to the environment.

Reclamation: Restoration of a site to a beneficial use which may be for purposes other than the original use.

Remediation: The improvement of a contaminated site to prevent, minimize or mitigate damage to human health or the environment. Remediation involves the development and application of a planned approach that removes, destroys, contains or otherwise reduces the availability of contaminants to receptors of concern.

Remediation Issue: Issues of concern for a specific aspect of the site.

Risk: A measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard.

Risk Assessment: Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.

Runoff: The part of rainfall that is not absorbed directly by the soil but is drained off in rills or streams.

Screening: A preliminary stage of the assessment process for quick evaluation of relatively simple and routine activities, or for determining the level of effort required for evaluating more complex projects.

Sediment: Loose, solid particles resulting from the breakdown of rocks, chemical precipitation or from organisms.

Seismic: Pertaining to, characteristic of, or produced by earthquakes.

Sievert or Sv: A unit of equivalent or effective dose. In theory, the unit Sv should only be applied at low doses and low dose rates. Equivalent and effective doses are frequently expressed as millisievert (mSv), equal to one-thousandth of a sievert, or as microsievert (μSv), equal to one-millionth of a sievert.

Staff Gauge: A pole or 'staff" graduated in standard units of measurement for the purpose of measuring depth.

Stopes: Underground mine working from which one has been extracted for processing and metal recovery.

Strike: Refers to the direction taken by a structural surface as it intersects the horizontal plane e.g. bedding or fault plane. The strike is at right angles to the direction of dip.

Structure (geological): Features produced by deformation or displacement of the rocks, such as a fold or fault.

Sulphides: Any mineral compound characterized by the chemical linkage of sulphur with a metal e.g. galena (PbS), pyrite (FeS_2).

Sulphuric acid (H_2SO_4): A toxic, corrosive, strongly acid, colourless liquid that is miscible with water and dissolves most metals.

Taiga: The northern forest of coniferous trees that lies just south of the arctic tundra.

Tailings: Finely ground rock particle material rejected from a mill after most of the recoverable ore minerals have been extracted.

Tailings: Residue of raw material separated out during the processing of mineral ores.

Tailings Containment Area or TCA: An area designated for the purpose of receiving and containing milling residues.

Tank farm: An area designed to contain various size tanks holding various types of liquids or gases, most commonly propane or petro-chemicals.

Thermocline: The transition layer separating the upper warm layer (epilimnion) from the lower cold water layer (hypolimnion) in lakes which is characterized by a rapid decline in temperature.

Till: An unsorted heterogeneous mixture of rock debris carried and deposited directly by a glacier, with very little subsequent reworking by melt water.

Ton: Imperial Ton or 2000 pounds.

tonne: Metric tonne which is also shown as t and equals about 2200 imperial pounds.

Topographic map: A map showing elevations by means of contour lines (i.e. lines joining points of equal elevation).

Total dissolved solids (TDS): The sum of all the concentrations of dissolved ions in a solution usually expressed as mg/L.

Total suspended solids (TSS): The sum total amount of suspended solid material in a sample, usually expressed as mg/L.

Total suspended solids (TSS): Defined as all the material in a sample of water which can be removed by a 0.45 µm glass fibre filter.

Track-etch cup: A device for measuring alpha radiation associated with radon gas and its progeny.

Traditional knowledge: Refers to the ancient understanding of philosophy, events and things passed on orally through generations by aboriginal people.

Traditional land use: Refers to land use by aboriginal people which reflect the historic activities of their people prior to European settlement (i.e. hunting, fishing, gathering).

Traditional lifestyle: Refers to the lifestyle of aboriginal people prior to European settlement.

Turnover: A period of lake wide circulation in spring and fall when surface water layers and bottom water layers are able to mix together.

Uncertainty: A quantitative expression of error.

Uptake: The process/act by which a contaminant (e.g. a radionuclide) enters a biological organism (e.g. inhalation, ingestion by humans).

Vent: An (vertical) opening used for input of fresh air or exhausting used air from underground.

Vent Raise: See Vent.

Waste rock: That rock or mineral which must be removed from a mine to keep the mining scheme practical, but which has no economic value.

Watershed: A drainage area or basin into which all surface water from a particular area collects and is transported.

Zooplankton: Any microscopic or nearly microscopic animals that move passively in aquatic ecosystems.

1 Introduction

Silver Bear Mines is the name used to refer collectively to five former mining sites close to the Camsell River, near Great Bear Lake in the Northwest Territories. These include Terra Mine (also known as Silver Bear Mine), Northrim Mine, Norex Mine, Graham Vein and Smallwood Mine. Mineral exploration and mining activities occurred at these sites from the 1930's with the greatest period of activity from 1968 to 1985. Silver and copper concentrates were the primary products and no mining has occurred since 1985.

These sites were abandoned by their developers between 1978 and 1985. The companies subsequently became insolvent and the sites are now the responsibility of the Contaminants and Remediation Directorate (CARD), of Indian and Northern Affairs Canada (INAC). The proven economic mineral reserves at all of the sites were exhausted; however, based on current economic conditions, one could not discount the potential future development of new or reopened existing mines. In fact, it is understood that active exploration is occurring both on the Silver Bear mine claims as well as surrounding lands.

Issues relating to remediation of the sites include chemical and physical concerns. The chemical concerns include contaminated waters, contaminant sources such as waste rock and tailings, hydrocarbon spills, residual concentrate, gaseous emissions and stored hazardous wastes. The physical hazards include mine openings, open pits, buildings, waste materials and site infrastructure. This remedial action plan has been developed to effectively mitigate any potential impacts associated with the chemical and physical concerns.

The purpose of this document is to identify the concerns requiring remediation, identify remediation methods that could be used to address these concerns, indicate the preferred remediation methods and show how they were selected, and to demonstrate the effectiveness and technical feasibility of the preferred methods. Detailed plans and engineering designs will be developed for each remediation measure as the project moves towards implementation.

1.1 Site Location and Access

The Silver Bear Mines are located approximately 390 kilometres north of Yellowknife, Northwest Territories, within the Sahtu settlement area. The mines are all within two kilometres of Rainy Lake, part of the Camsell River, which drains into Great Bear Lake just north of the Silver Bear Mines. The Camsell River, with a drainage area of 31,000 square kilometres, is the largest single tributary of Great Bear Lake. The location of the project area is shown in Figure 1.1.1. The nearest communities are Déline, 250 kilometres west of the mines on the western shore of Great Bear Lake, and Gamètì, 166 kilometres to the south. The land and water in the Silver Bear Mines area have traditionally been used by the people who now live in these communities.

The site is very remote, with principal access by air for personnel and routine supplies. For transport of heavier loads, such as fuel and heavy equipment, access may be available across Great Bear Lake from Déline either by boat or barge in the open water season, or by ice road in the winter. Access by ice road from Gamètì may also be feasible (see Figure 1.1.2 showing historic winter road). The total distance by ice roads and highways from the major supply centre of Edmonton, Alberta, is over 1,500 kilometres.

1.2 Site Status

The site is currently in a "Care and Maintenance" phase, which means that recent activities on site have been limited to environmental monitoring, site assessment, and the management of any immediate hazards to human health and safety, or the environment. The focus of activities has been to ensure the safety of all workers and visitors, protect the environment and develop the remedial action plan (RAP). In recent years this has been accomplished by preparing and utilizing the existing camp facilities to accommodate small teams of project staff, technical specialists, and workers from Déline. Since 2002 the monitoring and assessment work has been completed primarily in the period from June to September.

The mobile equipment on site includes several all terrain vehicles (ATVs), one light truck and one jeep. A small ATV mounted back-hoe excavator has been used for some of the site assessment work. Two boats with outboard motors are available to travel on the Camsell River and access lakes for monitoring. The airstrip is in poor condition and use of the runway is at the pilot's discretion. The majority of flights carrying personnel and supplies to the site are currently made with float planes.

1.2.1 Land Tenure

The Silver Bear Mines lie within the Sahtu Settlement Area and the overlap area with the Tłı̨chǫ Mǫwhì. There are no federal land leases or special land reserves in effect in the project area. Any Land Use Permits or Water Licences that are required to implement the remedial action plan would be issued by the Sahtu Land and Water Board. INAC-CARD does not currently hold a Land Use Permit or Water Licence because the limited extent of work being done at the site does not require them. Cooper Minerals has a land use permit and is undertaking a mineral exploration program on and around the Silver Bear sites.

1.2.2 Mineral Tenure

Active mineral claims cover the entire project area. The major mine infrastructure is found within the boundaries of five active claims (Claim Numbers F91557, F91558, F98364, F91460 and F80574). The claims were all recorded in 2005 and are registered in the names of three separate individuals (Data Authority - Mineral Claims, Mineral Leases and Prospecting Permits Database).

Two mineral leases issued to separate companies in 1979 and 1983 are still in effect in the project area. These cover two small zones between Terra Mine and Norex Mine, located away from the major site infrastructure, but including mine access roads.

The mineral tenure and legal rights of claim owners will be respected by INAC in the implementation of the remedial action plan. INAC will consult with holders of mineral rights on remediation activities affecting site access and potential exploration activities.

1.2.3 Heritage Values

The NWT Mining Heritage Society has toured the site and has identified the types of mining equipment with potential heritage values. A copy of their reports, which illustrates the types of equipment of interest, is included as NWT MHS 2006. Future discussions with the Heritage society will be required to assess whether this equipment may be salvaged for its historic value.

1.3 Policies and Guiding Principles for Remediation

The Silver Bear Mines are under the management of CARD. CARD works within a broader management system for all northern contaminated sites and must follow several guiding documents while managing and developing final remediation plans for the Silver Bear Mines. The following policies or guidance documents provide the broad context as to how CARD approaches remediation of contaminated sites in northern Canada:

- Treasury Board Federal Contaminated Sites Management Policy (Treasury Board 2002);
- Northern Affairs Program Contaminated Sites Management Policy (INAC 2002a);
- A Federal Approach to Contaminated Sites (CSMWG 2002);
- Abandoned Military Site Remediation (INAC 2005a);
- Reclamation Guidelines for Northern Canada (INAC 2006a).

The policies and principles in these documents of particular importance in the remediation of Silver Bear Mines are:

- Meet the overall INAC objective to contribute to a safer, healthier, sustainable environment for Aboriginal peoples and northern residents by striving to preserve and enhance the ecological integrity of the environment (Northern Affairs Program Contaminated Sites Management Policy, INAC 2002a);
- Take immediate and reasonable action to protect the environment and the health and safety of persons (Treasury Board Federal Contaminated Sites Management Policy, Treasury Board 2002);
- Meet federal and INAC policy requirements and legal obligations regarding the management of contaminated sites (Northern Affairs Program Contaminated Sites Management Policy, INAC 2002a);

- Ensure sound environmental stewardship of federal real property by avoiding contamination and by managing contaminated sites in a consistent and systematic manner that recognizes the principle of risk management and results in the best value for the Canadian taxpayer (Treasury Board Federal Contaminated Sites Management Policy, Treasury Board 2002);
- Provide a scientifically valid, risk management based framework for setting priorities, planning, implementing and reporting on the management of contaminated sites (Northern Affairs Program Contaminated Sites Management Policy, INAC 2002a);
- Develop a Remediation Plan to be sufficiently flexible to allow adjustments as the remediation progresses, including the flexibility to adapt to new and improved technologies and methodologies (Mine Site Reclamation Policy for the Northwest Territories, INAC 2002b);
- Adopt solutions tailored to the northern environment and peoples wherever possible; (INAC 2006b - management framework).

The following Land Claim agreements are of particular importance to the Silver Bear Mines as they govern the consultation approach and economic benefits for future contracts regarding the site:

- Sahtu Dene and Metis Comprehensive Land Claim Agreement (1993); and,
- Tłı̨chǫ Land Claim and Self Government Agreement (2003).

1.4 Community Involvement

The communities of Déline and Gamètì (beneficiaries of the Sahtu and Tłı̨chǫ Settlement Areas) have assisted with the development of the remediation plan for the Silver Bear Mines via many avenues.

Over the past five years, people from Déline have participated in the water quality and environmental investigations at Silver Bear. The results of these investigations have been presented to the communities of Déline and Gamètì each fall and meetings have been held in each community to understand people’s concerns with the abandoned mine sites.

Over the summer of 2007, representatives of the local communities formed a committee to review potential options for reclamation of the site. Community participants included members from Déline because they are within the Déline District of the Sahtu Settlement Area members from Tłı̨chǫ representing each community because the sites are within the Mowhi.

The community representatives have toured the site and participated in workshops to rank the alternatives. A key consideration in the workshops was the selection of goals and objectives for the Silver Bear Reclamation Plan. The goals and objectives were adapted from a previous program and agreed to by all parties. From the workshops, the communities have provided input as to their preferred options, options that are acceptable and options that are unacceptable. These reviews provided key input to the development of the RAP. Copies of the summary tables from the review of the alternatives for reclamation of the site are provided in Appendix 1.

Major meetings and presentations have included:

- June 26th, 2007: Presentation to the Déline community on background information regarding the RAP and site conditions at the Silver Bear Sites.
- July 12 and 13, 2007: Meeting with the community representative committee in Yellowknife to provide site overviews, issues and concerns and discuss the methods, goals and objectives for evaluation of the options for the RAP.
- August 22 to 24, 2007: Site visit to Silver Bear Mines by the community committee representatives from Déline, Gamètì, Behchokǫ̀ and Whatì. This visit included a meeting to review goals and objectives and initiate the review of the options for the RAP.
- September 5 and 6, 2007: Meetings in Déline with the community committee representatives to continue with the review of the options for the RAP.
- September 17-19, 2007: Meetings in Yellowknife with the community committee representatives to continue with the review of the options for the RAP.

Presentation materials and minutes for the meetings are provided in Appendix 1.

Traditional Knowledge studies have been completed with elders, hunters and trappers, residing in both Déline and Gamètì, who use the area around the Silver Bear Mines. This information has been used to focus remediation efforts and identify environmental risks on site. Joachim Obst 2007 contains results of a survey on Traditional Land Use.

2 Site History

2.1 Traditional Use of the Area

The area around the Silver Bear Mines has been used traditionally by Déline people of the Sahtu and Gamètì people of the Tłįchǫ. To assist in the development of remedial options for the mine sites, a cultural land use survey of elders and hunters from Gamètì and Déline using the area around the mines was conducted. The survey collected information on wildlife and cultural land use prior to mining in the 1970's and documented changes that may have occurred during and after the mining operation which ceased in the mid 1980's (see Joachim Obst, 2007). In December 2006, twelve elders and hunters from Gamètì were interviewed by G. J. Lafferty (INAC 2006c). In 2005, a similar survey was conducted in Déline by J. Vandermeer (INAC 2005b).

Elders and hunters reported that the Silver Bear Mines area has been a traditional harvest ground for country food, fur, fish, berries and plants. Before and after 1970, people hunted, trapped and fished around the mines from early October to April. In the past they travelled by dog teams which required lots of fish and meat, but nowadays snowmobiles are used and less meat and fish are required. Some people from Gamètì also visited the area in spring, and by boat in the summer, to fish and hunt. Sometimes they collected berries and plants for food, tea or medicinal use. People from Déline tended to travel and hunt in the area more during summer months. Three known burial sites are located south of the mines but more may be in the area.

Prior to the mine operation, before 1970, Barren-ground caribou were reported as healthy in the area. During and after the mine operation, many hunters from Gamètì were concerned that caribou, moose and the food chain may have been affected by contaminants from the mines. Similar concerns were expressed by hunters from Déline and also reported for the Colomac Mine (190 km SE of Silver Bear Mines) where caribou herds and moose ingested mine tailings. According to all hunters, other wildlife and fish around the Silver Bear Mines appeared to be healthy before and after 1970.

Hunters reported that Barren-ground caribou migrated from east to west in the fall, from west to east in spring, and plentiful caribou wintered in the Silver Bear Mines area from October to March or April. Before 1970, individual hunters annually harvested 20 to 30 and sometimes up to 75 caribou throughout the winter to provide a year's supply of food for their families and dog teams. After 1970, fewer caribou were taken annually because dog teams were replaced by snowmobiles. In recent years, some hunters noted a decline in the numbers of caribou while others believed they were still abundant. Recent caribou censuses indicated a decline of the Bathurst caribou herd of which large numbers traditionally have been wintering around the Silver Bear Mines area.(see Joachim Obst, 2007; INAC 2006c and INAC 2005b).

All hunters reported that woodland caribou occur further south-west and are generally absent around the Silver Bear Mines except for a few seen or hunted on rare occasions. Muskox are absent while moose are common and no changes in abundance had been observed before and after 1970 except for a Déline hunter reporting fewer moose around the mines after 1970. Most hunters harvested a few moose in winters when caribou were scarce. Black bears are common in the area while grizzly bears have been seen only occasionally. No changes in the abundance or health of bears were observed. Only a few people hunted black bears on rare occasions for meat in the past.

Before and after 1970, the Silver Bear Mines area has been a productive trapping area providing habitats for 13 species of furbearers. Most people trapped annually from 50 to 100 martens, 10 to 60 minks, 2 to 20 arctic foxes and as many red foxes. Some caught annually 1 to 3 wolverines, 2 to 8 lynx, 2 to 5 otters, 10 or more snowshoe hares, and incidentally a few ermines and squirrels. Others hunted annually from 10 to 80 beavers and 40 to 200 muskrats before and after 1970. Two people trapped 500 to 1000 muskrat per year in the area before 1970 and only 40 to 350 muskrats per year after 1970.

In general, fewer muskrats, beavers and furbearers were trapped by all hunters after 1970 partially due to a drastic decline in fur prices. Most hunters did not hunt wolves except occasionally. Nearly all hunters reported that furbearers have been abundant in the area before and after 1970 except for wolverine and lynx which naturally are less common there. A Déline hunter believed the abundance of wildlife in general declined after 1970. Also hunted on occasion were grouse, ptarmigan and waterfowl. A Gamètì hunter noticed a decline of scoters in recent years, an observation also reported elsewhere for diving ducks. The abundance of other birds appeared to be normal around the mines.

All hunters reported that fish were still abundant and no changes have been observed. The most commonly harvested fish in the area are lake trout, whitefish, northern pike, arctic grayling, pickerels, and sucker. Many people collected plants for food or medicine including berries, birch sap, birch and willow bark, willow, spruce gum, mushrooms, muskrat roots and aquatic plants.

The intensive traditional cultural use of the area around the Silver Bear Mines by many aboriginal hunters and their families from all communities located in the larger surrounding suggests that the area has been a productive and important hunting, trapping and fishing ground for many generations. Major concerns of elders and hunters were contaminants from mine tailings potentially entering the food chain. Before and after 1970, no changes have been reported in respect to the abundance of wildlife and fish in the area except for fewer caribou and scoters. The results of the survey were comparable with similar questionnaires conducted in Déline and also for the abandoned Colomac Mine. The concerns expressed in all surveys and communities were in particular about contaminants potentially entering the food chain and the human body.

2.2 Mining and Mineral Processing

2.2.1 Terra Mine

Mineral claims in the area occupied by the Terra Mine were first staked in the 1940's but intensive exploration of the site was not completed until the 1960's. The claims were acquired by Silver Bear Mines Limited, which became a subsidiary of Terra Mining and Exploration Limited in 1967. Drilling completed in 1967 and 1968 indicated high-grade silver deposits, and a decision was quickly made to put the site into production, although the extent of the ore reserves was unknown. The first large scale production began in 1969, with the expectation that continued mine development and exploration would prove the mine had merit. Mining continued from 1969 to 1985, with several interruptions.

The primary mining method used at Terra Mine was shrinkage stoping. Narrow stopes followed the mineralized veins, and the stopes were normally left un-filled at the end of the process. Ore was drawn from the stopes and hauled to the surface with diesel-powered mobile equipment, using a network of inclined ramps. The deepest mine workings, 1,300 feet (400 m) below surface, were completed in 1978. The North Zone deposit, located beneath the Camsell River, was found in 1976. The North Zone was accessed from a new portal on the north-west side of the property and was not connected with the rest of the mine. Ores were only produced from the North Zone in 1979.

The vein systems in the upper levels of the mine were largely exhausted by 1978, and production declined significantly in that year. The productivity of deeper mining was severely limited by the mine infrastructure and, because of the possibility of silver veins continuing at greater depths, plans were made to sink a shaft to hoist ore from the 1,300 foot level to surface. Work on the shaft and hoist infrastructure on surface commenced in 1978 but was not completed. Mining operations were suspended in 1981. Production from Terra Mine continued from 1982 to 1985, but mining activity also focused on the nearby Norex and Smallwood Mines in this period. From 1969 to 1985, the Terra Mine produced 460,000 t (short tons) of ore.

The original ore processing plant had a nominal capacity of 300 tpd (short tons per day). The plant employed gravity separation methods to produce a silver-bismuth concentrate, and froth flotation to produce a silver-copper concentrate. The flotation concentrates also contained bismuth, cobalt and nickel; however, the company was not able to recover enough of these metals to make their refining profitable. The gravity concentration process did not require the use of chemicals to extract the minerals. The froth flotation process required the use of lime as a pH modifier, xanthates as mineral collectors, and polypropylene glycol as a frothing agent.

The small quantities of highly valuable gravity concentrates were flown from the site to Yellowknife on a regular basis, and were shipped from there to silver refiners. The bulkier flotation concentrate was shipped periodically using a Hercules aircraft, and also by winter ice road. In 1983, the plant capacity was increased to 400 tpd with the installation of a second, larger ball mill. In addition to the 460,000 t of ore produced from the Terra Mine, an additional 63,000 t of ores from Norex Mine and

Smallwood Mine were processed in the mill at Terra Mine. The total tailings production from the processing of this ore is about 500,000 t. It is noteworthy that several pallets (~50) of concentrate remain on site.

2.2.2 Northrim Mine

The first development and underground exploration at the Northrim Mine was completed from 1933 to 1935. In 1968 the property was acquired by Silver Bear Mines Limited and a new adit was driven to intersect the earlier workings. Development work continued under Federated Mining Corporation in 1970 and production began in 1971. Operations ceased in 1972, but the mine was reactivated in 1975 under the operating name of Northrim Mines Limited. The mine suspended operations in 1978 and shortly thereafter the company went bankrupt. The mine workings reached a depth of 340 feet (104 m) below surface by 1978.

A small portable mill was used to process ore in 1971, using gravity separation methods. A larger mill was constructed in the underground workings and went into operation in 1972. The new mill used gravity separation as well as froth flotation methods. Records of production from this period are incomplete, but it is estimated that about 3,600 t of ore were milled in 1971 and 1972. Some of the tailings from this ore were discharged to the Camsell River near the mine entrance, as indicated by recent sediment sampling in the river, but historical records indicate that Hermandy Lake TCA was also used for tailings disposal in the initial phase of operations. Ore processing started again in late 1976 and a further 7,200 t of ore (approximately) were processed until production ceased in 1978. The total tailings production would be about 10,000 t.

2.2.3 Norex Mine and Graham Vein

Ore from the Graham Vein was first mined in 1970 and 1971 by Norex Resources Limited using open pit methods, and processed on site in a small test mill. Approximately 1,100 t of ore were processed on site using gravity separation methods in this period and it is believed that the tailings from this production were disposed of in and around Xeron Pond. An airstrip was cleared to service the operation, located near Smallwood Lake to the east of the site. Excavation of the decline to the Norex Mine commenced at the same time.

Terra Mining and Exploration Limited acquired an interest in the property in 1971, and a small quantity of ore from the underground mine was hauled to the Terra Mine for processing in 1973, using an ice-road. An all-weather road between the two mines was completed in 1974, while development and exploration of the Norex Mine continued, but continuous production did not start until 1977. Most of the underground mine workings were developed between 1977 and 1983, reaching a depth of 600 feet (180 m) below surface. Ore production came from two main veins, including the Graham Vein which was mined from underground as well as surface. Between 1973 and 1983 a total of 45,000 t of ore were hauled to Terra Mine for processing.

2.2.4 Smallwood Mine

Exploration completed by Terra Mining and Exploration Limited identified silver mineralization in the Smallwood Mine area in 1978. Underground development began through a decline ramp in 1979, and ore was hauled to the Terra Mine for processing. From 1979 to 1983, approximately 18,000 t of ore from Smallwood Mine were processed. The workings reached a depth of approximately 400 feet (120 m) below surface.

3 Current Site Conditions

3.1 Overview

The topography and major features of the project area are shown in Figure 3.1.1. The contours are based on aerial photography completed in July 2006, shown in Figure 3.1.2. This section presents information on the mine site features, including lakes used for tailings disposal, which are considered part of the sites. Information on other water bodies in the project area is presented with the discussion of current environmental conditions, in Section 4. A summary of the components of each mine site is provided in Table 3.1.1 on the following page.

3.2 Terra Mine

3.2.1 General Site Description

The Terra Mine is an underground mine extending to 400 metres below surface. The site surface features are shown in Figure 3.2.1 and Figure 3.2.2.

The site has several openings into the underground mine and a small open pit. Surface facilities include an ore processing plant, assay lab, power, heating and compressor plants, fuel storage tanks, maintenance shops, warehouses, offices, and a camp. A dock is located on the Camsell River and a 1,500 metre long airstrip sits on the northern shore of Moose Bay. Waste rock has been placed on the shore of Ho Hum Lake TCA and levelled to create storage yards for mining equipment and supplies. Tailings from ore processing have been disposed of in and adjacent to Ho Hum Lake TCA. Unpaved roads connect the various facilities, and an 8 kilometre haul road connects the Terra site with other mining sites to the east. The following sections provide information on the major components of the site.

3.2.2 Underground Mine Openings

There are thirteen openings into the underground mine, at the locations shown in Figure 3.2.3. The mine openings can be divided into three categories. The first category is vertical or sub-vertical openings, and includes four (possibly 5) ventilation raises and one ore hoisting shaft which was never commissioned. The second category is horizontally oriented openings, including portals or adits (which are horizontal tunnels in the ground) and inclined ramps leading down into the mine (“declines”), the entrances to which are known as portals. There are five portals at Terra. The third category of mine openings includes stopes that have been mined through to the surface and left open, or partially open. There are three openings in that category at Terra, as indicated in Figure 3.2.3. Other stopes have been mined to the surface within the open pit and backfilled level with the ground surface. These completely backfilled stopes are not included here as mine openings.

Table 3.1.1 Summary of Mine Site Components

Site Component	Terra Mine	Northrim Mine	Norex Mine	Graham Vein	Smallwood Mine
Mine Openings	• Raises / shaft (5) • Portals / adits (5) • Open or partially filled stopes (3) • Open pit	• Raises (5) • Portals / adits (3) • Open or partially filled stopes (3) • Shallow pits or trenches	• Raises (3) • Portals (2)	• Open pit / trench	• Raises (4) • Portals (2)
Waste Rock	• Ho-Hum Lake foreshore (145,000 m^3) • Airstrip (120,000 m^3) • Other infrastructure (97,000 m^3)	• Main piles (15,000 m^3) • Other infrastructure (3,000 m^3)	• Main Pile (45,000 m^3) • Other infrastructure	• Pile near trench (3,500 m^3)	• Main piles (35,000 m^3)
Tailings	• Exposed tailings at Ho-Hum Lake (2,000 m^2) • Submerged tailings in Ho-Hum Lake	• Exposed tailings at Hermandy Lake (1,500 m^2) • Smelter waste dump (100 m^2) • Submerged tailings in Hermandy Lake and Camsell River		• Tailings near Xeron Pond, mixed with other fill (1000 m^2) and likely submerged tailings in Xeron Pond	
Buildings and Equipment	• Camp, main office, crushing plant, mill, assay lab, powerhouse, warehouse, dry, vent plants, compressor plants, heating plants, freshwater pumphouse, workshops, storage sheds, fuel tanks • Non-hazardous waste (16,000 m^3) • Hazardous waste: including asbestos, lead paint, hydrocarbons (oils, fuels) • Waste hydrocarbons stored in drums (129,000 L, approx.)	• Camp, office, assay lab, mill (underground), smelter, fuel tanks • Non-hazardous waste (750 m^3) • Hazardous waste: including asbestos, lead paint, hydrocarbons (oils, fuels), mill reagents • Waste hydrocarbons stored in drums (7,000 L, approx.)	• Workshop / garage, compressor and vent plant, fuel tanks, shacks • Non-hazardous waste (940 m^3) • Hazardous waste: including lead paint, hydrocarbons (oils, fuels) • Waste hydrocarbons stored in drums (2,500 L, approx.)	• Ore bin and crushing plant (ruin)	• Compressor and vent plant, trailers, shacks, fuel tank • Non-hazardous waste (155 m^3) • Hazardous waste: including lead paint, hydrocarbons (oils, fuels)
Roads	• Site roads (3 km, approx.) • Haul road from Norex to Terra (8 km) • Roads constructed with waste rock, natural granular materials	• Site roads (340 m, approx.) • Roads constructed with waste rock, natural granular materials	• Site roads (1.5 km, approx.) • Roads constructed with waste rock, natural granular materials		• Site roads (5 km, approx.) • Roads constructed with waste rock, natural granular materials
Airstrips	• Airstrip constructed with waste rock, natural granular materials (sandy soil)				• Airstrip constructed with natural granular materials • Revegated
Waste Disposal Sites	• Old waste disposal sites (3)	• Old waste disposal sites (scattered)	• Scattered waste		• Scattered waste
Docks	• Dock with wooden retaining wall	• Dock with wooden retaining wall	• Dock on wooden piles (?)		
Hydrocarbon Contamination	• Contaminated soils and fill (21,000 m^3, approx.) • Contamination from spills of gasoline, diesel, heavy fuel, heavy lube/hydraulic oils	• Contaminated soils and fill (5,900 m^3, approx.) • Contamination from spills of gasoline, diesel, heavy fuel, heavy lube/hydraulic oils	• Contaminated soils and fill (3,900 m^3, approx.) • Contamination from spills of gasoline, diesel, heavy fuel, heavy lube/hydraulic oils	• Contaminated soils and fill (included in Norex estimate)	• Contaminated soils and fill (3,800 m^3, approx.) • Contamination from spills of gasoline, diesel, heavy fuel, heavy lube/hydraulic oils

The Terra Mine workings sit between two large bodies of water, the Camsell River and Ho Hum Lake TCA. The ground between the water bodies has steep rocky slopes that shed runoff rapidly and would not provide a lot of recharge to the groundwater. The water level within the flooded mine appears to be close to the level of the Camsell River and Ho Hum Lake TCA. Several of the adits and portals produce small flows of water, particularly early in the open water season, but the discharge of mine waters from the mine openings is limited by the terrain. Only the Norex portal produces a significant flow of water which discharges from spring to freeze up.

3.2.3 Open Pit Workings

The "open pit" mining area at Terra was limited to the single side hill cut area shown in Figure 3.2.4. Most of the disturbed area identified as the open pit was actually never mined as such. The "open pit" is also defined by a large area over which overburden soil was removed to reveal the bedrock underneath. This would have been done for geological assessments of the rock. On the west side, and central parts of the "open pit", several stopes were mined to surface from the underground workings. Most of these stopes were subsequently backfilled from above, but two of them remain open or partially open, leaving steep high walls that are difficult to see and potentially hazardous to humans or wildlife.

Mining did take place on the east side of the pit, where rock was drilled and blasted to gain access to a zone of mineralized rock outcropping in a natural cliff above the pit area. Most of the rock that was mined appears to be un-mineralized waste rock and remains in a pile on the south-east edge of the pit. Little of the mineralized outcrop appears to have been mined.

Another notable feature is the adit at the base of the pit. The floor of the adit is flooded, and a small trickle of water has been observed and monitored flowing from the adit early in the open water season. The adit is significantly higher than other mine openings that should be hydraulically connected to it, so the water may be sourced from local infiltration rather than the main body of mine water.

3.2.4 Crown Pillars

Little information is available regarding the stability of crown pillars at any of the mines. Mining was typically done in thin veins with near surface mining completed using open trenches. Where stopes were advanced to surface, these opening are typically less than 2 m wide. Based upon visual observations of the rock and lack of any caving, it is concluded that the rock is competent and it is unlikely that there are major crown pillar stability concerns.

SRK consulting have toured the site and reviewed available mine drawings. It is their opinion that if a definitive analysis of crown pillar stability is required then drilling of all potential pillar areas would be required to assess the depth and extent of the pillars and rock quality. This would require a drilling and assessment program of several hundred thousand dollars. Given the remoteness of the site, it would not be unreasonable to defer crown pillar investigations and institute a long term pillar monitoring program along with the ongoing monitoring activities at the site.

For the RAP, it was assumed that no remedial measures to enhance crown pillar stability would be required and that a routine monitoring program put in place to verify long term stability.

3.2.5 Waste Rock

General Description

Waste rock was mined underground and taken to the surface, where some of it was used as construction material, and some was dumped onto piles beside Ho Hum Lake TCA. Waste rock was also mined in the pit, where most of it still remains. Examples of construction uses include the airstrip, the roads and mine yards, and the pads on which fuel tanks and some of the buildings sit. There is no indication that bedrock was quarried on surface to make construction material, therefore, the entire infrastructure constructed with granular materials is assumed to have used mine waste rock, or locally excavated soils.

Whether it was mined underground or in the pit, waste rock had to be extracted to gain access to the valuable ore and provide services for mining. For example, waste rock would have been blasted and extracted to create the shafts, raises and ramps needed to send water, power and fresh air into the underground mine, and get ore to the mill on surface.

No mine records have been found to indicate the total amount of waste rock taken from the mine and placed on surface, but the volumes can be roughly estimated from the surface areas and apparent thicknesses of the material located around the site. From these volumes, approximate tonnages can be estimated. A total of about 650,000 t of waste rock was placed on surface over the life of the mine, which is distributed as shown in Table 3.2.1.

Table 3.2.1 Approximate Amounts of Waste Rock on Surface at Terra Mine

Location	Surface Area (m^2)	Estimated Volume (m^3)	Estimated tonnes (t)
Ho Hum Lake TCA Foreshore	38,000	145,000	260,000
Airstrip	68,000	120,000	220,000
Site Roads, Yards and Pads	56,000	85,000	150,000
Open Pit	4,000	12,000	22,000
TOTAL	166,000	362,000	652,000

Comparison of current conditions with historical aerial photographs indicates that waste rock has been placed within the original footprint of Ho Hum Lake TCA. In the area of the mill, this is limited to a small encroachment on the lake; however, a significant area was reclaimed from the lake at the south-east end of the airstrip by filling it in with waste rock. The airstrip encroaches to a limited extent on the Moose Bay foreshore area and the access road to Vent Raise #2, at the north-east extremity of the Terra site, encroaches on the edge of the Camsell River.

Most of the slopes at the edges of the waste rock features were formed by end-dumping rock from haul trucks, or by pushing it with a dozer, and the material lies at the angle of repose. This has resulted in steep slopes, up to approximately 1.4H:1V (36 degrees from horizontal). The slopes associated with many waste rock features, such the airstrip, road and yards, are quite low (less than 4 m high). The slopes at the edges of the waste rock piles in the mill area are much higher (as much as 13 m). The higher waste rock slopes may form a minor impediment to wildlife movement. A relatively shallow ramp of waste rock has been pushed down to the lake just below the mill building, and moose have been seen to use this ramp as a means of lake access in this area.

The rock is hard angular material showing little weathering and all of the slopes appear to be stable. No evidence of large-scale tension cracking or previous slope failures has been found. Since most of the high slopes are adjacent to Ho Hum Lake TCA in areas without natural shoreline features, slope failures, or ravelling of rock pieces from the slopes, are unlikely to affect people or animals.

Geochemical Characterization

The potential for contaminant release from mine waste rock has been assessed in three programs, completed in 1993, 2004 and 2005. EBA Engineering Limited completed a scoping level assessment in 1993 and additional data was collected by Rescan Environmental Services Limited in 2004. Rescan collected and tested 10 rock samples from the Terra site, using Acid Base Accounting (ABA) and leach extraction procedures.

In 2005, a much more comprehensive assessment was made by Lorax Environmental Services Limited (Lorax 2006) which included data from the earlier assessments. Lorax collected 45 rock samples at 35 locations on the Terra site. Most of the samples were collected from below surface (0.5 to 2 m depth), by digging trenches using various methods. The samples were tested for ABA parameters, total metal and water soluble metal contents. Groundwater samples were also collected from wells installed in the waste rock. Four groundwater wells were installed in or close to waste rock adjacent to Ho Hum Lake TCA and Moose Bay in 2005. The wells were sampled in August 2005.

The waste rock has been in place for an average of about 30 years. All of the Terra waste rock samples produced neutral paste pH and rinse pH results, indicating that the rocks are currently not acidic. Leach extraction tests, using pure water, were performed on all of the waste rock samples collected in 2005. The results indicate that some of the rock could be a source of arsenic loadings to Ho Hum Lake TCA and may influence the arsenic concentration in the lake water. Copper was also leached from the samples, but the concentrations were low.

Observations made during groundwater sampling indicate that the water level in the wells is controlled by the lake level and that water can flow freely through the porous rock fill. The indication is that lake water quality may influence the well water quality and the well water quality data should be interpreted with caution. The arsenic concentration in two of the wells adjacent to Ho Hum Lake TCA was twice that found in the lake, while copper was several times the lake concentration in two of the wells, and significantly higher than the leachate concentrations found in the laboratory leach extraction tests. These results suggest that the waste rock is a source of copper loadings to the lake. The single well in the airstrip waste rock produced samples with several times the amount of arsenic, cadmium, chromium, copper and zinc found in the water of Moose Bay. The well water pH was neutral. The results indicate that the airstrip material is a source of metal loadings to the bay, in addition to the discharge from Ho Hum Lake TCA.

The potential for the waste rock to become acidic in the future was assessed by comparing the proportions of acid-neutralizing carbonate minerals and acid-forming sulphide minerals. Results from such comparisons are generally interpreted as follows. When the acid neutralizing potential is more than two times the acid generating potential, (i.e. Neutralization Potential Ratio or NPR greater than 2), the material is very unlikely to become acidic. When the acid neutralizing potential is less than the acid generating potential (i.e. NPR less than 1), there is a definite potential for acidic conditions to develop. Results between those two cases, (i.e. NPR between 1 and 2) are uncertain.

The majority of the Terra waste rock samples (71%) had NPR values greater than two, indicating they will not become acidic. Only four samples (8%) had NPR values in the potentially acid generating range, and the remaining 21% were in the uncertain range. The NPR results showed no correlation with sample location.

The laboratory results must be interpreted in the light of the field observation that none of the rock is currently acidic, despite being exposed to oxidation for more than 30 years. If a significant potential for acid generation existed in this material, one would expect to see at least localized areas of acidic conditions by now. The fact that all of the field tests showed neutral conditions suggests that there is very little chance of significant acidification or significant increases in metal loadings in future.

In addition, although oxidation and some leaching is occurring, the oxidation rates are very low as evidenced by the low sulphate levels in Ho Hum Lake TCA which is also impacted by the oxidation of exposed tailings. Levels of sulphate in Ho Hum Lake of 20 mg/L compare with background lakes with levels up to 12 mg/L.

3.2.6 Tailings

General Description

The Terra mill recovered valuable minerals from the mined ore. The heavy minerals, such as native silver and native bismuth, were recovered using gravity separation methods, and copper sulphide minerals were recovered with a froth flotation process. The tailings (waste particles) from these processes were discharged to Ho Hum Lake TCA.

Almost all of the tailings were discharged into the lake itself and now lie under water, but a small amount of tailings were also placed on the lake shore. Ho Hum Lake TCA has a surface area of 213,000 m^2 and an estimated volume of 1,561,000 m^3. The mean depth is 7 metres and the maximum depth is just over 16 metres. Sediment sampling indicates that the entire lake bed has been influenced by tailings disposal, but higher concentrations of most metals are found in sediments below the mill and deeper parts of the lake towards its north-west end. This indicates that tailings were discharged in these areas, or drifted into these areas. Lower metal concentrations are found in the sediments at the south-east end of the lake.

Exposed Tailings

Tailings are exposed in two locations: the triangle shaped West Beach on the edge of Ho Hum Lake TCA just below the mill, and the East Beach tailings (which could also be waste rock fines as there is minimal sulphide and low arsenic and metals levels) which sit on natural ground and waste rock, raised several metres above the level of Ho Hum Lake TCA. These locations are shown in Figure 3.2.5. The area of exposed tailings is about 2,200 m^2. The West Beach was apparently the primary tailings discharge location, where the coarser tailings particles settled-out close to the pipe discharge. Mine records indicate that tailings were also discharged for a time directly into the deeper parts of the lake through a pipeline which floated on the water surface. The operational reason for the creation of the East Beach is not known and these tailings (or waste rock fines) may well have been placed there as a borrow source.

The exposed tailings have been sampled and tested in two primary programs. In 2004, Rescan took 11 samples from the West Beach and 2 samples from the East Beach, and tested them for ABA parameters, total metals, and water soluble metals. Lorax collected 6 more samples from the West Beach in 2005, and two samples from the East Beach, and conducted the same tests. The results from both sampling programs are presented in Lorax 2006.

Lorax and Rescan both found a small zone of tailings at the top of the West Beach that gave low rinse pH’s (3.5). All other rinse pH’s in both programs were above 7, indicating that most of the exposed tailings are not currently acidic. The ABA testing indicated that the small zone of tailings with low rinse pH will continue to generate acid, because of its high sulphide content (4 to 6% sulphur) and low neutralizing potential. All other tailings tested in 2004 and 2005 had relatively low sulphur contents below 0.5% and consistently high neutralizing potentials, resulting in calculated Neutralizing Potential Ratios above 2, and are consequently designated *not* potentially acid generating.

Leach extraction tests were performed on the tailings samples collected in 2005 to determine if metals in the tailings are water soluble. The leaching tests indicate that the exposed tailings are a source of metal loadings to the lake, even though most of the tailings are not acid generating or expected to become so. However, the surface areas of the tailings beaches are small and therefore infiltration to the tailings from direct precipitation or run-on will be limited. Small infiltration volumes will result in relatively small metal releases to the lake, with only a minor influence on the lake water quality.

It worthy to note that the East Tailings area material is not characteristic of Terra tailings excepting that the material is fine grained. Sulphide and metals levels are low and typically below levels found in waste rock levels.

Submerged Tailings

The great majority of the tailings (on the order of 500,000 t) produced at Terra Mine are located under water, in Ho Hum Lake TCA. In 2004 and 2005, 11 grab samples of sediment were collected from the lake bed and tested for total sulphur, total organic carbon and total metals contents. The data are summarized in Lorax 2006. The Ho Hum Lake TCA sediments have median concentrations of arsenic, cadmium, cobalt, copper, lead, nickel and zinc that are significantly elevated with respect to Tutcho Lake sediments. Tutcho Lake is located about 2 km south-west of the Terra Mine and has not been affected by mining activity and as such is used as a natural reference site for the area.

Leach extraction tests are not an appropriate way to assess whether contaminants could come out of the submerged tailings, because water will not percolate through it, as might occur in exposed tailings or waste rock. Instead, the issue of contaminant mobility was assessed by Lorax in 2005 using “peepers”. Peepers, or dialysis samplers, are specialized sampling devices that can be used to determine porewater quality at discrete, narrowly separated intervals. The variation of porewater concentrations with depth from the surface of the submerged tailings could indicate if there is an ongoing movement of contaminants between the tailings and the lake water column, which could occur in either direction. Lorax installed two peepers in the Ho Hum Lake TCA sediments, one in shallow water near the West Beach, and one in deeper water directly south of the beach. The peepers were left in place for approximately four weeks. The peeper at the deeper site was disturbed during the deployment and did not provide useable data.

The results from the shallow peeper test indicate that highly reducing conditions are found in the sediments, just a few centimetres below the surface. The dissolved concentrations of some elements, such as manganese, iron and arsenic, which are all quite soluble under reducing conditions, were much higher in the sediment porewater than in the lake water column immediately above the tailings. By contrast, copper, which has low solubility in reducing environments with sulphur available for precipitation, was at lower dissolved concentrations in the tailings porewater than in the water column immediately above.

The result of the peeper test does not provide a direct measurement of metal fluxes into or out of the tailings, but it does indicate the potential for fluxes. Since ionic diffusion will move dissolved species from zones of higher concentration to zones of lower concentration, the peeper results suggest that the submerged tailings could be a source of the arsenic found in the water column (i.e. diffusion drives dissolved arsenic out of the tailings into the lake water). By the same diffusive mechanism, the peeper results suggest that copper could be taken out of the water column and sequestered as a precipitate in the sediments.

It should be stressed that these potential contaminant movements are implied by the peeper data, but not proven. As an example of the complexities that could be involved, the peeper results indicate that diffusive flux should drive dissolved ferrous iron out of the tailings pores as well as the arsenic. Ferrous iron would be oxidized to the ferric form in the water column, and ferric iron and arsenic would combine to form insoluble iron-arsenic-oxide precipitates, which could then settle out on the lake bed. The peeper test data clearly indicates the potential for the submerged tailings to be a source of arsenic loadings to the lake, but it does not indicate the relative importance of the tailings in controlling the arsenic concentration in the lake.

Ho Hum Lake TCA Water

The water quality of Ho Hum Lake TCA has been monitored by INAC staff during every open water season since 2002. The data are summarized in INAC 2005c and INAC 2006d. The monitoring completed in 2005 and 2006 was more intensive than in previous years, and included collection of samples from the surface, mid-depth and bottom of the lake at two locations, and complete water column profiles of temperature, conductivity, dissolved oxygen and turbidity. As shown on Figure 3.2.6, the lake becomes thermally stratified each summer, with a sharp decrease in water temperature occurring between 4 and 7 metres below surface.

The concentrations of some metals in Ho Hum Lake TCA have been seen to vary with depth. Figure 3.2.7 shows the variation of the average total arsenic, copper, iron and manganese with depth in 2005 and 2006. Arsenic and manganese concentrations were higher at the bottom of the lake than at the surface on all of the sampling occasions in 2005, although no significant variations with depth were found in 2006. One reason to expect lower metal concentrations higher in the water column in summer is the fact that runoff entering the lake will not mix into the deeper water because the lake is thermally stratified. Dilution from clean runoff will occur mostly in the upper water column. However, this effect is not great enough to explain the higher arsenic concentrations at the bottom of the lake in 2005. Although the data are not consistent, the 2005 results suggest that the sediments at the bottom of the lake could be a source of the arsenic found in the water column.

The lake does not show any chemical stratification strong enough to keep the water column permanently stratified, and therefore, the lake should overturn and mix almost completely at the end of each open water season. This would be expected to occur in September or October, after the normal field work season ends, and water sampling has never been done on the mixed lake, after the fall overturn. We can estimate the average water quality of the mixed lake by calculating volume-weighted average concentrations, based on the depth sampling results and the known lake volume at various depths. This has been done with the data collected in August 2006 and the resulting volume-weighted average concentrations for all parameters are shown in Table 3.2.2. The data summarize the current average water quality for the lake in a mixed condition. For comparison, the table includes the Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (CCME-FAL guidelines; CCME 2006). Arsenic and copper in Ho Hum Lake TCA are both above the CCME-FAL guidelines.

Table 3.2.2 Ho Hum Lake TCA Current Average Water Quality 2006

Parameter	Units	Ho Hum Lake TCA [1]	CCME-FAL Guideline[2]
pH		7.9	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	74.8	
Hardness (as $CaCO_3$ equiv.)	mg/L	92.8	
Chloride (total)	mg/L	29.3	
Sulphate (total)	mg/L	20	
Calcium (total)	mg/L	28.6	
Magnesium (total)	mg/L	5.2	
Sodium (total)	mg/L	16.8	
Ammonia (total, as N)	mg/L	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	
Phosphorus (total)	mg/L	0.03	
Total Metals			
Aluminum	µg/L	47.6	100
Antimony	µg/L	2.4	
Arsenic	µg/L	80.7	5
Beryllium	µg/L	<0.1	
Cadmium	µg/L	<0.10	0.03
Chromium	µg/L	<0.3	1
Cobalt	µg/L	0.3	
Copper	µg/L	7.9	2
Iron	µg/L	104	300
Lead	µg/L	0.6	2
Lithium	µg/L	16.4	
Manganese	µg/L	9.9	
Mercury	µg/L	<0.02	0.1
Molybdenum	µg/L	4.7	73
Nickel	µg/L	5.6	65
Rubidium	µg/L	7.2	
Selenium	µg/L	<1	1
Silver	µg/L	<0.1	0.1
Thallium	µg/L	<0.1	
Uranium	µg/L	6	
Zinc	µg/L	<10	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values; if all results are below detection limit, this is noted with the "<" symbol and the detection limit value.

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

Table 3.2.3 Ho Hum Lake TCA Surface Water Quality

Parameter	Average Concentration (µg/L)			
	2003	2004	2005	2006
Arsenic (total)	99.0	93.1	77.9	79.2
Copper (total)	6.1	7.0	9.0	7.7

Surface water samples have been collected consistently from a location in the middle of the lake each year from 2003 through 2006. Table 3.2.3 shows the average concentrations of arsenic and copper in the surface water each year. The only apparent trend is a decrease in the arsenic concentrations over the four-year period. This suggests that the waste rock and tailings oxidation/leaching are not accelerating with time.

Ho Hum Lake TCA Discharge

Ho Hum Lake TCA discharges to Moose Bay through two low dykes at the north-west end of the lake. The locations of the dykes are shown in Figure 3.2.5. The old Upper Dyke is a low earthen structure which is almost inundated with water when the lake level is high, earlier in the open water season. In recent years, water has flowed over the Upper Dyke in June and July, and seeps through and around the dyke later in the year. The Lower Dyke is a larger structure that was built in the late 1970's to raise the lake level and control the outflow. It is constructed of coarse rock fill, with an internal zone of fine-grained soil intended to act as a water retaining element. The dyke is equipped with a concrete and steel decant weir. Wooden boards or "stop-logs" can be slid into the weir intake to control the level at which water would overflow into the weir box. Water is drained from the weir box to the downstream side of the dyke through a culvert. In the past, blockage of the discharge with a plywood board raised the water level in the pond inundating trees along the shoreline, many of which may have attributed to the death of the trees along the shoreline (likely due to lack of oxygen).

There are two distinct wetland zones in the Ho Hum Lake TCA outlet area, distinguished by their different water elevations. The Upper Wetland lies at the edge of Ho Hum Lake TCA, just upstream of the Upper Dyke, and in the channel between the Upper and Lower Dykes. The wetland surface area is about 2,300 m^2. There is limited growth of new vegetation in the Upper Wetland, which is partly the result of higher lake levels in the last two years (as a result of intentional blockage of the decant with plywood). In late 2004, the weir overflow was raised by almost one metre, resulting in a higher lake level and deep flooding of the wetland. The Upper Wetland is now full of decayed vegetation, although some new growth still occurs in shallower parts.

The Lower Wetland lies just below the Lower Dyke, where the water surface is between one and two metres lower than in the Upper Wetland. The surface area is about 2,800 m^2. The Lower Wetland is full of thriving vegetation, including sedges, horsetails and willows. The wetland discharges into Moose Bay, which is directly connected to the Camsell River.

All of the discharge from Ho Hum Lake TCA passes through one or both of the wetlands. Early in the year, when the flow volumes are high, most of the discharge passes through both wetlands. Later in the year, a significant portion of the lake outflow appears to flow as sub-surface seepage thus bypassing the Lower Wetland and can be seen emerging at the downstream toe of the Lower Dyke, near the north abutment.

Figure 3.2.8 shows the arsenic levels at various locations along the discharge route during the 2005 and 2006 discharge seasons. The data indicate that arsenic concentrations are reduced in the wetlands throughout the open water season, whether the lake outflow is high or low. This would occur if the lake outflow is diluted with cleaner water in the wetlands, or if arsenic is actually removed from the water. In fact, dilution and removal probably both occur. The last sampling station shown in Figure 3.2.8 is at the end of the Lower Wetland, where the wetland water is at the same elevation as Moose Bay. It is clear that cleaner water from Moose Bay will dilute the flow from Ho Hum Lake TCA at the end of the Lower Wetland. However, sampling within the wetlands also show arsenic reductions before there is any chance for significant dilution to occur.

Removal of arsenic from water in natural and engineered wetlands has been documented at many sites in North America. In most of the literature on these examples (e.g. Stottmeister 2006), it is suggested that chemical reduction and precipitation of arsenic as a stable arsenic sulphide is the primary mechanism for removal. Arsenic may also be attenuated through co-precipitation with iron, and other metals, sorption on sediment and soils, and to some extent, uptake in algae and plants.

Whether contaminants are diluted or removed in the wetlands between Ho Hum Lake TCA and Moose Bay, or both, the water discharged to the aquatic environment of Moose Bay is cleaner than Ho Hum TCA water. Table 3.2.4 summarizes water quality at the discharge from the wetland system in 2005 and 2006. For comparison, the table includes the CCME-FAL guideline values (CCME 2006).

Total arsenic, chromium, copper and silver concentrations have been greater than the guideline values on at least one sampling occasion in the last two years. It should be noted that these are the results of analyses for total metals, including any particulate. Samples collected early in the year, when runoff and lake outflows are at their highest, are likely to include some particulate contaminants, which will be less bio-available than dissolved species. The hydrology of the Ho Hum Lake TCA basin and estimated volume of the discharge is discussed in Section 4.2.1. The water quality within Moose Bay is presented in Section 4.2.2.

Table 3.2.4 Water Quality of Discharge to Moose Bay (2005 and 2006)

Parameter	Units	Total Concentrations[1]		CCME-FAL[2] Guideline[2]
		Median	Maximum	
pH		7.9	8.1	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	78.1	83.2	
Hardness (as $CaCO_3$ equiv.)	mg/L	98.7	115	
Chloride (total)	mg/L	21.0	26.9	
Sulphate (total)	mg/L	20	27	
Calcium (total)	mg/L	28.7	35.1	
Magnesium (total)	mg/L	6.5	7.7	
Sodium (total)	mg/L	12.5	15.0	
Ammonia (total, as N)	mg/L	<0.005	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	<0.01	
Phosphorus (total)	mg/L	0.04	0.05	
Total Metals				
Aluminum	µg/L	47.3	67	100
Antimony	µg/L	0.9	2.5	
Arsenic	µg/L	42.6	70.2	5
Beryllium	µg/L	<0.1	<0.1	
Cadmium	µg/L	<0.1	<0.1	0.03
Chromium	µg/L	0.3	2.2	1
Cobalt	µg/L	0.3	0.5	
Copper	µg/L	6.3	15.9	2
Iron	µg/L	131	236	300
Lead	µg/L	0.2	1.0	2
Lithium	µg/L	11.0	14.1	
Manganese	µg/L	20.5	42.8	
Mercury	µg/L	<0.02	<0.02	0.1
Molybdenum	µg/L	2.5	5.3	73
Nickel	µg/L	2.3	5.0	65
Rubidium	µg/L	4.8	6.2	
Selenium	µg/L	<1	<1	1
Silver	µg/L	<0.1	2.4	0.1
Thallium	µg/L	<0.1	<0.1	
Uranium	µg/L	1.9	3.3	
Zinc	µg/L	<10	<10	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of median values; if all results are below detection limit, this is noted with the "<" symbol and the detection limit value.

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

3.2.7 Buildings and Equipment

The buildings and non-mobile equipment at Terra include facilities for mine services, ore processing, assaying, fuel storage, power generation, equipment maintenance, warehousing, offices and accommodation. The major buildings and equipment are indicated in Figure 3.2.9.

The majority of buildings are steel framed and steel clad structures with concrete foundations and floors. These include the mine ventilation and compressor plants, the freshwater pumphouse, the crusher building, and the largest complex on site, which includes the assay lab, processing plant, power house, main warehouse, changing rooms, and offices. Most of the smaller shops and storage sheds are timber framed and timber sided, with steel roofs. The camp buildings include timber structures built on site, and ATCO trailer complexes.

The volume of non-hazardous material that would be generated from demolition of the buildings, and collection of equipment and debris from the storage yards, was assessed by Rescan Environmental Services in 2004 (Rescan 2005a). The estimated total volume of waste is just over 16,000 m^3. This includes steel, wood, concrete, and smaller quantities of other non-hazardous materials such as plastics, rubber, glass, insulating materials, and paper products.

The Terra site has a significant inventory of hazardous materials, which have been identified and quantified in several assessments completed since 1993. Three reports presenting the findings are Rescan 2005b, Golder 2006 and SRK 2006. The hazardous materials include buildings materials, such as asbestos containing materials, paints containing lead and batteries (and potentially contaminated soil). The asbestos containing materials are generally non-friable products including small amounts of insulation, and larger quantities of flooring materials (in the camp trailers). Window sealant and drywall tape containing asbestos have also been identified.

Extensive paint sampling has been completed throughout the site, and lead amended paints are found on building surfaces and equipment in most of the buildings. Paint containing PCB compounds has been found on some concrete surfaces in the mill and on the floor of the powerhouse.

An extensive hazardous materials removal program was completed in 2002, when electrical equipment containing PCB products was removed from the site. The only PCB materials remaining on site are the small quantities of PCB paint, and some PCB light ballasts in the mill complex that could not be accessed in 2002. Laboratory chemicals used in assaying were removed from the site in 2002.

The mill complex includes a significant inventory of lubricating oils inside equipment drives and gearboxes, and in the powerhouse generators. The reagent handling systems contain limited residues of the froth flotation reagents. A significant quantity of hydrated lime is stored in the yard outside the mill, but no other unused stocks of mill reagents have been identified. The lime is no longer active as a pH modifier, and therefore not considered a hazardous waste. The froth flotation cells in the mill contain small residues of ore and concentrate. Approximately 50 t of flotation concentrate containing copper is also found in bags at two outdoor locations along the airstrip and north-east of the crusher building.

Based on preliminary inspection, limited amounts of fuel and fuel sludge residue remain on site in the various tanks. Initial estimates of fuel and fuel sludge residue are less than 2500 L of fuel and less than 500 L of sludge. The fuel has not been sampled. It is possible that fuel also remains in distribution pipes around the site, but this has not been confirmed.

The Silver Bear Mines collectively have a large inventory of used and unused hydrocarbon products stored in steel drums. This issue was extensively assessed in 2004 and 2005, and the results are contained in Golder 2006. Over 90% of the drums were opened and sampled, and composite samples were prepared for groups of 5 to 10 drums. The samples were analysed for metals (cadmium, chromium, lead), chlorine, PCB's, glycols and flashpoint. The results were compared to the requirements of the Government of the Northwest Territories (GNWT) Environmental Protection Act, Used Oil and Waste Fuel Management Regulations (GNWT 2001). The regulations are not legally applicable to these sites, but the quality criteria were used as a guideline to assess the general suitability of the waste hydrocarbons for on-site incineration.

Including all of the Silver Bear Mines, the total inventory of liquid hydrocarbon products stored in drums, or hydrocarbon contaminated liquids, is estimated to be 140,000 litres. Of this, about 80,000 litres meet the GNWT quality requirements for incineration. About 35% of the total inventory (48,000 litres) exceeds the GNWT requirements for metals content, typically the lead value. The remaining 12,000 litres cannot be incinerated in its current form because of the low flashpoint. Most of these are mixtures of oil and water.

3.2.8 Roads

Apart from traffic surfaces on the waste rock piles and the airstrip, the Terra site has about three kilometres of roads. Typically, these are thin traffic surfaces of crushed waste rock laid on top of cleared native soil, with little or no embankment. The original traffic surfaces are worn through in extensive sections, exposing the soil underneath. None of the site roads cross significant drainage paths, and there are no significant issues of erosion of road materials due to runoff flows. Issues relating to waste rock as a potential source of contaminants are discussed in Section 3.2.5.

An all-weather haul road on the south side of Rainy Lake links the Terra Mine to the Norex, Graham Vein and Smallwood Mines, as shown in Figure 3.2.10. The road is eight kilometres long from the Terra waste rock pile to the Norex site, and the Smallwood site is a further 1.2 kilometres. The road was originally used to transport workers and equipment to the distant sites, and haul ore back for processing in the Terra mill. The road was apparently constructed with mine waste rock as well as locally excavated granular materials (soils and gravels). The current condition of the road is described in EBA 2006a.

The haul road crosses sloping ground that carries runoff drainage to Rainy Lake in several streams. The road crosses eight significant drainages between Terra and Norex, as identified in Figure 3.2.10.

Culverts were installed at most of these locations, but several of the culverts have failed and significant erosion of the road embankments has occurred. A representative of Fisheries and Oceans Canada has inspected the road and identified three drainage crossings that are used by fish, or likely to be used by fish, for habitat or migration (DFO 2007). These are crossing numbers 2, 6 and 7 as shown in the figure.

If the road is to be used again for large vehicle traffic for remediation works, significant repairs will be necessary. Much of the road is heavily overgrown with alder bushes that would have to be cleared. New culverts and fill material would be required where the road is washed out, and other culverts in danger of failing under load, would have to be replaced. Practical rehabilitation would allow the road to carry single lane traffic at a slow speed, but would not allow for hauling large quantities of construction or waste materials if required.

3.2.9 Airstrip

The airstrip lies on the north shore of Moose Bay and extends into the north-west corner of Ho Hum Lake TCA. It is 1,500 metres long and 25 metres wide, in its narrowest section, and was designed to accommodate aircraft up to the size of the C130 Hercules cargo plane. The runway surface lies about 3 metres above the water of Moose Bay, and the maximum thickness of fill material (at the north-west end) is about 4 metres.

The airstrip embankment is constructed of mine waste rock and, in some sections, sandy soil taken from a natural soil deposit on the north side of the airstrip. The surface is topped with crushed gravel, which presumably originated as mine waste rock. Issues relating to the waste rock as a potential source of metal contaminants are discussed in Section 3.2.5.

Runoff from a short, steep hill north of the airstrip drains through the fill material. Apparently, no culverts or other drainage systems were installed in the embankment. Extensive subsidence has taken place, particularly in the sections in which soil was used as fill material. The runway surface has frequent depressions in these sections that are as much as 2 metres deep. The nature of sediment sampled in Moose Bay indicates that fine-grained material was released from the airstrip as a result of this erosion.

Most aircraft cannot use the airstrip safely in its current condition. The runway has been used for small STOL (Short Take Off and Landing) aircraft, such as the Dehavilland Twin Otter. Recent upgrades by a third party have allowed for DC3 aircraft to land. The current condition of the airstrip and rehabilitation work necessary for its use is described in EBA 2006a.

3.2.10 Waste Disposal Sites

There are three principal waste disposal sites at the Terra Mine, all located adjacent to the Norex access road, as shown in Figure 3.2.11. Waste materials have been stored or discarded in lesser quantities at many other locations.

Waste Disposal Site #1 lies in a boulder field between Little Ho Hum Lake TCA and Jackfish Bay. The site appears to be a "bone-yard" primarily, where surplus equipment and materials have been dumped without being buried. This includes steel drums, which are mostly empty, or partly empty. The area is relatively dry, with no concentrated runoff pathways running through the site. Little Ho Hum Lake discharges to the north-west, away from the site.

Waste Disposal Site #2 is located 200 metres south of the first site, close to Jackfish Bay, but elevated several metres above the water in the bay. This site also appears to be a lay-down yard, or bone-yard, where equipment has been parked or dumped. The ground in the yard is covered with a layer of waste rock, and materials have been buried under the fill. The partly exposed materials are mostly steel. There are no concentrated runoff pathways at the site.

The third waste disposal site (#3) appears to be a shallow waste dump, where most of the waste has apparently been buried under a layer of soil. Some waste batteries and steel drums are found partly buried in the dump, and oil stains are found near the drums. The site lies close to Jackfish Bay, and the surface of the soil cover is only about one metre above the water level in the bay. A small drainage stream passes adjacent to the waste dump on its east side, forming a large pool that abuts the dump. This pool is at the same elevation as the water in Jackfish Bay and is directly connected to it by a channel. Another, much smaller and isolated pool is found just north of the dump; the pool is not directly connected to Jackfish Bay.

Surface water in the area of Waste Disposal Site #3 has been sampled routinely since 2005. The runoff water upstream of the landfill is very clean, but the water appears to be contaminated by leachate from the landfill further downstream. The water in the pool on the east side of the landfill contains elevated levels of iron and copper, several times the CCME-FAL guideline values (CCME 2006). The small isolated pool to the north of the landfill also contains water apparently contaminated by leachate from the landfill, with elevated concentrations of iron and arsenic.

3.2.11 Dock

A dock was constructed on the Camsell River to allow barges with significant draft to discharge cargo for the mine. The cargo would have included equipment, fuel, explosives, mill reagents and other supplies coming in, and copper flotation concentrate going out. Issues relating to hydrocarbon contamination of dock fill materials are covered under Section 3.2.12.

The dock which is in poor condition was apparently constructed by placing a heavy wooden retaining wall in the river, and backfilling behind it with soil and rock fill. The retaining wall may be held in place by piles driven into the river sediment, or steel anchor ties attached to solid ground under the fill behind the retaining wall, or both methods. These construction methods are not permanent, and eventually the retaining wall would give way, allowing dock fill materials to enter the river.

3.2.12 Hydrocarbon Contamination

Hydrocarbon contamination of native soils, and soil and rock fills at Terra and the other mine sites was assessed by EBA Engineering Limited in 2005 (EBA 2006b). Samples were collected from test pits to a maximum depth of one metre, and from greater depths in the docks using a hand operated drill. A total of 223 samples were collected and submitted for analyses including benzene, toluene, ethylbenzene, xylenes (BTEX) and hydrocarbon fractions F1 through F4. Samples were classified as contaminated, or otherwise, based on the Canada Wide Standards for petroleum hydrocarbons developed by the CCME (CCME 2001). The criteria for BTEX contamination were the CCME soil quality guidelines (CCME 2006).

Extensive hydrocarbon contamination of soil and fill was found at the Terra site, with an estimated plan area of 21,000 m^2 in total. The volume of material is tentatively estimated at 21,000 m^3. This was based on the maximum depth of the test pits. The contamination could be deeper than one metre in some locations, but is also shallower than one metre in areas of shallow bedrock. The primary areas of hydrocarbon contamination are indicated in Figure 3.2.12, along with the types of contaminants and estimated volumes of contaminated material in each area. The locations include areas where waste hydrocarbon products have been stored in drums and all of the larger fuel storage and fuel handling areas. Generally, the lighter-fraction hydrocarbon contaminants and BTEX are found near the fuel tanks, while heavier fractions are found at the waste oil storage areas.

The assessment report classified the contaminated areas according to a recommended sequence of priority. High priority areas host more volatile and mobile contamination, close to valued ecosystem components such as lakes. Medium priority plumes have more volatile contamination, further away from water bodies, or heavier and less mobile contaminants closer to water bodies. The low priority plumes were judged to be stable plumes and distant from valued ecosystem components. The priority classifications are shown in Figure 3.2.12. At Terra, about 6,600 m^3 of material is considered high priority, 11,300 m^3 is medium priority, and about 3,100 m^3 is considered low priority.

3.3 Northrim Mine

3.3.1 General Site Description

Northrim is an underground mine extending just over 100 metres below surface. The surface features are shown in Figure 3.3.1 and Figure 3.3.2. Surface facilities include a smelter building, assay lab, fuel storage tanks, offices, and a camp. There are several openings into the mine. A dock is located on the Camsell River. Waste rock has been placed on the shore of the river and in a small pile above the river. Process tailings have been disposed of in Hermandy Lake TCA, as well as the Camsell River. Unpaved roads connect the dock area with other site facilities. The following sections provide information on the major components of the site.

3.3.2 Underground Mine Openings

The openings into the underground mine include five vertical or sub-vertical raises, and three horizontal adits. The locations of the openings are shown in Figure 3.3.3. Portal #3 leads to three large, interconnected excavations containing a power plant, electrical equipment, ore processing equipment and some leftover process reagents. These facilities are described further in Section 3.3.5. Other openings are not known to contain material levels of equipment.

The mine workings at Northrim include at least three stopes that have been mined from underground to surface and left open, or partially open. Several shallow pits and trenches also remain open. The three open stopes are difficult to see and clearly pose a hazard to humans and wildlife.

The water level in the mine is controlled by the adjacent Camsell River, and any water emerging from the adits near the shoreline will mostly be the result of local infiltration. The Mine area is steep and rocky, so infiltration into the ground will be low. As a result, the adits produce only small trickles of water, typically more flow early in the open water season.

3.3.3 Waste Rock

General Description

The waste rock stored on surface at Northrim all came from the underground mine. Most of the rock was placed in an embankment along the edge of the Camsell River leading to a small pile above the river, known as the North Pile. Waste rock was also used to build infrastructure, such as the roadway and dock at the edge of the river, other roads providing access to Hermandy Lake TCA, where some of the tailings were disposed of, and pads for fuel tanks and building foundations.

The volume of waste rock has been roughly estimated from the surface areas and apparent thickness of material in various locations. There is an estimated 15,000 m^3 (about 27,000 t) in the larger waste deposits to the east of the mine adits, and a further 3,000 m^3 (about 5,500 t) in the infrastructure features elsewhere on the site. This is significantly less waste rock than found at the Terra Mine site.

Originally, there would have been little level ground in the area where the mine adits were excavated and the Camsell River would have come close to the bedrock. Waste rock was pushed into the river to provide access to the adits and the North Pile, and space for building construction and storage. Tailings were also discharged into the river in this area, some of which visually appears to have been incorporated into the roadway and dock.

High waste rock slopes occur on the North Pile, and along the edge of the embankment leading to the pile. The highest slopes on the south-east side of the pile are about 10 metres above the natural ground. The material appears to lie at the angle of repose (about 1.4H:1V), or flatter, and was probably dumped directly from mine vehicles, or pushed with a dozer. The material is hard and angular, and the slopes appear stable, showing no evidence of previous slope failures. Some of the slopes may act as a minor barrier to wildlife movement, but these slopes occur over limited distances (less than 100 metres).

Geochemical Characterization

The potential for contaminant release from the waste rock at Northrim was assessed by Rescan in 2004 and Lorax in 2005. A total of 15 samples were collected and tested with Acid Base Accounting (ABA) and leach extraction procedures. All of the data is presented in Lorax 2006. In 2005, two groundwater sampling wells were installed in or near the waste rock.

As was the case for the Terra Mine waste rock, all of the Northrim waste rock samples exhibited paste pH or rinse pH results in the neutral range, indicating that the rocks are currently not acidic. Leach extraction tests were performed on all of the waste rock samples collected in 2005. The results indicate that arsenic can be leached from the rock under pH neutral conditions.

Two groundwater sampling wells were installed at Northrim in 2005. One is located in the rock and soil fill forming the roadway in front of the main adit, beside the Camsell River. The second is located in native soil, just below the toe of the North Pile. Water samples were taken from the wells on one occasion, in August 2005. The water from both wells contained concentrations of arsenic and zinc that were elevated with respect to the concentrations found in the Camsell River.

Laboratory tests suggested that there is little potential for acidic conditions to develop in the Northrim waste rock in the future. About half of the waste rock samples had NPR values greater than two, and about one-third of the samples were in the uncertain range between one and two. Three samples had NPR values less than one, and would be designated as potentially acid generating. One of those samples was taken from a naturally mineralized un-mined outcrop, and the other two came from the small waste rock deposit immediately in front of the mine entrance.

The results as a whole show that the Northrim waste rock is currently a source of some metal loadings to the Camsell River although, water quality monitoring data indicated no changes to Camsell River water quality is occurring. The relatively small area of waste rock means that these loadings are not expected to increase the metal concentrations in the river. Future increases in metal loadings are possible, but are very unlikely to be significant.

3.3.4 Tailings

General Description

Valuable minerals were recovered from the ore in a small processing plant located underground at Northrim Mine and the tailings were discharged in two general locations. Records indicate that tailings were initially discharged into the Camsell River for a period of about one year (1971), and then discharged to Hermandy Lake TCA periodically from 1972 until milling operations ceased permanently in 1978. This suggests that the great majority of tailings produced at Northrim are located at Hermandy Lake TCA. Material thought to be tailings are found within the lake, and at two locations at the edge of the lake; at the north end, and in the south-east corner of the lake. These locations are shown in Figure 3.3.4.

Exposed Tailings

A tailings discharge pipeline runs from the underground mill to the north end of Hermandy Lake TCA. The extent of tailings on the north shore of the lake was investigated by Lorax in 2005, and the results of that work are presented in Lorax 2006. A series of 12 trenches were dug, including several through surface vegetation and soil, to determine if tailings had been covered over. Materials described as tailings were found at two locations on the north shore (150 m^2), and it was concluded from sampling and inspections that the exposed sandy materials are limited to a short beach, less than 3 metres wide and 50 metres long. These materials have low levels of sulphide and very low levels of arsenic and lead which indicate these materials are not likely to be tailings.

Tailings are found covered with muskeg and grasses (i.e. not exposed), on the shore at the south-east corner of Hermandy Lake TCA, between the lake and the Leachate Pond (see Figure 3.3.4). The surface area of the muskeg covered tailings is estimated to be approximately 1,300 m^2. Five tailings samples were collected from this area in 2004 and 2005. The paste pH or rinse pH of all samples were greater than 7, indicating that this material is not currently acidic. The sulphur contents were relatively high (median 1.7%), but the neutralizing capacities were also high, and all of the Neutralizing Potential Ratios were greater than 2, indicating that these tailings are not potentially acid generating. Leach extraction tests conducted on two of the samples produced leachates with metal concentrations that were elevated with respect to Hermandy Lake TCA water. The leach extraction tests indicate that the tailings are a source of metal loadings to Hermandy Lake TCA, despite the fact that they are not acidic. Again, the surface area of the tailings is relatively small, so the loadings to the lake from this source will be relatively small.

A dump of process waste is found on the south side of the Leachate Pond. This material appears to be oxidized waste from a smelting process, rather than tailings from gravity separation and froth flotation processes. Large furnace crucibles are found amongst the waste. Two samples of this material were collected and tested in 2004. The material had alkaline paste pH's and was designated not potentially acid generating. Leach extraction tests produced leachates with very high maximum concentrations of arsenic, copper and iron. Any leachate from the dump is likely to carry high concentrations of these metals although the small surface area of the dump (about 100 m^2) will limit the volume of leachate produced.

Hermandy Lake TCA currently discharges to the south-east, through the Leachate Pond, towards the Camsell River. Metal loadings from the waste dump would enter the Leachate Pond and drain in the same direction. The waste dump is therefore likely to be a source of contaminants found in the drainage to the Camsell River.

Submerged Tailings

Tailings are found under water in two locations; in the Camsell River near the mine entrance, and in Hermandy Lake TCA. Eleven samples of sediment have been collected from the Camsell River at Northrim, in programs completed in 2004 and 2005. The samples were tested for total sulphur and total metals in an attempt to identify an influence from tailings deposition. The total sulphur contents varied from 0.03 to 0.9%, with a median of 0.25%. These values are similar to those found in the sediments of Ho Hum Lake TCA, at the Terra Mine. The higher values were found in sediments closer to the shoreline, downstream of the mine adits. The metals content of three samples collected close to the Northrim dock and immediately downstream were elevated with respect to Tutcho Lake, and in a similar range to the values for Ho Hum Lake TCA sediments. Samples collected away from the dock were much lower in metals. The conclusion is that tailings were discharged into the river near the Northrim dock. Monitoring of water quality in the Camsell River below the tailings shows no impacts on water quality.

In 2004 and 2005, twelve samples of sediment were collected from Hermandy Lake TCA and tested for total sulphur and metals. The sulphur concentrations ranged from 0.04 to 2.5%, with a median of 1.3%. These values are typically greater than found at Ho Hum Lake TCA. Hermandy Lake TCA sediments have concentrations of arsenic, cadmium, cobalt, copper, lead, nickel and zinc that are typically greater than Tutcho Lake, and comparable to the range found at Ho Hum Lake TCA. Elevated metal concentrations in sediments are found throughout the lake, but the highest values occur at the north end of the lake. The sampling results and appearance of the sediments confirm that tailings were discharged to the lake.

Hermandy Lake TCA Water

The water quality of Hermandy Lake TCA has been monitored by INAC staff since 2004. Surface samples have been collected at two locations (north and south), several times during each open water season. The lake depth varies from two metres at the southern sampling site to seven metres at the north. The results of surface sampling in 2006 are summarized in Table 3.3.1. For comparison, the table includes the CCME-FAL guideline values (CCME 2006). The concentrations of arsenic and copper in the lake water have been greater than the guideline values on at least one sampling occasion.

Hermandy Lake TCA Discharge

Hermandy Lake TCA currently discharges through the Leachate Pond at the south-east corner of the lake. The Leachate Pond drains down a steep hill to the Camsell River, about 300 metres from the lake. The original, natural discharge route was from the south-west corner of the lake. As part of the tailings disposal system, a low berm was built on the original discharge route, to retain water and re-direct flow to the south-east. Water on the existing drainage route from Hermandy Lake TCA to the Camsell River has been sampled routinely since 2004. This includes sampling at three locations; in the Leachate Pond, in the stream flowing from the Leachate Pond, and in the Camsell River at the point where the drainage enters the river. The sampling indicates that the concentrations of several metals increase as the discharge drains from the lake towards the river. This is shown in Table 3.3.2, which summarizes the average concentrations in the drainage path in 2005 and 2006.

Table 3.3.1 Water Quality of Hermandy Lake TCA (2005 and 2006)

Parameter	Units	Total Concentrations[1]		CCME-FAL Guideline[2]
		Median	Maximum	
pH		7.9	8.0	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	63.9	65.8	
Hardness (as $CaCO_3$ equiv.)	mg/L	77.7	82.4	
Chloride (total)	mg/L	<0.7	<0.7	
Sulphate (total)	mg/L	10	11	
Calcium (total)	mg/L	23.1	24.3	
Magnesium (total)	mg/L	4.7	5.3	
Sodium (total)	mg/L	1.4	1.5	
Ammonia (total, as N)	mg/L	0.007	0.010	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	<0.01	
Phosphorus (total)	mg/L	0.02	0.02	
Total Metals				
Aluminum	µg/L	<30	32.0	100
Antimony	µg/L	0.1	0.4	
Arsenic	µg/L	9.9	10.6	5
Beryllium	µg/L	<0.1	<0.1	
Cadmium	µg/L	<0.1	<0.1	0.03
Chromium	µg/L	0.3	0.4	1
Cobalt	µg/L	0.2	0.2	
Copper	µg/L	3.3	3.8	2
Iron	µg/L	56	81	300
Lead	µg/L	0.8	0.8	2
Lithium	µg/L	1.4	2.0	
Manganese	µg/L	4.7	7.7	
Mercury	µg/L	<0.02	<0.02	0.1
Molybdenum	µg/L	1.1	1.7	73
Nickel	µg/L	1.1	1.2	65
Rubidium	µg/L	1.7	2.0	
Selenium	µg/L	<1	<1	1
Silver	µg/L	<0.1	<0.1	0.1
Thallium	µg/L	<0.1	<0.1	
Uranium	µg/L	0.2	0.3	
Zinc	µg/L	<10	<10	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of median values; if all results are below detection limit, this is noted with the "<" symbol and the detection limit value.

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

Table 3.3.2 Water Quality of Discharge to Camsell River (2005 and 2006)

Parameter	Units	Average Concentrations[1]				CCME-FAL Guideline[2]
		Hermandy Lake TCA	Leachate Pond	Outlet Stream	Camsell River (at inflow point)	
pH		7.9	7.6	7.4	7.6	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	63.9	85.6	142	68.4	
Hardness (as $CaCO_3$ equiv.)	mg/L	77.7	98.0	145	81.0	
Chloride (total)	mg/L	<0.7	<0.7	<0.7	1.8	
Sulphate (total)	mg/L	10	10	5	11	
Calcium (total)	mg/L	23.1	29.2	43.1	21.2	
Magnesium (total)	mg/L	4.7	6.1	8.9	7.2	
Sodium (total)	mg/L	1.4	3.1	3.6	2.3	
Ammonia (total, as N)	mg/L	0.007	0.010	<0.005	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	<0.01	<0.01	<0.01	
Phosphorus (total)	mg/L	0.02	0.09	0.03	0.04	
Total Metals						
Aluminum	µg/L	<30	<30	<30	203	100
Antimony	µg/L	0.1	0.6	0.2	0.1	
Arsenic	µg/L	9.9	58.6	21.2	7.3	5
Beryllium	µg/L	<0.1	<0.1	<0.1	<0.1	
Cadmium	µg/L	<0.1	<0.1	<0.1	<0.1	0.03
Chromium	µg/L	0.3	0.3	0.5	0.6	1
Cobalt	µg/L	0.2	2.1	3.1	1.5	
Copper	µg/L	3.3	4.8	9.5	4.6	2
Iron	µg/L	56	181	440	1007	300
Lead	µg/L	0.8	10.9	2.5	2.5	2
Lithium	µg/L	1.4	2.2	1.4	2.4	
Manganese	µg/L	4.7	33.4	371	76.5	
Mercury	µg/L	<0.02	<0.02	<0.02	<0.02	0.1
Molybdenum	µg/L	1.1	1.1	1.0	0.5	73
Nickel	µg/L	1.1	2.9	2.1	1.3	65
Rubidium	µg/L	1.7	3.8	2.1	1.7	
Selenium	µg/L	<1	<1	<1	<1	1
Silver	µg/L	<0.1	<0.1	0.2	0.2	0.1
Thallium	µg/L	<0.1	<0.1	<0.1	<0.1	
Uranium	µg/L	0.2	0.2	0.1	0.7	
Zinc	µg/L	<10	18	19.5	10.5	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values;

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

The monitoring data indicate that arsenic, copper, iron and lead are picked up on the drainage path, and the Camsell River water exceeds the CCME-FAL guidelines for these metals at the point where the drainage from Hermandy Lake TCA enters the river. The estimated volume of the lake discharge is discussed in Section 4.2.1.

Water Quality data for the Camsell River does not indicate any effects from either the tailings in the river or discharges from the mine site and tailings area.

3.3.5 Buildings and Equipment

The buildings and equipment include ore processing facilities housed in an underground excavation, mine services facilities, such as ventilation plants, a smelter building containing furnaces, an assay lab, a camp and offices, fuel storage tanks, and various equipment and industrial debris deposited between Hermandy Lake TCA and the Camsell River. The locations of these components are shown in Figure 3.3.1.

The volume of non-hazardous waste that would be generated from demolition of the buildings and collection of equipment and debris is estimated to be 750 m^3 (see Rescan 2005a). The material would be comprised primarily of steel and wood.

Hazardous building materials have been identified at Northrim. These include small amounts of non-friable asbestos containing materials. Lead-amended paint was found on two fuel tanks. Interior paint was also found to contain lead, but at concentrations that should not present a concern for waste disposal. One sample of paint from a fuel tank was found to contain PCB, but at a low concentration (20 µg/g) that does not present a waste disposal concern (see Rescan 2005a).

The underground processing facilities consist of three large, inter-connected chambers. The first contains a diesel-powered generator, the second contains processing equipment including conveyor belts, a crusher, a classifier, a concentrating table, froth flotation cells and pumps. The equipment in the first and second chambers contains lubricating oils in drives, gearboxes, or sumps. Several steel drums containing hydrocarbon products are also stored in the first chamber.

The third chamber is a storage area for process reagents, and includes significant quantities of hydrated lime (calcium hydroxide) and soda ash (sodium carbonate), and a small quantity of the flotation reagent potassium amyl xanthate. The ceiling in the third chamber is a wide span of rock, without any rock-bolts or other roof support. The floor has a thick deposit of ice in which many of the reagent containers are buried.

The Northrim site has a significant inventory of hydrocarbon products stored in drums, including used oils, waste fuel and glycol. The details of the assessment of these materials are contained in Golder 2006.

3.3.6 Roads

There are only 340 metres of roadways at Northrim that are recognizable as such, although there are additional tracks that may have taken vehicular traffic at one time. Similar to the Terra site, the roads are generally just thin traffic surfaces of waste rock covering cleared soil, and there are no large road embankments. No significant erosion of road materials caused by runoff drainage has been noted.

3.3.7 Waste Disposal Sites

The principal site of waste disposal at Northrim is the wooded slope between the Leachate Pond and the camp, west of the fuel tank farm. Debris of all kinds litters the slope, including old equipment and steel drums, both empty and filled with waste hydrocarbons (see Golder 2006).

3.3.8 Dock

Similar to the Terra Mine, the Northrim site is equipped with a dock on the edge of the Camsell River providing sufficient depth of water for large barges to re-supply the site. The supplies handled at the dock included fuel and the dock fill materials have been contaminated with spilled hydrocarbons. The issue of hydrocarbon contaminated soils and fill is discussed in Section 3.2.12 and Section 3.3.9.

The dock is formed by a wooden retaining wall planted in the river, which holds the dock fill in place. The fill appears to include broken rock, soil, and some mill tailings or other fine-grained mine waste. Unless removed or supported, the dock retaining wall will eventually give way, allowing the fill materials to enter the river.

During the open water season in 2006 the Camsell River discharge was higher than normal, and the water level at the Silver Bear Mines was relatively high. The Northrim dock was largely submerged under water from June through August, suggesting that considerable settlement of the dock fill has taken place since the dock was constructed 30 years ago.

3.3.9 Hydrocarbon Contamination

Hydrocarbon contamination of soils and fill at Northrim was assessed in 2005. The general assessment approach is described in Section 3.2.12, and a detailed report on the work is contained in EBA 2006b.

An estimated total of 5,900 m^3 soil and fill at Northrim is contaminated with hydrocarbons. The primary areas of contamination are shown in Figure 3.3.5, indicating the types of contaminants and the estimated volumes of material in each area. The areas include the main fuel tank farm, a storage area for waste hydrocarbons in drums just downstream of the Leachate Pond, and the dock area. The lightest-fraction hydrocarbons and some BTEX were found in areas where fuel was stored or handled.

The contaminated materials have been classified into remediation priorities according to the type of contamination and its location with respect to water bodies (described in Section 3.2.12). An estimated volume of 1,900 m^3 of material is considered a high remediation priority, while 1,500 m^3 is considered medium priority and 2,500 m^3 has been classed as low priority.

3.4 Norex Mine and Graham Vein

3.4.1 General Site Description

The Norex Mine and Graham Vein trench were originally mined independently, but were later connected when the Norex workings were used to mine the Graham Vein from below. The Norex workings go to a depth of 180 metres below surface. The surface features of the Norex and Graham Vein sites are shown in Figure 3.4.1 and Figure 3.4.2.

The surface features at Norex include a waste rock pile, located just below the mine entrance, a maintenance garage, a ventilation and compressor plant, and fuel tanks. At Graham Vein, the features include an open mining trench, an old wooden ore bin and the remains of a crushing plant. A small amount of tailings was produced at Graham Vein and was disposed of in or adjacent to Xeron Pond.

3.4.2 Underground Mine Openings

The mine openings associated with Norex include two portals at the waste rock pile, one of which leads to an underground maintenance shop, the other provides access to the ramp, or decline, leading down into the mine. There are three vertical ventilation raises in the area. The mine openings are shown in Figure 3.4.3.

The main portal at Norex produces a significant flow of water, originating from the flooded decline and the mine workings below. In the summer of 2006, the flow rate was roughly estimated to vary between 30 and 60 litres per minute by S. Schultz of SRK. The drainage from the portal is a potential concern with respect to its quality; that issue is discussed further in Section 3.4.4.

3.4.3 Open Pit Workings

The Graham Vein trench is classified as open pit workings because it was mined partly from surface. The vein was also mined from the Norex workings below and the trench is connected to the mine. The underground stope was partially backfilled, and the backfill has sufficiently low permeability that local runoff water accumulates in the bottom of the trench. The trench is about 50 metres long, and varies in width from about 4 metres towards the bottom, to as much as 15 metres in the mouth. The open trench appears to be about 15 metres deep at the deepest section.

3.4.4 Waste Rock

General Description

The majority of the waste rock at the Norex and Graham Vein sites is found in a single pile just below the Norex Mine entrance. A small amount of waste (about 3,500 m^3) is also located in a flat, low pile located at the entrance to the Graham Vein trench. As at the other sites, waste rock was used to construct roads in the area and may have been used to build part of the haul road to the Terra Mine.

Based on the surface area and apparent thickness of the Norex pile, it contains roughly 45,000 m^3 of waste rock (about 80,000 t). The slopes on the edges of the pile are about 6 metres above the adjacent natural ground. The side slopes are steep, but appear to be stable. The material is hard and angular, and there is no evidence of previous instability.

Geochemical Characterization

A total of 21 waste rock samples were collected in 2004 and 2005 for ABA and leach extraction tests. All of the results are presented in Lorax 2006. One waste rock sample had an acidic rinse pH. This was a sample from the Norex waste pile with a pH of 5.5. Leach extraction tests indicated that some of the waste rock could be a source of zinc loadings to the environment. Parts of the waste rock pile must also release cadmium, lead and zinc, because the seepage emerging from the pile contains elevated concentrations of these metals.

About 30% of the waste rock samples collected at Norex and Graham Vein had NPR values greater than 2, and would not be considered potentially acid generating. About 33% of the samples were in the uncertain range between one and two. The remaining 38% of samples had NPR values less than 1, and would be designated potentially acid generating. Three of the eight samples with NPR's below 1 were collected close to the Norex main portal. In contrast to the Terra and Northrim results, the testing of waste rock at Norex indicates a potential for acidic conditions to develop in future. The fact that slightly acidic conditions were measured in one sample supports this conclusion.

Mine and Waste Rock Drainage

Seepages emerging from the Norex waste rock pile have been routinely monitored since 2002. The majority of seepage occurs on the north-east side of the pile and has elevated levels of arsenic, cadmium, copper, lead and zinc. The source of most of this water is drainage from the main portal, which enters the waste rock pile soon after it emerges from the mine. From June through August 2006, the volume of mine drainage was estimated to vary from 30 to 60 litres per minute, with the lower flow rate occurring later in the year. Table 3.4.1 summarizes the quality of water draining from the Norex portal and the associated downstream seepage emerging from the waste rock pile in 2005 and 2006.

The data show remarkable changes in the chemistry of this water as it flows from the mine portal into the waste rock pile, and emerges from the pile just 170 metres downstream. The water draining from the mine workings, which is not acidic, contains high concentrations of iron and manganese, and relatively high levels of arsenic. The cadmium, lead and zinc concentrations are relatively low. As the water moves from the mine portal into and through the waste pile, iron is oxidized from the soluble ferrous to insoluble ferric form and precipitated, resulting in extensive iron staining on the ground near the portal. Manganese would also be oxidized and precipitated, and arsenic would be co-precipitated with the iron and manganese. By the time the drainage emerges as seepage from the pile, the iron, manganese and arsenic concentrations are all significantly reduced. The waste rock is a source of heavy metals including copper, cobalt, lead and zinc. Zinc increases are most notable, increasing from 26 µg/L in the mine drainage to more than 1000 µg/L in the waste pile seepage. The level of these metals in the discharge has no material effect on the Camsell River.

Table 3.4.1 Water Quality of Norex Site Drainage (2005 and 2006)

Parameter	Units	Average Concentrations[1]		CCME-FAL Guideline[2]
		Mine Drainage	Waste Pile Seepage (NE Side)	
pH		8.0	7.9	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	161	145	
Hardness (as $CaCO_3$ equiv.)	mg/L	164	198	
Chloride (total)	mg/L	1.8	1.5	
Sulphate (total)	mg/L	41	91	
Calcium (total)	mg/L	48.6	62.2	
Magnesium (total)	mg/L	10.3	10.3	
Sodium (total)	mg/L	15.2	14.0	
Ammonia (total, as N)	mg/L	0.28	0.009	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	0.25	
Phosphorus (total)	mg/L	0.06	0.03	
Total Metals				
Aluminum	µg/L	18.7	32.0	100
Antimony	µg/L	0.8	1.4	
Arsenic	µg/L	186.3	45.0	5
Barium	µg/L	61.1	35.0	
Beryllium	µg/L	0.1	0.1	
Cadmium	µg/L	0.1	1.5	0.03
Cesium	µg/L	0.1	0.1	
Chromium	µg/L	2.6	1.4	1
Cobalt	µg/L	2.1	33.8	
Copper	µg/L	1.8	20.1	2
Iron	µg/L	4291.7	157.3	300
Lead	µg/L	38.7	109.1	2
Lithium	µg/L	10.8	10.6	
Manganese	µg/L	342.5	122.1	
Mercury	µg/L	0.0	0.0	0.1
Molybdenum	µg/L	19.1	18.3	73
Nickel	µg/L	1.8	15.8	65
Rubidium	µg/L	8.0	7.9	
Selenium	µg/L	0.6	0.7	1
Silver	µg/L	0.1	0.1	0.1
Strontium	µg/L	280.2	263.7	
Thallium	µg/L	0.1	0.1	
Titanium	µg/L	0.8	0.6	
Uranium	µg/L	11.4	9.0	
Vanadium	µg/L	1.6	0.9	
Zinc	µg/L	26.3	1007.7	30

Notes:
1 Results below detection limit are assumed to equal detection limit for calculation of average values;
2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

The drainage stream from the Norex site flows north for a distance of 600 metres through wetland areas before discharging into the Camsell River. In July and August 2006, the water quality on this drainage route was assessed. Samples were taken from the stream about 10 metres upstream of its discharge into the Camsell River, and from the river just off-shore from the discharge point. The averages of the two data sets are shown in Table 3.4.2.

The data indicate that very effective removal of several metals takes place along the drainage route, including arsenic, cadmium, copper, lead, nickel and zinc. Rapid dilution in the Camsell River reduces contaminant concentrations below the CCME-FAL guideline values (CCME 2006) close to the shoreline.

3.4.5 Tailings

A small amount of tailings, about 1,100 t according to historical records, was produced from the test processing undertaken at the Graham Vein site in 1970 and 1971. The ore was obtained from the Graham Vein trench, as well as the initial development of the decline at the Norex site. Sampling suggests that some of the tailings are found near the remaining processing facilities, mixed with sandy borrow soil and waste rock, and appear to have been discharged to Xeron Pond.

Xeron Pond is a shallow pond with a small catchment area, surrounded by marsh vegetation. There is no visual evidence of tailings near the pond or under the water, but sediment sampling seems to confirm an influence of tailings disposal on the lake sediments. In 2005, Lorax Environmental Services (SD A) collected five samples of sediment from the pond, which were analyzed for total sulphur and metals.

The total sulphur ranged from 0.68 to 0.80%, with a median concentration of 0.75%, which is higher than the median concentration found in Ho Hum Lake TCA at the Terra site. An abundance of organic matter in the sediments is obvious from the appearance of the samples, including one core sample that consisted of brown sediment with high organic content throughout its 35 centimetre length. The abundance of organic matter in the sediments would produce highly reducing conditions that are likely to precipitate metals from the water column in sulphide forms.

The Xeron Pond sediments had concentrations of cadmium, copper and zinc that are typically greater than Tutcho Lake. The cadmium (1.8 to 2.2 mg/kg) and zinc (913 to 1090 mg/kg) concentrations are also higher than found at Ho Hum Lake TCA. These metal concentrations may be relatively elevated by the process of sulphide precipitation. The source of precipitated metals in the sediments could be dissolved species from deeper sediments, or runoff entering the pond from the mine site.

Table 3.4.2 Water Quality of Discharge to Camsell River (2006)

Parameter	Units	Average Concentrations[1]		CCME-FAL Guideline[2]
		Stream Flow (downstream of wetlands)	Camsell River (near inflow point)	
pH		7.9	8.0	6.5 – 9
Alkalinity (total, as CaCO3)	mg/L	152	52.0	
Hardness (as CaCO3 equiv.)	mg/L	197	71.2	
Chloride (total)	mg/L	1.3	2.2	
Sulphate (total)	mg/L	65	13	
Calcium (total)	mg/L	58.7	16.9	
Magnesium (total)	mg/L	12.3	7.1	
Sodium (total)	mg/L	13.2	2.2	
Ammonia (total, as N)	mg/L	<0.005	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	<0.01	
Phosphorus (total)	mg/L	<0.01	<0.01	
Total Metals				
Aluminum	µg/L	155.5	54.6	100
Antimony	µg/L	0.15	0.1	
Arsenic	µg/L	1.85	0.2	5
Barium	µg/L	29.3	11	
Beryllium	µg/L	0.1	0.1	
Cadmium	µg/L	0.1	0.075	0.03
Cesium	µg/L	0.1	0.1	
Chromium	µg/L	0.6	0.45	1
Cobalt	µg/L	0.15	0.1	
Copper	µg/L	2.85	1.1	2
Iron	µg/L	262	94	300
Lead	µg/L	0.1	0.35	2
Lithium	µg/L	9	2.1	
Manganese	µg/L	15	3.45	
Mercury	µg/L	0.02	0.02	0.1
Molybdenum	µg/L	5.65	0.25	73
Nickel	µg/L	1.25	0.35	65
Rubidium	µg/L	2	1.3	
Selenium	µg/L	1	0.65	1
Silver	µg/L	0.15	0.1	0.1
Strontium	µg/L	198	51.35	
Thallium	µg/L	0.1	0.1	
Titanium	µg/L	7.2	2.35	
Uranium	µg/L	2.2	0.45	
Vanadium	µg/L	0.75	0.3	
Zinc	µg/L	10	5.3	30

Notes:
1 Results below detection limit are assumed to equal detection limit for calculation of average values;
2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

The quality of Xeron Pond water has been monitored by INAC staff since 2002. Initially, surface samples were collected only at the shoreline, but samples have been collected from the middle of lake since 2005, at surface and about one metre from the bottom. The data collected in 2005 and 2006 are summarized in Table 3.4.3, which shows average concentrations in the surface water.

Although the concentrations of several elements in the Xeron Pond water are higher than found at the un-impacted reference site, Tutcho Lake, almost all of these are below the CCME-FAL guideline values (CCME 2006). A few elements measure above CCME-FAL limits (Cd, Se) as a result of the high method detection limits for these elements. Chromium levels are elevated consistent with background lake samples. Lead levels are less than CCME-FAL criteria when one anomalously high value is removed from the mean. Silver does have some measured values above method detection limits and on average may exceed CCME-FAL criteria. Tailings in or near Xeron Pond may influence the current water quality, but this appears to be a limited impact.

3.4.6 Buildings and Equipment

Buildings and equipment at Norex and Graham Vein include ventilation and compressor plants, a maintenance garage, fuel storage tanks, a wooden ore bin and the remains of a crushing plant. The locations of these components are shown in Figure 3.4.1.

The volume of non-hazardous waste that would be generated from demolition of the buildings and collection of equipment and debris is estimated to be 940 m^3 (see Rescan 2005a). This material would be comprised primarily of steel and wood.

Lead-amended paint has been identified on two fuel storage tanks at Norex. Other materials requiring special waste disposal include a small inventory of hydrocarbon products stored in drums (approximately 2,400 litres). Assessment of this issue is discussed collectively with the other Silver Bear Mines in Section 3.2.7, and details contained in Golder 2006.

3.4.7 Roads

The primary road considered part of the Norex site runs just over one kilometre, from the waste rock pile to the Norex Dock. The road is heavily overgrown with alder bushes, and is currently only used for all terrain vehicles. The condition of the road and the potential for its use by large vehicles is unknown. The road does not have any significant drainage crossings.

About half a kilometre of roads provide access to parts of the Graham Vein site. These roads are generally in very poor condition. They do not cross any significant streams. Issues relating to the haul road between Norex and Terra are discussed in Section 3.2.8.

Table 3.4.3 Water Quality of Xeron Pond (2005 and 2006)

Parameter	Units	Average Concentrations[1]	CCME-FAL Guideline[2]
pH		7.1	6.5 – 9
Alkalinity (total, as CaCO3)	mg/L	17.8	
Hardness (as CaCO3 equiv.)	mg/L	24.8	
Chloride (total)	mg/L	<0.7	
Sulphate (total)	mg/L	3	
Calcium (total)	mg/L	6.6	
Magnesium (total)	mg/L	2.0	
Sodium (total)	mg/L	1.3	
Ammonia (total, as N)	mg/L	0.01	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	0.05	
Phosphorus (total)	mg/L	0.04	
Total Metals			
Aluminum	µg/L	61.6	100
Antimony	µg/L	0.9	
Arsenic	µg/L	0.6	5
Barium	µg/L	11.6	
Beryllium	µg/L	0.1	
Cadmium	µg/L	0.1	0.03
Cesium	µg/L	0.1	
Chromium	µg/L	18.8	1
Cobalt	µg/L	0.1	
Copper	µg/L	1.0	2
Iron	µg/L	156.2	300
Lead	µg/L	66.2 (0.2)[3]	2
Lithium	µg/L	0.8	
Manganese	µg/L	12.8	
Mercury	µg/L	0.0	0.1
Molybdenum	µg/L	2.3	73
Nickel	µg/L	0.3	65
Rubidium	µg/L	1.6	
Selenium	µg/L	1.0	1
Silver	µg/L	0.2	0.1
Strontium	µg/L	11.6	
Thallium	µg/L	0.1	
Titanium	µg/L	0.5	
Uranium	µg/L	0.2	
Vanadium	µg/L	0.2	
Zinc	µg/L	15.0	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values;

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

3 Mean value with high reading for June 2006 eliminated.

3.4.8 Hydrocarbon Contamination

Hydrocarbon contamination of soils and fill at Norex and Graham Vein was assessed in 2005. The general assessment approach is described in Section 3.2.12, and details of the work are contained in EBA 2006b.

The total quantity of contaminated material is estimated to be 3,900 m^3. The primary areas of contamination are the fuel tank farm and main drum storage area at Norex, located on the west side of the waste rock pile. The areas of contamination are shown in Figure 3.4.4, with the type of contaminants and estimated volumes of contaminated material in each area. Of the total quantity, an estimated 200 m^3 is considered a high remediation priority, 1,500 m^3 is considered medium priority and 2,200 m^3 is classed as low priority.

3.5 Smallwood Mine

3.5.1 General Site Description

The underground mine workings at Smallwood extend to a depth of 120 metres. The surface features of the site are shown in Figure 3.5.1 and Figure 3.5.2. The surface features include several mine openings, a ventilation and compressor plant, shacks and trailers, and a waste rock pile at the mine entrance. A road extends from the mine to an airstrip, east of the mine, and continues around Smallwood Lake to an exploration site at the south end of the lake. Ore mined at Smallwood was hauled to the mill at Terra on the all-weather road.

3.5.2 Underground Mine Openings

The mine openings associated with Smallwood include four vertical ventilation raises, and two portals. One portal opens into an underground shop, the other provides access to the main decline. The locations are shown in Figure 3.5.3. None of the mine openings at Smallwood produce any water.

3.5.3 Waste Rock

General Description

Waste rock at the Smallwood Mine is located in piles in the immediate area of the mine entrance. The primary pile lies below the mine portals, just above Smallwood Lake. A secondary, long and narrow pile extends north-east from the mine entrance. Some of the waste rock taken from the Smallwood workings would probably have been used to construct roads in the area.

On the flat, levelled surface of the main waste rock pile, there are several smaller stockpiles of broken rock. These materials were apparently classified as low-grade ores when they were mined, as indicated by signs posted nearby. The material in most of the stockpiles is also clearly extensively mineralized. The total volume of waste rock in piles near the mine entrance is roughly estimated at

35,000 m^3 (about 65,000 t). Of this, about 1,600 m^3 appears to have been stockpiled as low-grade ore.

As found at the other waste rock piles at the Silver Bear Mines, the rock at Smallwood is angular hard material, with the steepest slopes at the angle of repose (about 1.4H:1V). The slopes appear stable, and no evidence of previous slope failures has been found.

The high rock slopes of the main pile (about 7 metres high) are set back from the edge of Smallwood Lake by at least a few metres. These slopes may act as a minor impediment to wildlife movement, but they occur over a limited distance (140 metres) and alternative shallower slopes are likely to be evident to wildlife seeking passage through the area.

Geochemical Characterization

A total of 20 samples of Smallwood rock were collected in 2004 and 2005 for ABA and leach extraction tests. All of the data is presented in Lorax 2006. Two groundwater wells were installed in native soil just below the toe of the main waste rock pile, on the edge of Smallwood Lake, and water samples were collected in 2005 and 2006.

The leach extraction test results indicate that the waste rock could be a source of zinc and cadmium loadings to Smallwood Lake. This inference is supported by the elevated concentrations of arsenic, cadmium, iron and zinc measured in groundwater samples from both of the wells. The concentration of zinc is particularly elevated in the groundwater at both wells, with the highest result being 14.8 mg/L. However, metal concentrations in Smallwood Lake itself are low, indicating that the current metal loadings from the Smallwood waste rock piles are not significant. The Smallwood Lake water quality data is summarized in Section 4.2.2 below.

Results of the ABA testing suggest that there is a potential for metal loadings to increase in the future. The majority (85%) of the Smallwood samples had NPR values less than 1, indicating a potential to produce acid drainage. About 15% of the samples were in the uncertain range between one and two, and none of the samples collected at Smallwood had NPR values greater than 2. Two waste rock samples from Smallwood had rinse pH's less than 7, confirming that acidic conditions are possible. However, at least four of the "potentially acid generating" samples came from the ore stockpiles on the dump surface.

It should be noted that current oxidation rates of the waste rock appear to be quite low as evidenced by the fact that the rock has been in place for more than 25 years and sulphate levels in Smallwood Lake below the pile are quite low (13 mg/L) and metals levels have been stable over the past 5 years of monitoring.

3.5.4 Buildings and Equipment

Buildings and equipment at Smallwood include ventilation and compressor plants, one large fuel storage tank, a trailer and shacks. These components are shown in Figure 3.5.1.

The volume of non-hazardous waste that would require disposal is estimated to be 155 m^3 (see Rescan 2005a). This material would be comprised primarily of steel and wood.

Lead-amended paint has been identified on the fuel storage tank and the trailer. A number of empty steel barrels are found at the site, and one drum containing hydrocarbon waste.

3.5.5 Roads

There are five kilometres of roads in the area of Smallwood Lake, including roads connecting mine features such as the ventilation raises, and a small road that runs around the east side of Smallwood Lake, and beyond the lake to an exploration site.

The condition of the roads leading to and around the site is good, with no significant erosion from runoff flows. The road from Smallwood to the exploration site has not been inspected closely, but the route and terrain suggest that runoff flows to the road embankment would be too low to cause significant erosion problems.

3.5.6 Airstrip

The airstrip to the east of Smallwood Mine was constructed in 1970 for the purpose of exploring the Graham Vein showing and was only used for a few years. The airstrip was capable of handling Douglas DC3 aircraft. The runway appears to have been formed with re-graded local soil and not mine waste rock. The airstrip is overgrown with vegetation. Its location is distant from any water bodies and therefore sediment release from the site is not a concern.

3.5.7 Hydrocarbon Contamination

Hydrocarbon contamination at Smallwood was assessed in 2005. The results of the assessment are reported in EBA 2006b. The general assessment approach is described in Section 3.2.12.

The total volume of contaminated soil and fill is estimated at 3,800 m^3, located on the waste rock pile, at the tank farm, and the mine services plant at the portal. The contaminated areas are shown in Figure 3.5.4, with the type of contaminants and estimated volumes of contaminated materials in each area. The estimated volume designated as high priority is 500 m^3 on the waste rock pile, where more volatile contaminants were found in close proximity to Smallwood Lake.

4 Current Environmental Conditions

4.1 Climate

There are no meteorological stations close to the project area with long term records including recent years. The closest stations are Yellowknife, 395 kilometres south-east of the Silver Bear Mines, and Norman Wells, 400 kilometres to the west, at approximately the same latitude. The Climate Normals for Norman Wells (1971 to 2000) published by Environment Canada indicate average air temperatures below zero from October to April. The coldest month is typically January (average –27 ^{o}C) and the warmest month is typically July (average 17 ^{o}C). The average annual rainfall at Norman Wells from 1971 to 2000 was 166 mm. The average air temperatures at Yellowknife are similar to Norman Wells, although the months of October and November are distinctly warmer at the lower latitude. The average annual rainfall at Yellowknife from 1971 to 2000 was 165 mm.

An automated weather station was installed at Ho Hum Lake TCA, on the Terra Mine site, in June 2005. The data collected at the station is presented in INAC 2007. Total rainfall measured at the station from July to October 2005 was 64 mm. Rainfall measured from May to mid-August 2006 was 118 mm. These values, from incomplete rainfall seasons, are likely to be significantly lower than the total rainfall amounts in these years. Long term rainfall records are available for Port Radium. Sufficient data are not available to confirm similar precipitation patterns.

The data collected at the Ho Hum Lake TCA weather station allows for the calculation of lake evaporation, which is dependent on wind velocity, air temperature and humidity, and water temperature. Lake evaporation calculated with the Penman Combination method was 177 mm from June 29 to September 24, 2005, and 297 mm from June 2 to August 22, 2006. These data both represent incomplete seasons for lake evaporation, although the rate of evaporation would be expected to decrease significantly after August 22, as air and water temperatures decrease. Therefore, the evaporation estimated for the measurement period in 2006 would be close to the actual annual value. In 2006, approximately 45% of the total estimated lake evaporation occurred in June.

Indian and Northern Affairs Canada has completed end-of-winter snow surveys at multiple sites in the Snare River Basin south of Silver Bear for almost 30 years, since 1978. The two sites closest to Silver Bear are Mesa Lake (162 km east-south-east) and Castor Lake (163 km south-east), with average end-of-winter snow water equivalents of 134 mm and 123 mm, respectively. These are amongst the highest average values for snow survey sites in the Snare River Basin. These values do not necessarily indicate average conditions at the Silver Bear Mines, because the close proximity of Great Bear Lake could significantly increase the amount of snowfall at Silver Bear.

Snow surveys were also completed at Terra Mine and Norex Mine in April 2006. Two vegetated sites in the Ho Hum Lake TCA catchment had an average snow water equivalent of 217 mm. An unvegetated site near the main portal at Norex had a snow water equivalent of 175 mm. The end-of-winter snow water equivalents measured at the survey sites in the Snare River Basin in 2006 were well above the long term averages. The Mesa Lake and Castor Lake sites were 151% and 140% of the long term averages for these sites, indicating that the values measured at Silver Bear in 2006 may exceed the long term average by a similar amount.

4.2 Surface Waters

4.2.1 Surface Hydrology

The available climate data for the Silver Bear Mines area has been used to estimate water balances and annual discharges for the Ho Hum Lake TCA and Hermandy Lake TCA basins. The calculations are described in INAC 2007.

Runoff coefficients are used in the calculations to estimate water losses due to evapotranspiration from land and storage in soils. These coefficients are difficult to estimate from measurements and can be highly variable between sites, being dependant on the amount of soil cover, types of soil, types of vegetation and the topography within the basin, amongst other factors. They also vary significantly from year to year, depending on climatic conditions. For this reason, the water balances have been calculated using a range of runoff coefficients that fit within ranges estimated in the literature for small catchments within the same ecological zone. This results in a range of low and high estimates for annual lake discharge.

In the absence of long term climate records for the Silver Bear Mines, or directly comparable locations nearby, the water balances have been estimated based on the data collected in 2006. As discussed in Section 4.1, the available rainfall data are likely to under-estimate the actual rainfall in 2006, and are likely to be lower than the mean annual rainfall. The 2006 snow water equivalent data are likely to be higher than the mean annual value. The lake evaporation calculated from the available data for 2006 is similar to the annual averages estimated for other sites under study by Indian and Northern Affairs Canada, such as Colomac Mine (195 km south-east), and is likely to represent a reasonable estimate of the average value for Silver Bear. The estimated water balance of Ho Hum Lake TCA in 2006 is summarized in Table 4.2.1.

Data collected from a water level sensor installed in Ho Hum Lake TCA indicates that maximum lake levels were reached in early June in 2005, and late May in 2006. In both cases, these peak outflow periods were later than the peak snowmelt periods, indicating that some of the snowmelt is stored in the pond.

The estimated water balance of Hermandy Lake TCA in 2006 is summarized in Table 4.2.2. A water level sensor installed in Hermandy Lake TCA indicated the maximum water level was reached in early May in 2006.

Table 4.2.1 Estimated Annual Water Balance of Ho Hum Lake TCA (2006 Data)

Parameter	Unit	Value	Value
Measured Data			
Total Catchment Area	hectare	192	
Water Surface Area	hectare	29	
Land Area	hectare	163	
Snow Water Equivalent	mm	203	
Rainfall	mm	118	
Lake Evaporation	mm	297	
Land Runoff Coefficients		Low Estimate	High Estimate
Snowmelt		0.40	0.80
Rainfall		0.20	0.60
Annual Water Balance		Low Estimate	High Estimate
Input: Snow Water	m^3	390,000	390,000
Input: Rain Water	m^3	227,000	227,000
Output: Lake Evaporation	m^3	-86,000	-86,000
Output: Evapotranspiration and Storage	m^3	-353,000	-143,000
Net Annual Accumulation or Discharge	m^3	178,000	388,000

Table 4.2.2 Estimated Annual Water Balance of Hermandy Lake TCA (2006 Data)

Parameter	Unit	Value	Value
Measured Data			
Total Catchment Area	hectare	42	
Water Surface Area	hectare	3.4	
Land Area	hectare	39	
Snow Water Equivalent	mm	203	
Rainfall	mm	118	
Lake Evaporation	mm	297	
Land Runoff Coefficients		Low Estimate	High Estimate
Snowmelt		0.40	0.80
Rainfall		0.20	0.60
Annual Water Balance		Low Estimate	High Estimate
Input: Snow Water	m^3	85,000	85,000
Input: Rain Water	m^3	50,000	50,000
Output: Lake Evaporation	m^3	-10,000	-10,000
Output: Evapotranspiration and Storage	m^3	-84,000	-34,000
Net Annual Accumulation or Discharge	m^3	41,000	91,000

4.2.2 Water Quality

Water quality in the environment near the Silver Bear Mines has been extensively monitored on a regular basis since 2003. The results of the recent monitoring, in 2005 and 2006, are summarized in this section to broadly characterize the quality of the aquatic environment. This summary does not include the quality of water in Ho Hum Lake TCA or Hermandy Lake TCA, which are considered tailings containment areas and integral parts of the Terra site and Northrim site, respectively. On-site water quality is discussed in Section 3, which describes current site conditions.

The following sections describe water quality in the environment around the Silver Bear Mines, including several reference sites that have not been affected by mining activity, sites in Rainy Lake near Terra Mine, sites in Moose Bay downstream of the discharge from Ho Hum Lake TCA, and sites in Smallwood Lake beside Smallwood Mine. The locations of the sampling sites are shown in Figure 4.2.1. The average values provided have been calculated from the results of six sampling campaigns, completed in June, July and August of 2005 and 2006. Detailed results can be found in INAC 2005c and INAC 2006d.

Very high values were obtained for total chromium and total lead at numerous sites in the June 2006 campaign. For example, the reported chromium and lead values were in the range of several hundred to several thousand times higher than the average of results from the other sampling campaigns, for most of the sites discussed herein. The high lead levels are believed to be the result of laboratory contamination (in the preservative), however, the reasons for elevated chromium are not known and no particular quality control concerns are apparent.

Reference Sites

Surface water samples have been collected from Tutcho Lake and three sites along the Camsell River system, upstream of the Silver Bear Mines. Table 4.2.3 summarizes average concentrations of selected parameters in 2005 and 2006.

The pH of the waters was slightly alkaline, ranging from 7.7 to 8.0. The mean hardness of the Camsell River water (62 to 67 mg $CaCO_3$/L) was slightly higher than that of Tutcho Lake (37 mg $CaCO_3$/L). Total phosphorus and nitrogen compounds in the system were low, often measured at or below the method detection limit (MDL). Average concentrations of calcium, magnesium and sulphate were 14, 6, and 9 mg/L, respectively.

Cadmium concentrations were often reported as greater than the CCME-FAL guideline of 0.03 µg/L (although the MDL for cadmium was 0.05 µg/L). The maximum cadmium concentration reported was 0.36 µg/L from the Balachey Lake sample collected in July 2005. Other metal concentrations were below CCME-FAL guidelines and were often near or below MDL's.

Table 4.2.3 Typical Water Quality of Reference Sites (2005 and 2006)

Parameter	Units	Average Concentrations[1]				CCME-FAL Guideline[2]
		Clut Lake	Balachey Lake	Jason Bay	Tutcho Lake	
pH		7.9	7.9	8.0	7.7	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	47.8	51.1	51.5	32.6	
Hardness (as $CaCO_3$ equiv.)	mg/L	61.7	65.2	67.4	37.1	
Chloride (total)	mg/L	1.82	2.08	2.08	<0.70	
Sulphate (total)	mg/L	10.4	12.0	12.3	2.0	
Calcium (total)	mg/L	14.9	15.5	16.0	10.2	
Magnesium (total)	mg/L	5.92	6.42	6.70	2.83	
Sodium (total)	mg/L	1.82	2.02	2.03	1.40	
Ammonia (total, as N)	mg/L	<0.005	<0.005	<0.005	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	0.020	0.024	<0.010	0.015	
Phosphorus (total)	mg/L	0.012	0.012	<0.010	<0.010	
Total Metals						
Aluminum	µg/L	19.517	20.8	12.083	25.84	100
Antimony	µg/L	0.4167	0.3333	0.6	0.24	
Arsenic	µg/L	0.2667	0.2	0.5	0.2	5
Barium	µg/L	9.55	10.933	8.1833	10.62	
Beryllium	µg/L	0.1	0.1	0.1	0.1	
Cadmium	µg/L	0.0667	0.11	0.0583	0.05	0.03
Cesium	µg/L	0.1	0.1	0.1	0.1	
Chromium	µg/L	7.95	5.6333	10.667	4.18	1
Cobalt	µg/L	0.0917	0.0917	0.0917	0.09	
Copper	µg/L	1.2333	1.05	1.3167	0.96	2
Iron	µg/L	50.5	52.167	52.5	57.4	300
Lead	µg/L	24.75	23.25	46.817	11.46	2
Lithium	µg/L	1.4667	1.8167	0.9833	1.98	
Manganese	µg/L	1.5	1.0833	1.2333	1.38	
Mercury	µg/L	0.0183	0.0183	0.0183	0.018	0.1
Molybdenum	µg/L	0.7333	0.6167	1.05	0.5	73
Nickel	µg/L	0.3167	0.2833	0.25	0.32	65
Rubidium	µg/L	1.2	1.1833	1.2333	1.24	
Selenium	µg/L	0.5667	0.45	0.45	0.34	1
Silver	µg/L	0.1	0.1	0.1	0.1	0.1
Strontium	µg/L	38.233	47.7	23.083	47.74	
Thallium	µg/L	0.1	0.1	0.1	0.1	
Titanium	µg/L	0.7333	0.8333	0.3667	1.04	
Uranium	µg/L	0.3167	0.3833	0.15	0.34	
Vanadium	µg/L	0.15	0.1833	0.15	0.24	
Zinc	µg/L	6.4833	3.9667	5.4333	2.14	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values; 2 CCME-FAL – Canadian Council of Ministers of the Environment environmental quality guidelines for the protection of Freshwater Aquatic Life (CCME 2006).

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

Rainy Lake Sites

Samples collected from two locations in the Camsell River at Rainy Lake exhibited slightly alkaline average pH values of 7.9 and can be considered moderately soft (67 to 69 mg $CaCO_3$/L hardness) (see Table 4.2.4). Total phosphorus and nitrogen compounds in the system were low, often measuring at or below the MDL. Average concentrations of calcium, magnesium and sulphate were 17, 6, and 12 mg/L, respectively. Metal concentrations were greater at the Jackfish Bay sampling location (T-1). Copper concentrations at this site were consistently above CCME-FAL guidelines (maximum 6.4 µg/L in July 2005). Chromium levels for all locations were elevated above CCME-FAL guidelines for all stations in June 2006. This may be an artifact or the result of high levels of suspended chromium during this very wet period with high runoff conditions. All other sample periods have low levels of chromium.

Moose Bay Sites

Samples collected from three locations in Moose Bay exhibited slightly alkaline average pH values of approximately 8 and average hardness values between 64 and 96 mg $CaCO_3$/L (Table 4.2.5). Total phosphorus and nitrogen compounds in the system were low. Average concentrations of calcium, magnesium and sulphate were between 15 and 29, 6.1 and 6.3, and 12 and 20 mg/L, respectively.

Metal concentrations were greatest at the T-6 sampling location which is at the discharge from the lower wetland at the outlet of Ho Hum Lake TCA. Arsenic and copper concentrations at this site were consistently above CCME-FAL guidelines (maximum 91 µg/L total arsenic in June 2006 and 16 µg/L copper in June 2005). Chromium and lead concentrations exceeded CCME-FAL guidelines on one occasion in August 2006 (2.2 and 8.8 µg/L, respectively). The average silver concentration for this site is also skewed by a single sample (2.4 µg/L in June 2005) that was above CCME-FAL guidelines.

The June 2005 sample from the T-10 location had relatively high concentrations of arsenic, copper, lithium, manganese and uranium (65, 15, 14, 40 and 4 µg/L, respectively). The sample from August 2006 exceeded CCME-FAL guidelines for aluminum (140 µg/L). The August 2006 sample from T-12 exceeded CCME-FAL guidelines for chromium and lead (2.2 and 12.7 µg/L, respectively).

Smallwood Lake Sites

Samples collected from two locations in Smallwood Lake exhibited slightly alkaline average pH values of 7.7 and average hardness values of approximately 45 mg $CaCO_3$/L (Table 4.2.6). Total phosphorus and nitrogen compounds in the system were low. Average concentrations of calcium, magnesium and sulphate were 12, 3.6, and 14 mg/L, respectively. Copper concentrations fluctuated around the CCME-FAL guideline of 2 µg/L (maximum 2.3 µg/L). Other metal concentrations were generally low.

Table 4.2.4 Typical Water Quality of Camsell River at Rainy Lake (2005 and 2006)

Parameter	Units	Average Concentrations[1]		CCME-FAL Guideline[2]
		T-1 (Jackfish Bay)	T-4	
pH		7.9	7.9	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	50.4	50.3	
Hardness (as $CaCO_3$ equiv.)	mg/L	69.0	66.5	
Chloride (total)	mg/L	7.92	2.05	
Sulphate (total)	mg/L	12	11.75	
Calcium (total)	mg/L	18.1	16.1	
Magnesium (total)	mg/L	5.8	6.4	
Sodium (total)	mg/L	5.12	1.98	
Ammonia (total, as N)	mg/L	<0.005	0.006	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.01	<0.01	
Phosphorus (total)	mg/L	<0.01	<0.01	
Total Metals				
Aluminum	µg/L	45.83	35.65	100
Antimony	µg/L	0.10	0.09	
Arsenic	µg/L	2.15	0.35	5
Barium	µg/L	10.82	10.10	
Beryllium	µg/L	0.10	0.10	
Cadmium	µg/L	0.10	0.08	0.03
Cesium	µg/L	0.10	0.10	
Chromium	µg/L	0.38	0.32	1
Cobalt	µg/L	0.10	0.15	
Copper	µg/L	3.95	1.28	2
Iron	µg/L	107.83	63.00	300
Lead	µg/L	0.67	0.15	2
Lithium	µg/L	2.23	2.07	
Manganese	µg/L	6.22	2.02	
Mercury	µg/L	0.02	0.02	0.1
Molybdenum	µg/L	0.23	0.23	73
Nickel	µg/L	0.47	0.40	65
Rubidium	µg/L	1.23	1.23	
Selenium	µg/L	1.00	0.77	1
Silver	µg/L	0.20	0.23	0.1
Strontium	µg/L	43.32	47.03	
Thallium	µg/L	0.10	0.10	
Titanium	µg/L	1.77	1.50	
Uranium	µg/L	0.37	0.40	
Vanadium	µg/L	0.27	0.17	
Zinc	µg/L	10.00	7.98	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values; 2 CCME-FAL – Canadian Council of Ministers of the Environment environmental quality guidelines for the protection of Freshwater Aquatic Life (CCME 2006).

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

Table 4.2.5 Typical Water Quality of Moose Bay (2005 and 2006)

Parameter	Units	Average Concentrations[1]			CCME-FAL Guideline[2]
		T-6	T-10	T-12	
pH		7.9	8.0	7.9	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	77.8	50.7	50.5	
Hardness (as $CaCO_3$ equiv.)	mg/L	96.2	65.9	64.2	
Chloride (total)	mg/L	16.9	2.3	2.125	
Sulphate (total)	mg/L	20.2	11.75	11.5	
Calcium (total)	mg/L	28.5	16.0	15.4	
Magnesium (total)	mg/L	6.1	6.325	6.25	
Sodium (total)	mg/L	10.18	2.1	1.975	
Ammonia (total, as N)	mg/L	0.008	<0.005	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	<0.010	<0.010	<0.010	
Phosphorus (total)	mg/L	0.038	<0.010	<0.010	
Total Metals					
Aluminum	µg/L	55.38	56.92	36.42	100
Antimony	µg/L	1.60	0.72	0.15	
Arsenic	µg/L	46.00	11.37	0.45	5
Barium	µg/L	23.82	14.05	10.63	
Beryllium	µg/L	0.10	0.10	0.10	
Cadmium	µg/L	0.09	0.09	0.08	0.03
Cesium	µg/L	0.10	0.10	0.10	
Chromium	µg/L	8.22	5.43	1.07	1
Cobalt	µg/L	0.25	0.18	0.12	
Copper	µg/L	8.88	3.57	1.13	2
Iron	µg/L	146.33	92.00	60.00	300
Lead	µg/L	22.03	14.53	3.40	2
Lithium	µg/L	10.58	4.05	2.13	
Manganese	µg/L	25.30	8.77	1.95	
Mercury	µg/L	0.02	0.02	0.02	0.1
Molybdenum	µg/L	3.63	1.53	0.33	73
Nickel	µg/L	2.82	1.05	0.42	65
Rubidium	µg/L	5.13	2.20	1.25	
Selenium	µg/L	0.88	0.88	0.77	1
Silver	µg/L	0.50	0.10	0.10	0.1
Strontium	µg/L	119.95	63.38	48.00	
Thallium	µg/L	0.10	0.10	0.10	
Titanium	µg/L	1.80	2.73	1.65	
Uranium	µg/L	1.97	0.93	0.40	
Vanadium	µg/L	0.33	0.27	0.22	
Zinc	µg/L	9.43	9.00	7.47	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values; 2 CCME-FAL – Canadian Council of Ministers of the Environment environmental quality guidelines for the protection of Freshwater Aquatic Life (CCME 2006)

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

Table 4.2.6 Typical Water Quality of Smallwood Lake (2005 and 2006)

Parameter	Units	Average Concentrations[1]		CCME-FAL Guideline[2]
		SM-6	SM-7	
pH		7.7	7.7	6.5 – 9
Alkalinity (total, as $CaCO_3$)	mg/L	32.3	32.5	
Hardness (as $CaCO_3$ equiv.)	mg/L	44.4	45.7	
Chloride (total)	mg/L	0.7	0.7	
Sulphate (total)	mg/L	13.8	13.8	
Calcium (total)	mg/L	11.9	12.3	
Magnesium (total)	mg/L	3.58	3.68	
Sodium (total)	mg/L	2.18	2.14	
Ammonia (total, as N)	mg/L	0.007	<0.005	~ 2
Nitrate + Nitrite (totals, as N)	mg/L	0.013	0.020	
Phosphorus (total)	mg/L	<0.010	<0.010	
Total Metals				
Aluminum	µg/L	21.92	15.72	100
Antimony	µg/L	1.47	0.50	
Arsenic	µg/L	0.62	0.57	5
Barium	µg/L	12.45	8.17	
Beryllium	µg/L	0.10	0.10	
Cadmium	µg/L	0.06	0.06	0.03
Cesium	µg/L	0.10	0.10	
Chromium	µg/L	31.53	8.27	1
Cobalt	µg/L	0.10	0.10	
Copper	µg/L	2.15	2.02	2
Iron	µg/L	51.83	50.50	300
Lead	µg/L	109.28	32.05	2
Lithium	µg/L	0.85	0.93	
Manganese	µg/L	9.75	9.77	
Mercury	µg/L	0.02	0.02	0.1
Molybdenum	µg/L	2.98	1.38	73
Nickel	µg/L	0.35	0.32	65
Rubidium	µg/L	1.52	1.52	
Selenium	µg/L	0.45	0.45	1
Silver	µg/L	0.10	0.10	0.1
Strontium	µg/L	22.50	22.43	
Thallium	µg/L	0.10	0.10	
Titanium	µg/L	0.37	0.27	
Uranium	µg/L	0.20	0.20	
Vanadium	µg/L	0.17	0.18	
Zinc	µg/L	18.58	15.57	30

Notes:

1 Results below detection limit are assumed to equal detection limit for calculation of average values; 2 CCME-FAL – Canadian Council of Ministers of the Environment environmental quality guidelines for the protection of Freshwater Aquatic Life (CCME 2006).

2 CCME-FAL guidelines (CCME 2006) shown for total ammonia, aluminum, cadmium, copper, lead and nickel are calculated minimum values, based on range of water hardness in receiving waters, and/or pH, and/or temperature.

4.2.3 Sediment Quality

Sediment sampling in the Silver Bear Mines area was completed in 2004 and 2005 by Rescan Environmental Services Limited and Lorax Environmental Services Limited. Five lake sites were sampled, including Tutcho Lake, Ho Hum Lake TCA, Little Ho Hum Lake TCA, Hermandy Lake TCA and Smallwood Lake. Three sites on the Camsell River were sampled, including Jason Bay, the Northrim dock area and Moose Bay. The sediment quality parameters measured included grain size, pH, organic carbon, nutrients and total metals. The results of this work are presented in Lorax 2006 and Rescan 2005c. The sediment qualities of Ho Hum Lake TCA and Hermandy Lake TCA are discussed in Section 3, as these are tailings disposal areas and considered components of the Terra Mine and Northrim Mine sites.

Sediments were sampled in two areas known to be un-impacted by mining activities; Tutcho Lake, near the Terra Mine, and Jason Bay on the Camsell River, just upstream of the Northrim Mine. The two reference sites had relatively low organic carbon and nutrient contents, and the total metals concentrations were also low.

The sediments in Little Ho Hum Lake TCA were sampled to determine if the lake had been affected by any tailings disposal, or flow of contaminated water from Ho Hum Lake TCA. The sediments had higher organic carbon and nutrient contents than Tutcho Lake. The metal levels were generally higher than found at Tutcho Lake, but the data do not clearly indicate any impact from tailings disposal.

Sediments collected from Moose Bay had relatively low levels of organic carbon and nutrients, similar to the levels measured at Jason Bay. The levels of some metals were higher than found at Jason Bay, and the arsenic concentrations were particularly elevated. The maximum arsenic concentration was 217 mg/kg at the sampling site closest to the outlet of Ho Hum Lake TCA (2005 data). The data show a clear trend of decreasing arsenic concentrations with distance from Ho Hum Lake TCA. The lowest value in Moose Bay was 14 mg/kg found at the mouth of the bay, near the end of the airstrip. The mean sediment arsenic concentration in Moose Bay was 92 mg/kg. For comparison, the Jason Bay sediments ranged from 6 to 10 mg/kg. The Moose Bay sediments clearly show an impact from historic discharges of contaminated water from Ho Hum Lake TCA, and possibly from fine tailings carried as suspended sediment in the lake discharge, when the mine was in operation.

The sediments in the Camsell River near the Northrim dock were suspected to be contaminated from historic tailings discharges, and the sediment sampling in 2004 and 2005 confirmed this. The concentrations of several metals were significantly elevated with respect to Jason Bay. The mean arsenic concentration in the area was 445 mg/kg (2005 data). The sampling also indicated that the extent of tailings influence on the river sediments is limited to a relatively small area, within about 75 metres of the shoreline. Samples taken outside this area had similar arsenic concentrations to the un-impacted Jason Bay site.

The Smallwood Lake sediments had relatively low levels of organic carbon and nitrogen, but distinctly higher concentrations of available phosphorus compared to Tutcho Lake. This is probably a natural difference and is unlikely to be related to mining activity near the lake. The concentrations of almost all metals in the Smallwood Lake sediments were similar to, or lower than, the concentrations found in Tutcho Lake. The exception was zinc, which ranged from 139 to 446 mg/kg, with a mean of 279 mg/kg. For comparison, the mean zinc concentration in the Tutcho Lake sediments was 128 mg/kg. The sediment data from Smallwood Lake suggest a possible impact from mining activity, although the higher zinc concentrations could be natural. The same geology and mineralization that lead to the development of Smallwood Mine could also affect the natural sediment quality. As noted in Section 4.2.2, zinc concentrations in the lake water are low.

4.2.4 Groundwater Pathways

The site is generally characterized by bedrock exposures with shallow lenses of soil deposits especially on or beside the river valleys and lakes. Groundwater flows in this environment typically follow the topography, flowing from bedrock ridges towards the rivers and lake valleys. Groundwater at the site is controlled by permafrost and the mine workings. Within bedrock outcrops, which predominate throughout the site, fractures represent a potential mechanism of groundwater flow. However, given the latitude of the site, permafrost is expected to be present, thereby limiting flow.

The primary areas of concern with groundwater discharges include:

- Groundwater discharges from the mines (surface openings). Only the Norex adit has a perennial discharge during the open water season. All mine discharges are monitored as they exit from the mines. Monitoring indicates these discharges are not having a material effect on the Camsell River.

- Groundwater below the waste rock piles. Waste rock piles are located beside Smallwood Lake, Ho-Hum Lake, Camsell River at Northrim and Terra Mine and beside the Norex Portal. Monitoring wells have been installed at several locations to monitor groundwater below the piles. Groundwater at these sites contains elevated levels of several contaminants including zinc and arsenic. The flow pathways to the surface receptor are very short and the impacts of the groundwater discharges are assessed through an expensive surface water quality monitoring program. Based upon surface water quality monitoring data, groundwater discharges are not having a material effect on surface water quality.

4.3 Aquatic Life

Extensive aquatic studies were completed in the Silver Bear Mines area by Rescan Environmental Services in September 2004 (Rescan 2005c). The work included collection of benthic macroinvertebrate (benthos) and fish samples from eight sites in the area. Five lake sites were sampled, including Tutcho Lake, Ho Hum Lake TCA, Little Ho Hum Lake TCA, Hermandy Lake TCA and Smallwood Lake. The Camsell River was sampled at Moose Bay, near the Northrim site and at Jason Bay.

Five benthos samples were obtained from each site, using an Ekman grab sampler. Benthos densities and taxonomic diversity indices were calculated from the field data. Fish communities were sampled using gillnets and minnow traps in multiple locations at each site. The fish communities were characterized based on field and laboratory data, using variables such as relative species abundance, catch-per-unit-effort, average length and weight, length-frequency distributions, length-weight regressions, diet, and metal concentrations in muscle and liver. Fish habitat was also assessed at all of the sites, based on the relative areas of different substrate materials (grain size).

Benthic invertebrate density was higher at the reference sites (Tutcho Lake and Jason Bay) than at the sites impacted, or potentially impacted, by mining activity. Benthos densities were particularly low at Little Ho Hum, Hermandy and Smallwood lakes, although Ho Hum Lake TCA had a comparatively healthy benthic invertebrate community. Overall, benthos groups such as dipterans, amphipods and molluscs were common at all sites. Dipteran diversity indices, calculated from the taxonomic data, generally follow the trend of benthos density between sites, where sites with high density also have high diversity.

A total of 130 fish were caught in gillnets, with a total of 32.1 hours of effort. The majority were lake whitefish (56% of total catch); the remainder consisted of lake trout (22%), northern pike (8%), lake cisco (5%), longnose sucker (4%) and round whitefish (4%). The average catch-per-unit-effort was greatest for lake whitefish, which were caught at Tutcho Lake and the three Camsell River sites. Northern pike were found in the largest number of sites (5), while longnose suckers were found only in Smallwood Lake and lake cisco were only found in Tutcho Lake. Tutcho Lake had the greatest catch-per-unit effort, followed by Smallwood Lake, Jason Bay, Northrim, Moose Bay and Little Ho Hum Lake TCA. No fish were caught in gillnets at Hermandy Lake TCA or Ho Hum Lake TCA.

A total of 61 minnow trap sets were conducted at all of the sites, initially for periods up to 9 hours. Despite a total effort of 353 hours of total trap time between the sites, the only fish captured was a single ninespine stickleback in Ho Hum Lake TCA. Two minnow traps were set overnight in the outflow of Ho Hum Lake TCA, immediately downstream of the weir at the lower dyke (within the weir box), and upstream of the weir between the lower and upper dykes. After 26 hours, 430 fish were captured downstream of the weir and 20 were captured upstream of the weir. Of the total fish caught, 435 were ninespine sticklebacks and 15 were white suckers. The data indicates that the dyke acts as a barrier to fish passage for part of the year, in periods of low water flow.

4.4 Terrestrial Life

During September 2004, Rescan Environmental Services completed a terrestrial habitat assessment in the Silver Bear Mines area to characterize the terrestrial environment (Rescan 2005d). The work included identifying important wildlife habitat and wildlife resources for the area, species composition for the area, species of conservation concern and Valued Ecosystem Component wildlife species. Valued Ecosystem Component (VEC) is a term used to describe parts of the environment that are especially important for cultural, scientific, economic or aesthetic reasons. Three VEC wildlife species were identified for the Silver Bear Mines area, including bear, caribou and moose.

The Silver Bear Mines are situated at the border between the northern edge of the Taiga Shield Terrestrial Ecological zone and the south-eastern edge of the Taiga Plains Terrestrial Ecological zone. Five habitat types were identified in the area during the wildlife habitat survey, including spruce forest, spruce-birch forest, burned forest, wetland water-margin and wetland. Important wildlife habitat and wildlife resources observed at Silver Bear Mines included foraging areas for VEC species (bear, caribou and moose), wetlands, potential hunting areas and roads.

Important foraging areas for bear, caribou and moose were observed at all of the mine sites. In particular, berry bushes such as currents, cranberry, bear berry and blueberry, which are a favourable food source for black bears during the summer and fall, were observed within the re-vegetated burned forest habitat types. Moose Bay provided wetland habitats which included vegetation species (willow, sedges and horsetails) that are essential foraging species for moose year round. Important winter foraging habitat for caribou was observed on the east side of Hermandy Lake TCA and consisted of a high proportion of lichens within spruce forest habitat.

Numerous wetlands were observed within the area surrounding the Silver Bear Mines. Wetlands are considered ecologically important ecosystems. They naturally filter water resources and clean out excess nutrients and pollutants that might otherwise flow into rivers, streams and lakes. Wetlands in the Silver Bear area potentially provide important food, water and shelter for northern wildlife such as moose, caribou, black bears, frogs and many species of birds including ducks, geese, swans, wading birds, song birds and migratory waterfowl.

Roads are important wildlife resources. Wildlife sign, dominantly consisting of moose and bear scats, were observed frequently along the road between Terra Mine and Norex Mine. This suggests that the Terra-Norex Road may have been used as a wildlife corridor during migration and dispersal.

Over sixteen mammal species are potentially present within the Silver Bear Mines area. Characteristic large mammals include the Blue-nose East herd of barren-ground caribou, moose, black bear, grizzly bear, wolf, wolverine, snowshoe hare, arctic fox, beaver, and lynx. During field surveys in the summer of 2004, seven mammal species were observed, including black bear, moose, wolverine, beaver, red squirrel, snowshoe hare, and vole. Bear and moose sign were observed frequently along roads, the Terra airstrip, and near the infrastructure of all of the mine sites.

4.5 Birds

A reconnaissance survey of birds using the Silver Bear Mine sites was completed in late July 2006 as reported in Joachim Obst 2006. The objectives were to document observations on the presence and nesting sites of raptors, owls, waterfowl, shorebirds and migratory birds, focussing especially on structures earmarked for demolition and sites potentially requiring remediation work. The late seasonal timing of the survey was ideal for recording potential productive raptor nest sites with chicks, and waterfowl with broods within the footprints of the mine sites. However, the survey was completed after the fledging period for songbirds and shorebirds, and the survey provided only ancillary observations of these species. Trails and gravel roads at the Terra Mine site were surveyed on foot three times per day. Additional observations on raptors and waterfowl were obtained during boat trips on the Camsell River from Terra Mine to the Northrim and Norex sites, and during a helicopter tour of the sites. Walking surveys of the Northrim, Norex, Graham Vein and Smallwood sites were also completed.

From July 19 to 24, 28 of the 38 species of birds observed at the Silver Bear Mines were confirmed as breeding. Of these, 12 species had nested in mine buildings and within tailings and waste rock disposal areas, and 24 species nested or were present within the mine site footprints. Nine of the species found within the mine footprints have been ranked as “sensitive species” in the Northwest Territories, by the department of Resources, Wildlife and Economic Development, meaning that their populations either have been declining, or are naturally low and not secure in the north. Four sensitive species nested in mine structures or waste disposal sites, including Boreal Chickadee, Barn Swallow, Northern Flicker and Lesser Yellowlegs.

An old nest of the American Kestrel was found in a shack at the Terra Mine. According to site staff, the nest was successfully used by kestrels in 2005, but kestrels were absent in 2006. American Kestrels raised at least two fledglings at the Norex Mine in 2006. The entrance to the mine appeared to offer the only suitable nest site for kestrels in the area, although the nest location could not be confirmed. Another pair of kestrels with an undetermined number of chicks nested in a cliff about 1.7 kilometres north-west of the Northrim Mine.

A pair of Bald Eagles raised a chick in a tree nest located about 400 metres north of the Norex Mine. A second, unused Bald Eagle tree nest was found beside the Camsell River, immediately below the White Eagle Falls. Other observations of Bald Eagles included: an adult about 2 kilometres south-east of the Smallwood Mine; immature and sub-adult eagles in the area just west of the Northrim and Norex sites; an adult seen flying several times over the Terra site; and, five additional locations with adults in the southern parts of Conjuror Bay. The remains of two deteriorated eagle stick nests were located in cliffs between the Terra and Northrim Mines, but it was unclear if these old nests had originally been built by Bald Eagles or Golden Eagles. Two Golden Eagle nests (including one apparently still in use) were seen from the air about 8 to 10 kilometres north of the Silver Bear Mines. A Rough-legged Hawk was seen in the same area.

Great Horned Owls were not observed or heard during the relatively short survey, despite the many suitable nest sites present in buildings and natural cliffs. The main prey of Great Horned Owls, the Snowshoe Hare, appeared to be abundant, with several observations of hares being made every day within the mine footprints.

A family of Common Ravens with at least two fully fledged young were seen daily in the Terra Mine area. A raven stick nest had been located earlier in the year in the ore bin tower above the crushing plant. The nest apparently collapsed soon after the young fledged.

A territorial pair of common loons was present on Ho Hum Lake TCA. The pair appeared to be feeding on aquatic invertebrates and did not have chicks. Several times the loons were seen in flight to and from Moose Bay. Common loons were also observed on the Camsell River near the Terra airstrip, at Conjuror Bay north of Terra, on Smallwood Lake, and three locations around the Northrim and Norex sites. A pair of Pacific Loons, seen with a young chick, nested at Hermandy Lake TCA and an additional single adult was seen feeding in Little Ho Hum Lake TCA. A pair of Red-throated Loons raised one or more chicks on a pond next to the Smallwood Mine, and an additional adult was heard around two small lakes located between Ho Hum and Tutcho Lakes.

A pair of Tundra Swans nested on the north shore of the Camsell River, about one kilometre north-east of the Northrim Mine. An adult swan and cygnet were seen on the water near the nest. A pair of Tundra Swans was also seen on the lake just above White Eagle Falls. An additional five pairs were observed at scattered locations around the southern parts of Conjuror Bay.

A female Bufflehead with four ducklings was observed on a small pond just north-west of Smallwood Mine. The only suitable nest sites for Buffleheads in the area were in abandoned buildings at the mine site. A female American Wigeon with a brood was seen in the southern part of Conjuror Bay and a single adult female Wigeon was observed in Moose Bay. White-winged Scoters and Red-breasted Mergansers were regularly sited on the Camsell River between White Eagle Falls and Conjuror Bay.

4.6 Species at Risk in Canada

Of the mammal and bird species identified through the ENR database as potentially being present in the Great Bear watershed, 10 have been designated as “species at risk” in Canada (see Table 4.8-1). Assessments for candidate species are conducted by the Committee on the Status of Endangered Species in Canada (COSEWIC) who provide recommendations on the levels of protection needed to allow the recovery of declining species. Candidate species are listed under specific classifications depending on their numbers and the health of the population as follows (Macdonald 2004):

Extinct:	a species no longer exists.
Extirpated:	a species no longer exits in the wild in Canada, but occurs elsewhere.
Endangered:	a species faces imminent extirpation or extinction.
Threatened:	a species likely to become endangered if limiting factors are not reversed.
Special Concern:	a species that may be particularly sensitive to human activities or natural events.

Species protected under the Species at Risk Act (SARA) are listed on Schedule 1 of SARA. SARA also includes endangered and threatened species on Schedule 2 and species of concern on Schedule 3 that are under review for inclusion on Schedule 1.

Table 4.6.1 Species at Risk Potentially Occurring in the Great Bear Lake Watershed

Common Name	Scientific Name	Status	Status under SARA
Mammals			
Woodland caribou, Boreal population	*Rangifer tarandus caribou*	Threatened	Schedule 1
Woodland caribou, Northern mountain population	*Rangifer tarandus caribou*	Special Concern	
Barren-ground caribou, Dolphin and Union population	*Rangifer tarandus groenlandicus*	Special Concern	
Grizzly bear	*Ursus arctos*	Special Concern	
Wolverine, Western population	*Gulo gulo*	Special Concern	Schedule 1
Birds			
Eskimo curlew	*Numenius borealis*	Endangered	Schedule 1
Common Nighthawk	*Chordeilis minor*	Threatened	Schedule 1 designation pending
Rusty blackbird	*Euphagus carolinus*	Special Concern	Schedule 1 designation pending
Peregrine falcon (anatum)	*Falco peregrinus anatum*	Special Concern	Schedule 1
Peregrine falcon (tundrius)	*Falco peregrinus tundrius*	Special Concern	Schedule 3
Short-eared owl	*Asio flammeus*	Special Concern	Schedule 3

Note: Data was compiled from ENR (2007), COSEWIC (2007), and the Species at Risk site of Environment Canada.

Of the species at risk listed on Table 4.6-1, the woodland caribou was considered in the site-specific ecological and human health risk assessment that was conducted for the Silver Bear sites (SENES 2007). The risk assessment did not identify any risks to woodland caribou.

4.7 Radioactivity

4.7.1 Gamma Levels

Elevated levels of background radiation are common at many mining sites around Great Bear Lake (for example Contact Lake). Although the Silver Bear Mines were not highly mineralized with uranium, uranium is present in all ore and tends to report to the mineral concentrates exported from the sites. A gamma radiation survey was completed at Terra mine by the Low Level Radioactivity Waste management Office in July 2007. The measured gamma levels are shown in Figure 4.7.1.

The raw data were processed to get averages for each of the 10 m by 10 m grids as shown in Table 4.7.1. The overall average value was 14 μR/h, with maximum values ranging up to about 20 μR/h for most of the individual site areas.

Table 4.7.1 Terra Mine Site – Summary of Gamma Radiation Exposure Rate Readings

Site Area	Number of 10 x 10 m grids	Mean (μR/h)	Maximum Mean (μR/h)	Maximum Individual (μR/h)
Above West Tailings Beach	44	13	16	21
East Tailings	40	12	16	33
Mill West	186	15	43	123
North from East Tailings	90	13	20	34
Outside Silver Bear	153	16	173	221
Silver Bear Camp	101	13	17	23
Storage Yard	67	13	18	35
West Tailings Beach	30	13	16	22
All	615	14	173	221

Note: values are for 10 m by 10 m area

Gamma radiation rates vary at sites in these areas depending on the mineralization present in the soils and rock. Table 4.7.2 shows the distribution of measured concentrations from the survey. Few of the 10 m by 10 m average measurements exceeded 30 μR/h.

Figure 4.7.1 shows a plot of the 10 m by 10 m gamma radiation levels measured during the survey along with the individual measurements giving rise to these values. Areas with gamma radiation exposure rates exceeding 60 μR/h are located at the dumping station next to the crusher mill and further south-east from this location likely associated with the concentrate storage.

A baseline value of 15 μR/h has been used previously for some locations in this general area and most blocks on this site have concentrations of 15 μR/h or lower. Only six blocks have concentrations exceeding 60 μR/h. On this basis, workers or other people at the site would be minimally exposed to above-background levels of gamma radiation.

To put the measured values in perspective from a dose point of view, exposure for 1000 hours per year to an exposure rate of twice the measured average value (i.e. 30 μR/h or 15 μR/h above background) would result in an above-background dose rate of less than 0.1 millisieverts per year (0.1 mSv/y). This dose rate is a factor of 10 below the dose limit for members of the public for emissions from nuclear facilities, such as uranium mines and mills.

Table 4.7.2 Distribution of Radioactivity ((µR/h) on 10 m by 10 m Grids

Location	Number of 10m by 10 m grids	Number of 10 m by 10 m grids by Radioactivity Class (µR/h)				
		0-15	15-30	30-60	60-120	120-240
Above West Tailings Beach	44	40	4			
East Tailings	40	39	1			
Mill West	186	85	99	2		
North from East Tailings	90	86	4			
Outside Silver Bear	153	119	27	4	2	1
Silver Bear Camp	101	94	7			
Storage Yard	67	60	7			
West Tailings Beach	30	29	1			
All	615	483	125	4	2	1

In addition to the gamma survey, radiological analyses were conducted at all surface water sampling stations in July 2007. The water quality results are shown on Table 4.6.3. The data show that only low levels of radiological constituents are present in surface waters around the sites and all measured values are well below Canadian drinking water standards and Metal Mining Effluent Regulations (applies to radium-226).

Table 4.7.3 Radiological Analysis Silver Bear Water Sampling Stations

Station #	Ra-226 Bq/L[2]	Pb-210 Bq/L
NX-1	0.06	0.07
T-6	0.005 [1]	0.02 [1]
T-8A	0.005	0.02
T-8B	0.008	0.02
T-8C	0.005	0.02
T-16	0.01	0.02
T-25	0.008	0.02
TMW-04	0.02	0.02
TMW-05	0.02	0.02
NO-1	0.006	0.02
NO-11A	0.005	0.02
R-1	0.005	0.02
R-3	0.005	0.02
SM-7A	0.008	0.02

Note 1- Method detection Limit

Note 2- Metal Mine Effluent Regulation Limit- Monthly average 0.37 Bq/L. Canadian Drinking Water Standard Guideline is 0.6 Bq/L.

5 Ecological and Human Health Risks

Comparison of water, sediment and soil quality with CCME guideline values provides a screening tool to identify potential environmental concerns, but does not predict site specific risks. The CCME guidelines are intended to be broadly applicable across Canada, but do not necessarily reflect local conditions. For that reason, the CCME recommends that site specific risk assessments be carried out. To better understand the potential for the mine sites to have any adverse effects on the local environment, or humans that may use the area, a risk assessment was completed. The assessment looked in detail at human health and ecological risks in the Terra Mine area, and also some specific potential concerns relating to the Northrim Mine and Norex Mine. The results of the risk assessment are presented in detail in SENES 2007. A summary of the results and conclusions of that report are presented herein.

In the first stage of the assessment, the available data on current environmental quality in the Terra Mine area were used to identify "constituents of potential concern" (COPC) to be carried through the human health and ecological risk assessment. Information on vegetation was obtained from Rescan 2005e and supplementary information on community composition and metal concentrations in Ho Hum Lake and Moose Bay Wetand information was through available through NEC 2006. The COPC identified included several metals and petroleum hydrocarbons.

A pathways model was used to estimate the exposure levels (intakes or doses) to selected ecological receptors and people from current levels of COPC in the environment, taking into consideration the location and dietary characteristics of the receptors. The pathways model relied on measured environmental quality data from the site, but also employed transfer factors from literature sources to estimate concentrations in environmental media that were not measured (e.g. berries and benthic organisms), but which are sources of food for receptors considered in the assessments. Exposure estimates were then compared to toxicity reference values to identify combinations of COPC and receptors that may experience potential adverse effects. Remediation measures may be considered for any adverse effects that are considered significant and unacceptable to users of the sites, while recognizing that not all risks can be mitigated with practical measures.

5.1 Ecological Risk Assessment

For the ecological risk assessment, a range of ecological receptors were examined from different trophic levels in the aquatic and terrestrial environments. The following sections summarize the results and conclusions.

5.1.1 Terra Mine

Ho Hum Lake TCA Aquatic Biota

The assessment for aquatic receptors indicated that toxicity reference values are exceeded for phytoplankton (arsenic and copper exposure) and zooplankton (copper exposure) in Ho Hum Lake TCA. While there are no data on the phytoplankton and zooplankton in Ho Hum Lake TCA, it is likely that the species that are present are metal tolerant. Effects on fish in Ho Hum Lake TCA were not assessed because aquatic studies have found no fish other than minnows in the lake.

Sediment toxicity reference values for several metals are exceeded in Ho Hum Lake TCA and the wetland area between the lake and Moose Bay, indicating the possibility of potential adverse effects on the benthic communities in these areas. This is confirmed by the sampling of benthic organisms in Ho Hum Lake TCA, which indicated lower abundance and diversity of benthic invertebrates compared to Moose Bay, and undisturbed lakes in the area.

Moose Bay Aquatic Biota

Arsenic concentrations in the inner part of Moose Bay exceed toxicity reference values for phytoplankton, and copper concentrations exceed toxicity reference values for phytoplankton and zooplankton throughout Moose Bay. The copper toxicity reference value for forage fish is also exceeded in the inner part of Moose Bay, closer to the wetland discharge from Ho Hum Lake TCA. However, studies of fish in Moose Bay indicate that the fish are healthy and, even through arsenic and copper concentrations in the bay are affected by the discharge from Ho Hum Lake TCA, it is unlikely that the ecosystem is experiencing adverse effects from exposure to these elements in the water column.

Sediment toxicity reference values for arsenic and nickel are exceeded in Moose Bay. However, the results of benthic community surveys indicate abundance and diversity that are similar to undisturbed lakes in the area. This suggests that it is unlikely benthic organisms in the bay are experiencing adverse effects.

Terrestrial Biota

The assessment of exposure of terrestrial receptors at the Terra Mine indicates that there are no risks of adverse effects for terrestrial wildlife or waterfowl, with the exception of arsenic exposure to muskrat in the Ho Hum Lake TCA area, including the wetland between the lake and Moose Bay. Elevated arsenic concentrations in the aquatic vegetation are the main pathway for exposure. The affected vegetation is in a small area and, therefore, potential effects (if any) would be confined to small numbers of muskrat rather than the entire population in the mine area.

5.1.2 Northrim Mine

The potential ecological effects of arsenic in water and sediment in the area of Hermandy Lake TCA and the Leachate Pond were evaluated. The sediment quality was based on analyses of tailings samples collected at the margins of the two water bodies. The aquatic risk assessment indicates potential adverse effects on phytoplankton in the Leachate Pond, and benthic organisms in the Leachate Pond and Hermandy Lake TCA. These effects are confirmed by benthic surveys indicating relatively low abundance and diversity in Hermandy Lake TCA.

Potential effects on beavers and loons were also considered in the assessment. The results indicate potential adverse effects from arsenic exposure for beavers present on Hermandy Lake TCA or the Leachate Pond, but loon populations using either water body would not be affected. These are relatively small water bodies and any effects would be confined to small numbers of animals. Covering exposed tailings at the margins of the water bodies would significantly decrease the exposure of beavers.

5.1.3 Norex Mine

Contaminants in drainage from the Norex Mine site are effectively removed in the downstream wetlands and water sampling indicates that the drainage is unlikely to have any adverse effects on aquatic life in the Camsell River. Risk assessment methods were used to evaluate the potential for adverse effects on terrestrial wildlife that might use the site drainage stream as a source of drinking water. Potential effects on hare and grouse (or ptarmigan) consuming water from the current mine portal drainage and waste rock pile drainage streams were assessed, and no adverse effects were indicated.

5.2 Human Health Risk Assessment

A human health risk assessment was carried out for hypothetical campers (an adult and a child) at the Terra Mine for varying periods of time, from 200 hours per year up to 3 months per year. It was assumed the campers would hunt and fish at the site and take the food back to their communities where it would be consumed. The hypothetical campers were also assumed to drink water continuously either from Ho Hum Lake TCA or Moose Bay.

The exposure of the hypothetical campers present for up to 3 months on the site were below levels that are considered to have potential adverse health effects for all contaminants, with the exception of arsenic. The arsenic concentration in Ho Hum Lake TCA and the inner parts of Moose Bay are above the Health Canada drinking water guideline of 10 µg/L. The assessment indicated that drinking untreated water from these locations over a period 200 hours per year would not pose a significant risk, but the risk of health effects would increase over longer periods, and drinking the water daily over one to three months per year would not be recommended. Note that while the risk assessment for mercury associated with the consumption of fish resulted in a marginal exceedence of the HQ value, the measured concentrations of mercury in fish was the same as at the reference and was about half of the HC guidance of 0.5mg/kg wet weight.

6 Remedial Action Plan

6.1 Overview

This section presents the remediation options and preferred remediation measures for the Silver Bear Mines. The presentation is complicated by the fact that there are five mine sites, each with a number of features that could conceivably require different remediation methods. To simplify the presentation, the sections are arranged as follows:

The first four sections (6.2 through 6.5) deal with the water quality issues specific to each mine site. Remediation measures for components that affect water quality, such as waste rock and tailings, are included as appropriate for each site.

Sections 6.6 through 6.12 address the remediation of components that are common to several sites, such as mine openings, buildings, and roads. Those sections generally describe remediation methods that would be applied to all areas, and site specific issues are discussed only where there are exceptions.

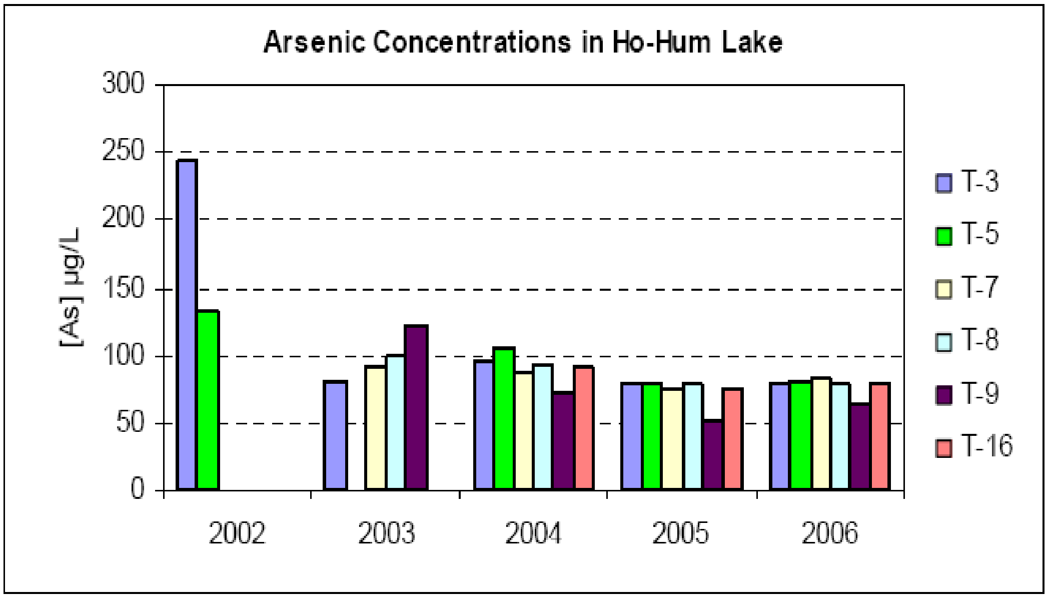
Section 6.13 presents a summary of the preferred remediation measures.

6.2 Terra Mine Waste Rock, Tailings and Ho Hum Lake TCA

6.2.1 Key Issues

The waste rock and tailings at Terra Mine, and their relationship to Ho Hum Lake TCA are discussed in Sections 3.2.4 and 3.2.5. The key issues to be addressed are:

The waste rock is currently a source of metal loadings to Ho Hum Lake TCA, including arsenic and copper. These loadings will continue in the future and will be one factor affecting the long term water quality of Ho Hum Lake TCA and its discharge to Moose Bay. Geochemical testing indicates that the waste rock oxidation rates are very low and given the high natural alkalinity in the system and the fact that waste rock is unlikely to produce acidic drainage in the future, the metal releases are unlikely to increase significantly. Monitoring over the past 5 years indicates water quality is stable.



Most of the tailings are located under water in Ho Hum Lake TCA. The submerged tailings could be a source of arsenic loadings to the lake and may be another factor affecting the long term water quality of the lake. Two small areas of tailings (~2,200 m^2) are exposed above water on the north side of Ho Hum Lake TCA.

The quality of water in Ho Hum Lake TCA contains elevated concentrations of arsenic and copper above CCME-FAL guidelines but levels remain well below Federal Metal Mining Effluent Standards (MMER) that would apply to discharges from an operating mine and tailings area.

The quality of water in Moose Bay is much better than Ho Hum Lake TCA, although arsenic and copper concentrations are typically still above the CCME-FAL guidelines near the Ho Hum Lake TCA inlet to Moose bay and in the inner Moose Bay. Monitoring in Moose Bay away from the inlet stream from Ho Hum Lake indicates levels are essentially at background. The results of the ecological risk assessment indicate some theoretical potential for negative effects on phytoplankton, benthic organisms and forage fish near the Ho Hum discharge to Moose Bay. However, sampling and analysis of the aquatic biota have not shown any negative effects.

6.2.2 Potential Remediation Methods

The basic objective of any remediation activities in this area would be to control contaminant concentrations in Ho Hum Lake TCA and/or its discharge to Moose Bay. Remediation methods that might contribute to achieving that objective are:

- Construction of soil covers on the waste rock or exposed tailings;
- Relocating the waste rock or exposed tailings under water;
- Raising the lake level to flood the exposed tailings;

- Covering the submerged tailings;
- Diverting drainage away from the waste piles to reduce leaching;
- Treating the overflow water using active chemical methods (i.e. a treatment plant);
- Treating water using passive chemical methods (i.e. a reactive wall); and,
- Treating water using the wetlands between Ho Hum Lake TCA and Moose Bay.

These methods are briefly discussed in this section, and the pros and cons of each method are summarized in Table 6.2.1.

Soil covers on the waste rock or exposed tailings would be intended to reduce the amount of water that comes into contact with these materials. Soil covers could be designed to shed some of the water as surface overflow, or temporarily store water in the soil pores for later release by evaporation. Soil covers would reduce the arsenic and copper loadings to Ho Hum Lake TCA, but could not eliminate them. Metal loadings would continue from zones in the waste rock that are flushed by lake water, and from the submerged tailings. The flushing of the waste rock by fluctuating water levels and lake currents is likely to be a dominant factor contributing to contaminant loadings from the waste. The main disadvantage of soil covers is the new environmental impact that would be created by excavating large volumes of soil in the borrow areas and the short term erosion from the cover material until vegetation was re-established.

The data presented in Lorax 2006 indicate that loadings of arsenic and other contaminants from the exposed tailings are actually very small, and even if these loadings could be eliminated with soil covers, the long term arsenic concentration in the lake water could only be reduced by a few micrograms per litre. A simpler type of cover for exposed tailings could be constructed using waste rock. It would prevent humans and animals from coming into contact with the tailings, and prevent release of tailings dust to the air.

The capacity of Ho Hum Lake TCA would allow all of the waste rock and exposed tailings to be placed in the lake. That would prevent any further oxidation of metal sulphide minerals, and could reduce the total amount of metals released from the rock in the long term. However, the geochemical testing indicates that oxidation has already occurred and soluble metals are stored in the piles. The metals would dissolve rapidly once the rock or tailings are placed in the lake and the relocation of the rock would potentially cause a significant disturbance to the tailings in the lake. The potential for an immediate, very negative effect on Ho Hum Lake TCA water quality is the main disadvantage of this option.

Raising the lake level to flood exposed tailings may reduce long term metal releases from these tailings by preventing further sulphide oxidation. A water cover would also prevent the release of tailings dust. The lake level would have to be increased by about two metres to cover the West Beach tailings. To do this, two water retaining dams would have to be constructed and maintained, one at the outlet to Moose Bay and another between Ho Hum Lake TCA and Little Ho Hum Lake. The long-term maintenance of dams at a remote site is undesirable and a major disadvantage for this method. Furthermore, the East Beach tailings, which are elevated well above lake level, would still require other remediation methods. Another disadvantage would be the destruction of the upper wetland area which currently serves to naturally attenuate arsenic and copper levels.

Contaminant loadings from the submerged tailings could be reduced, and the lake water quality improved, by covering the tailings under water with a fine-grained natural soil, taken from borrow sites in the area although there would be major technical challenges to implementing this option. However, since the waste rock beside the lake is a significant contaminant source, the benefits of only covering the submerged tailings could be limited. Implementation of this method would be complex and a new environmental impact would be created by excavating the large volumes of soil required.

Under the existing conditions, drainage from the hillsides currently flows through or across the waste piles with no effort to channel the drainage and minimize leaching of contaminants. It is expected that some minor ditching and channelling of the flows draining to Ho Hum Lake TCA would reduce the contact of surface runoff with waste rock and as such would reduce loadings to Ho Hum Lake TCA. This could be achieved at a modest cost and would be considered good practice.

The possibility of using active water treatment processes to remove arsenic and other metals from the lake discharge has been investigated. A laboratory water treatment test program was completed in 2005, using water collected from Ho Hum Lake TCA (Elbow Creek 2005). The test work investigated the performance of two chemical processes, known as iron co-precipitation and elemental iron adsorption. Both processes were capable of removing arsenic from the water down to concentrations of 5 µg/L under laboratory conditions. However, treatment plants in operation at Canadian mines, using what is considered the best available technology for arsenic removal, typically produce effluents with arsenic levels that on average range from 25 to 180 µg/L with monthly averages of about 400 µg/L (SENES 1999). That would not be any improvement on the quality of water that is currently discharged from the end of the wetland into Moose Bay. Other factors that make active treatment undesirable, include: water treatment would need to continue well into the future; active treatment would require transporting and handling significant quantities of chemicals and fuel with all the related risks to worker safety and the environment; and active treatment produces high strength arsenic waste that will require disposal. The only environmental benefit would be the reduction of arsenic levels in the water in the near-shore area near the inlet of Moose Bay.

A relatively passive chemical method to improve the quality of water discharged to Moose Bay has also been considered. The idea of using “reactive walls” to attenuate arsenic has been investigated by a number of researchers on a test scale. In practise, a reactive wall would be a permeable zone of ground through which the water to be treated would flow, containing a reactive medium of iron minerals or other media that would adsorb or precipitate arsenic from the water. In concept, this kind of treatment appears attractive for a remote site such as Terra, because the reactive wall would only have to be renewed with new reactive material every few years, and the system would not require operators and electrical power. However, this type of technology is best suited to removal of contaminant in groundwaters and not well suited to highly variable surface water flows that are expected for the discharge from Ho Hum Lake TCA. As such, reactive barriers for treatment of the Ho Hum Lake TCA discharge are not believed to be a suitable application for this technology.

Table 6.2.1 Potential Remediation Methods for Ho Hum Lake TCA

Remediation Method	Advantages	Disadvantages
Place soil covers on waste rock and/or tailings	Reduces metal loadings to Ho Hum Lake TCA	Water quality improvements may be limited Creates new disturbance in soil borrow areas Short term erosion of covers Requires maintenance High cost
Relocate waste rock and/or tailings under water	Potentially will reduce long term metal releases to Ho Hum Lake TCA	Immediate, very negative effect on lake water quality Disturbance of submerged tailings High cost
Raise lake level to flood exposed tailings	Prevents release of tailings dust to air Reduces long term metal releases to Ho Hum Lake TCA	Limited water quality benefits Requires maintenance of water retaining structures Negative impacts on the upper wetland High cost
Cover submerged tailings	Could reduce metal loadings to Ho Hum Lake TCA	Water quality improvements may be limited Creates new disturbance in soil borrow areas Would be technically challenging to implement Potential release of sediment to Moose Bay High cost
Divert clean drainage	Potentially will reduce contaminant loadings to Ho Hum Lake TCA	Only practical to divert a portion of the surface drainage
Treat water with active chemical methods	Reduces metal concentrations in near shore waters of the inner bay of Moose Bay	Requires long term operation and maintenance Produces concentrated arsenic wastes that will require disposal Chemical and fuel transportation risks High cost
Treat water with passive chemical methods	Could reduce metal concentrations in discharge	Feasibility unproven and unlikely to be applicable to Ho Hum Lake TCA discharge Requires long term maintenance Does not reduce metal concentrations in Ho Hum Lake TCA Produces high strength arsenic waste that requires disposal
Enhance existing wetlands	Reduces arsenic concentrations in discharge Does not require maintenance Proven effectiveness at this site	Does not reduce metal concentrations in Ho Hum Lake TCA

The existing wetlands currently reduce arsenic concentrations in the water discharged from Ho Hum Lake TCA to Moose Bay. The enhancement of wetlands at the outlet of Ho Hum Lake TCA would be expected to contribute to further natural attenuation of arsenic.

6.2.3 Preferred Remedial Plan

As part of the consultation process, local community representatives participated in an assessment of the alternatives. The results are compiled in Appendix 1.

The preferred remediation methods identified by the local communities and those selected for the RAP for the Ho Hum Lake TCA area are discussed below and shown on Figure 6.2.1.

The preferred option identified by the communities and included in the RAP is to cover all of the exposed tailings with rock, to minimize risks by preventing contact with humans or animals, and stopping the release of tailings dust. The primary area of tailings to be covered (about 1,200 m^2) is the West Beach. A second area which has been classified as tailings but does not have sulphide or elevated metals is the East Beach (about 1,000 m^2). These areas are shown in Figure 3.2.5. The cover for the West area would extend a short distance below the water level to minimize erosion of the tailings by wave and ice action, and prevent exposure of the tailings if the lake level drops during very dry years.

A conceptual section through the cover is shown in Figure 6.2.2. The tailings would be re-graded in some areas to make placement of the cover material more efficient. The cover material would be mine waste rock at least 0.5 metres in thickness. Waste rock with low metal leaching potential would be selected for the covers. In some areas, where the tailings are relatively wet or fine-grained, a layer of geosynthetic filter fabric would be placed on the tailings surface to prevent the tailings from piping upwards through the waste rock. Most of the waste rock at Terra is relatively fine-grained and would make covers with even surfaces that would be easily traversed by wildlife.

All options considered that the outlet dyke at Ho Hum Lake TCA would be upgraded. The dyke at the outlet of Ho Hum Lake TCA would be expected to deteriorate slowly and eventually fail in the long term. The dyke leaks water at its north abutment, and this could erode and weaken the structure. The weir and drainage culvert inside the dyke could become blocked by debris, forcing water to flow over the dyke. Eventually the culvert would corrode and collapse, with the same effect. To address these issues, part of the remediation for the lake outlet would involve removing material from the top of the entire dyke to lower its height by about 1.5 metres. The weir intake box and drainage culvert inside the dyke would be backfilled and sealed. The crest of the lowered structure would then be about one metre above the ground on the downstream side. This is the lowest practical height for the structure without draining the upper wetland area, which needs to be preserved. For the RAP it has been assumed that the existing dyke will also be upgraded to enhance term stability and to minimize seepage losses.

The existing decant would be replaced with a spillway over the crest of the structure, allowing the lake to discharge by overflowing the dyke. The spillway would be a wide, shallow channel armoured with coarse rock to prevent erosion during periods of high flow. The lowered dyke would retain water at a level about one metre lower than the current maximum level, and Ho Hum Lake

TCA would be lowered to the same level. The wide channel would ensure than the lake discharge is drained rapidly during high flow periods, without a large increase in the lake level.

A typical plan and section of the proposed upgraded dyke as prepared by EBA (Feb 2006) is shown in Figure 6.2.3.

The actual dyke section will be similar but the elevation reduced with the lowered dyke retaining water only one metre above the downstream toe. During lower flow periods, most of the lake discharge would overflow through the spillway, although some sub-surface seepage could continue to occur. The final design for lowering the dyke and installing the spillway will address the potential need for enhancements to the existing seepage cut-off system in the dyke to minimize the sub-surface flow.

Wetland enhancement was selected by the communities and for the RAP as a preferred method to improve Ho Hum Lake TCA discharge quality. The enhancement is to be achieved by lowering and stabilizing the lake levels which results in shallower and more consistent water levels in the upper wetland area, helping wetland plants to become re-established. The upper wetland was degraded when the water level in Ho Hum Lake TCA was artificially raised. The preferred approach is to allow natural recolonization, although some enhancements may be possible. For example, aquatic plants could be harvested from other wetlands in the area and re-planted in the upper wetland to speed its development. Diverting clean water draining to Ho Hum Lake TCA (where practical) away from the waste rock was a preferred option by the communities to minimize future risks and is proposed for the RAP.

The overall reclamation works for the site are shown on Figure 6.2.4. With these plans in place, the following benefits should be observed:

- Eliminate dust and exposure from uncovered tailings;
- Reduced loadings and environmental effects from contaminants draining into and overflowing from Ho Hum lake TCA; and,
- Long term physical and chemical stability of the site.

6.2.4 Monitoring and Contingencies

The preferred remediation approach for Ho Hum Lake TCA is based on the conclusion that current metal loadings from the waste rock and tailings are unlikely to increase significantly in the future. Monitoring will be essential to verify that conclusion. The water quality of Ho Hum Lake TCA and Moose Bay will be monitored in the long term. If the monitoring shows trends of increasing metal concentrations with the potential for unacceptable effects, targeted investigations will be implemented to determine if the changes are caused by increased loadings from the waste rock. The investigations will attempt to determine if particular zones of waste rock are causing increased metal loadings. Potential remedial actions could include covering or relocating problematic portions of the rock.

The performance of the tailings covers will be monitored with periodic visual inspections, looking for signs of cover erosion, excessive settlement, or piping of tailings into the cover material. If any of these problems result in significant exposure of tailings, the cover will be repaired.

The condition of the wetlands will be monitored with periodic visual inspections. The performance of the wetlands in reducing arsenic concentrations will also be assessed by monitoring water quality upstream, downstream and within the wetland. If the wetland performance was to decline significantly, and arsenic concentrations in Moose Bay were to increase as a result to levels considered unacceptable, the cause of the change would be investigated. Potential remedial actions could involve modifying or expanding the wetlands to increase the removal of arsenic. Monitoring plans are described further in Section 7.

6.3 Northrim Mine Waste Rock, Tailings and Hermandy Lake TCA

6.3.1 Key Issues

The waste rock and tailings at the Northrim Mine, and their relationship to Hermandy Lake TCA and the Camsell River, are discussed in Section 3.3.3 and 3.3.4. The key issues are:

Groundwater at the waste rock piles contains elevated levels of arsenic and zinc, indicating that the waste rock is currently a source of these metals. The amount of rock is relatively small and it is located away from any significant runoff drainage routes. As a result of these conditions, the loadings would be too small to cause increases in metal concentrations in the river. This is confirmed by monitoring in the Camsell River which shows no differences in water quality above and below drainage from the Northrim mine site.

None of the waste rock sampled is currently acidic. Geochemical testing indicates that less than 10% of the rock has a potential to produce acidic drainage with increased metal concentrations in the future. Long term monitoring will be required to identify any changes that could have adverse effects on the environment.
Two small areas of exposed tailings are located at the north end and the south-east corner of Hermandy Lake TCA adjacent to the Leachate Pond. Metal loadings from the tailings have not to date (and would not be expected to) have a significant effect on the water quality of Hermandy Lake TCA. In fact the exposed material on the north shore (150 m^2) does not appear to be tailings. Most of the tailings produced at Northrim Mine lie under water in Hermandy Lake TCA. Despite the presence of tailings, the lake water quality is relatively good.

A small dump of what appears to be smelter process waste and tailings lies exposed just south of the Leachate Pond. This material contains very high levels of some soluble metals and may contribute to elevated metal concentrations in the Leachate Pond and the discharge from Hermandy Lake TCA, which is routed through the pond. The discharge from Hermandy Lake TCA becomes progressively more contaminated with some metals on its current drainage path through the Leachate Pond to the Camsell River. Suspected sources of contaminants include the smelter process waste and other tailings within and adjacent to the Leachate Pond.

Tailings are located under water in the Camsell River, close to the mine facilities. Sampling indicates an impact on sediment quality in this area, but no effects on water quality in the river have been measured.

The results of the risk assessment indicate potential negative effects on phytoplankton in the Leachate Pond, and benthic organisms in both Hermandy Lake TCA and the Leachate Pond. Beavers could be adversely affected by the sediment quality and water quality in the Leachate Pond and Hermandy Lake TCA.

6.3.2 Potential Remediation Methods-Waste Rock

A small portion of the waste rock is acid generating and ground water below the pile is contaminated. The waste piles are not impacting on Camsell River water quality and waste rock has been in place for more than 30 years.

Alternatives considered for the RAP included:

- Leave as is;
- Relocation of small piles along the river to the main pile or Leachate Pond; and,
- Covering of the surface of the pile to enhance vegetation.

6.3.3 Proposed Remedial Plan-Waste Rock

All options are reasonable given that the waste piles are not impacting the Camsell River. The communities preferred option was to relocate the waste rock piles along the river. Given that waste rock will be required to backfill a portion of Leachate Pond and cover exposed tailings, waste rock along the river will be preferentially used as the backfill material and augmented with rock from the pile as required.

6.3.4 Potential Remediation Methods-Tailings, Leachate Pond and Hermandy Lake TCA

Metal loadings from exposed tailings adjacent to Hermandy Lake TCA are small and the water quality of the lake is relatively good. Therefore, relocating or covering those tailings with low-permeability covers are also not considered necessary. The primary concern with most of the exposed tailings is the potential for direct contact with humans or animals, or the release of tailings dust. These concerns could be addressed by placing simple waste rock covers on the tailings.

The smelter process waste/tailings area located on the south side of the Leachate Pond has very high levels of soluble arsenic and copper. Potential methods to reduce metal releases from the smelter waste dump include covering the waste *in-situ* with a low permeability cover, or excavating the waste to be contained and covered at another location. The objective in both cases would be to minimize the flow of water through the waste. Given that the Leachate Pond area also contains tailings and waste rock, which also contributes to contamination, a large quantity of material would have to be relocated and a new disposal area developed. Since it is inadvisable to relocate the waste to Hermandy Lake TCA given its present good water quality, relocation and development of a new site would only be considered if *in-situ* reclamation was not practical.

A low-permeability cover for the smelter waste could be constructed with a layer of compacted fine-grained soil or a plastic liner. Covering the waste *in-situ* should be effective in reducing the metal loadings, but some potential would remain for lateral groundwater movement under the cover to release contaminants from the waste. Another option would be to excavate the waste and place it in a smaller footprint at another location, and cover it there.

Since the quality of water in Hermandy Lake TCA is relatively good, remediation has not been considered for the lake itself. The remaining concern is the contamination picked up by the lake discharge through Leachate Pond.

The remediation methods considered for the smelter waste/tailings in Leachate Pond and Hermandy Lake TCA discharge are:

- Leave as is;
- Covering of the exposed tailings and smelter waste and re-routing the drainage around the pond;
- Covering of the exposed tailings and smelter waste and re-routing the discharge to the former outlet of Hermandy Lake TCA by constructing a low dyke; and,
- Relocating tailings (to a new disposal area).

The advantages and disadvantages of these alternatives are reviewed in Table 6.3.1.

Table 6.3.1 Potential Remediation Methods for Hermandy Lake TCA Discharge

Remediation Method	Advantages	Disadvantages
Leave as is	Low cost No measureable impact on Camsell River	Potential dusting and exposure to animals from exposed tailings Long term erosion
Cover exposed tailings and diverting drainage around Leachate Pond	Reduces contaminant loadings Prevents dusting and exposure to animals	Hermandy Lake TCA former drainage not restored New diversion ditch needs maintenance Higher cost
Cover exposed tailings and re-route discharge with low dyke	Reduces metal concentrations in lake discharge	Some additional borrow requirements for dam Long term maintenance of dyke Higher cost
Relocate tailings (a new disposal area)	Reduced loadings from Leachate Pond Prevents dusting and exposure to animals	Significant short term disturbance and contamination High Cost New disposal area to monitor and maintain

6.3.5 Preferred Remedial Plan-Hermandy Lake TCA Discharge

All of the remediation methods described above are practical and feasible options for improving the quality discharge from Hermandy Lake TCA. The plan described in this section is one combination of methods that would effectively reduce contaminant releases to the environment and address potential risks to wildlife.

The preferred remediation methods identified by the local communities and those selected for the RAP for the Hermandy Lake TCA area were covering the exposed tailings/smelter waste in and around Leachate Pond and re-establishing the drainage to the former outlet of Hermandy Lake TCA. The preferred option for the tailings in the Camsell River was to leave them in place as the zone of sediment impacted was small and relocation/covering would cause further disturbance/contamination in the river. These cover options minimize future risks by eliminating exposure of tailings and smelter wastes to animals and people. Leaving tailings submerged and in place minimizes future risk to water quality associated with relocation.

Re-establishing the drainage to the former outlet Hermandy Lake TCA was the preferred alternative to minimize metal releases to the environment by reducing water flow through the contaminated area. If the discharge from Hermandy Lake TCA were to be re-routed away from the Leachate Pond, the catchment providing runoff to the pond would be reduced in size by more than 90%, with a proportional decrease in water flow through the contaminated area. Before Hermandy Lake TCA was used for tailings disposal, the lake drained south-west to the Camsell River. This drainage pathway was closed off with a low rock berm to create the current drainage route through the Leachate Pond. The old drainage route has become overgrown with vegetation, but parts of the old channel are still visible.

The lake discharge could be returned to the original discharge route by constructing a low dyke on the south-east side of the Leachate Pond, with a low-permeability core or internal seepage cut-off wall. The crest of the dyke would be about one metre above the existing ground surface. At the discharge location, a portion of the existing rock berm at the former outlet of Hermandy Lake TCA would be removed to re-establish drainage through the marshland. The advantage of the low dyke method is that the combined discharge from Hermandy Lake TCA/Leachate Pond area would be much cleaner than it is now, the discharge would be re-routed through the wetland marsh which would enhance natural attenuation and metal releases to the Camsell River would be reduced. The main disadvantage is that a structure would be left on site, and it would have to be repaired in the future if it ceased to function as designed, due to settlement or erosion.

An alternative to the low dyke remediation method would be to backfill a portion of Leachate Pond. The majority of the fill could be waste rock, but it would incorporate a low-permeability zone of compacted soil, effectively creating a low-permeability dyke within the fill. Filling in the Leachate Pond would have a similar positive effect on the Hermandy Lake TCA discharge as the low dyke method, and any risks posed to wildlife by the Leachate Pond would be eliminated. Another advantage of this method is that, if carefully constructed, it would require no long term maintenance. A disadvantage is that the pond sediment probably contains contaminated pore water which could be released to the pond when the sediments are compressed by the fill material. This could result in a temporary increase in contaminant releases, or require short term water treatment. For the RAP, infilling part of the pond has been selected as this will reduce any long term maintenance for the site.

The proposed plan is summarized in Figure 6.3.1.

The smelter waste dump would be covered with a low-permeability cover. The remaining exposed tailings where present adjacent to the Leachate Pond would be covered with waste rock. This will prevent contact between animals, such as beavers, and any tailings or contaminated sediments near the shore area of the pond.

The Hermandy Lake TCA discharge would be re-routed away from the Leachate Pond by partially backfilling the pond, which would in effect create a massive dyke at the exiting outlet Hermandy Lake TCA and the Leachate Pond. The intent would be to create a very stable structure with no long term maintenance requirements. The fill would incorporate a low-permeability zone of compacted fine-grained soil, to prevent seepage through the fill. A portion of the rock berm at the original drainage route would be removed and a shallow discharge channel would be excavated through the marshland.

Tailings in Camsell River would be left as is.

With these reclamation plans in place the following benefits are expected:

- Eliminate dust and exposure from uncovered tailings;

- Reduced loadings and environmental effects from contaminants draining from Hermandy Lake TCA and the Leachate Pond overflowing to the Camsell river; and,

- Long term physical and chemical stability of the site.

6.3.6 Monitoring and Contingencies

The water quality of Hermandy Lake TCA and its discharge stream along with the Camsell River upstream and downstream of Northrim will be monitored. Monitoring will also be required of the cover over the smelter waste/tailings and of the discharge channel reopened at the former outlet of Hermandy Lake TCA. Monitoring plans are described further in Section 7.

6.4 Norex Mine Waste Rock

6.4.1 Key Issues

The waste rock at Norex Mine is described in Section 3.4.4. The key issues concerning remediation are:

The rock is currently a source of metal releases to the environment. In particular, the releases of cadmium, lead and zinc in drainage from the rock pile are a remediation concern. Most of the water producing drainage from the rock pile comes from the Norex Mine portal above the pile.

Metals are effectively removed from the drainage in wetlands downstream of the site, before the drainage reaches the Camsell River. As a result, the drainage is unlikely to have any adverse effects on aquatic life in the Camsell River.

The results of the risk assessment indicate that the site drainage would have no adverse effects on hare or grouse/ptarmigan that could use it as a source of drinking water.

Most of the waste rock is not currently acidic, although some of the rock has the potential to produce acidic drainage with increased metal concentrations in the future. Long term monitoring will be required to identify any changes that could have adverse effects on the environment.

6.4.2 Potential Remedial Methods

High metal concentrations in drainage from the waste rock pile are a concern primarily because of the high flow rate, and the resulting large metal loadings to the wetlands. Reducing the volume of drainage is therefore a primary remediation objective. The surface area of the pile is relatively small, so infiltration to the pile from direct precipitation is limited, and the surrounding terrain is such that the volume of natural runoff draining into the waste rock pile is low. Runoff calculations indicate that about one quarter of the annual drainage from the pile originates from local runoff, while the remaining three-quarters originate from the Norex Mine. If that water source could be eliminated, the metal loadings from the waste rock pile would be greatly reduced. The methods which could be considered to reduce the drainage volume and metal loadings from the waste rock are:

- Divert the mine drainage around the pile using an open channel; and,
- Construct a hydraulic seal to prevent mine drainage at this location.

Both of these methods are described below and their pros and cons are summarized in Table 6.4.1.

A small channel could be constructed to convey water directly from the mine portal to the north-east side of the waste rock pile, and join the existing drainage route from the site. The channel would be excavated in rock fill and soil, and would be lined as necessary to prevent leakage. The advantage of this remediation method is that it would reduce the volume of drainage from the waste rock pile, with a consequent reduction in metal loadings to the environment, particularly the cadmium, lead and zinc that are picked up within the pile. The channel would also be relatively simple to construct. The disadvantage is that arsenic in the mine drainage would continue to be released from the site.

The hydraulic seal option would involve the construction of a concrete bulkhead in the ramp leading down into the mine from both of the portals at the waste rock pile. The ideal bulkhead location is currently partially flooded with minewater, which would have to be pumped out to make the construction site dry. The bulkhead would be made with steel reinforced concrete.

Sealing the mine entrance with a concrete bulkhead would prevent discharge from the mine into the waste rock pile. The water level in the mine workings would rise, and the mine could discharge water at another location as a result. If discharge were to occur at another mine opening, it would almost certainly occur at the bottom of the Graham Vein trench, which is connected to a backfilled stope in the Norex mine underneath. Since this elevation is 30 metres higher than the Norex main portal, the hydraulic gradients into the mine from the local water table would be reduced, and the volume of the mine discharge would also be reduced.

The advantage of this remediation method is that all metal releases from the site, including arsenic, would be reduced. The main disadvantage is the complexity and high cost of this method. As with other concrete seals, the hydraulic seal would not last indefinitely and would eventually have to be replaced to remain effective. There would also be a risk that drainage from the mine with elevated levels of arsenic could occur at some unexpected location through drill holes, in which case, the hydraulic seal could be no more effective remediation than the open channel method.

The main difference between the methods is the potential to reduce arsenic releases in mine drainage using the more complex hydraulic seal method. However, the arsenic releases are not actually a significant environmental concern. Most of the arsenic is precipitated with iron and removed from the drainage before it leaves the site and almost all of the remaining arsenic is removed in the wetlands before the drainage joins the Camsell River. The risk assessment results indicate that the mine drainage does not pose a risk to wildlife, even at the higher arsenic concentrations found at the mine portal.

Table 6.4.1 Potential Remediation Methods for Norex Site Drainage

Remediation Method	Advantages	Disadvantages
Open channel to divert mine drainage	Reduced metal releases to wetlands (cadmium, lead, zinc)	Releases of arsenic in periodic mine drainage would continue Relatively simple to construct
Hydraulic seal to control mine drainage	Reduced all metal releases (including arsenic)	Requires eventual replacement. May not be fully effective Complex and high cost

Given the above discussions, the alternatives considered for addressing contaminants from the waste rock pile included:

- Leave as is;
- Cover with soil and vegetate; and,
- Seal or divert portal drainage around the pile.

The benefits of covering the rock with soil are considered to be minor at this time. Most of the metal loadings can be eliminated by reducing the drainage volume and the benefits of additional remediation measures would be limited. Also, the wetlands downstream of the site have proven effective in removing metals from the site drainage before the water reaches the Camsell River. The wetlands would be expected to continue to remove metals from the remaining site drainage. The preferred option by the communities was to divert the drainage around the piles in a channel to reduce the flushing of contaminants from the pile.

6.4.3 Preferred Remedial Plan

The open channel is the preferred remediation method, because it is more simple and reliable, and the alternative method offers no significant additional benefits.

The channel location is shown in Figure 6.4.1. The base of the channel would be excavated in native soil or waste rock fill, and would be lined as necessary with low-permeability materials, such as compacted fine-grained soils or a synthetic membrane. The channel bed and liner materials would be protected against erosion with riprap as necessary. The channel would be designed to continue to function in the long term without regular maintenance.

Both of the mine portals at the waste rock pile would be sealed in a conventional manner, by backfilling the mouth of the opening with broken rock. Coarse rock pieces would be placed in a layer at the bottom of the backfill. The mine would continue to drain water through the coarse rock.

With these reclamation plans in place the following benefits are expected:

- Reduced contaminant loadings from the waste rock pile drainage to the Camsell River; and,
- Long term physical and chemical stability of the site

6.4.4 Monitoring and Contingencies

The preferred remediation approach for Norex is based on the conclusion that metal releases from the waste rock will not pose any risk to the environment, once the volume of drainage is reduced with the new drainage channel. However, some of the rock could become acidic in the future, and metal releases could increase as a result. Monitoring will be required to determine if any changes are occurring that could adversely affect the downstream terrestrial or aquatic environments.

The quality of drainage from the mine workings (in the new channel) and the waste rock pile will be monitored in the long term. The quality of the combined site drainage just before it joins the Camsell River will also be monitored. If the monitoring shows trends of increasing metal concentrations with the potential for unacceptable effects, targeted investigations will be implemented to determine the source of the increased metal loadings. If a particular zone of waste rock is found to cause increased metal loadings, measures may be taken to reduce the metal loadings from that zone. The measures could include covering the rock *in-situ*, or extracting the rock for containment elsewhere. If the mine drainage is the source of increased metal loadings, measures to reduce the loadings will be assessed. The measures could include enhancement of the wetland treatment occurring downstream, or perhaps covering of the waste pile.

The performance of the mine drainage channel will be monitored through periodic visual inspections, looking for signs of erosion, excessive settlement, or leakage. If the channel fails to function as designed, keeping mine drainage out of the waste rock pile, the channel will be repaired. Monitoring plans are described further in Section 7.

6.5 Smallwood Mine Waste Rock

6.5.1 Key Issues

Issues concerning potential environmental impacts of waste rock at Smallwood are discussed in Section 3.5.3. The key issues concerning remediation of the waste rock are:

- Groundwater at the waste rock pile contains elevated levels of cadmium and zinc, indicating that the rock is currently a source of these metals. The relatively small size of the rock pile and its location away from any significant drainage courses indicate that metal loadings to Smallwood Lake would be relatively small, and this is supported by the fact that the lake water quality is good.
- Most of the rock is not currently acidic, although geochemical testing indicates that the majority of it has the potential to produce acidic drainage in the future, with increased

concentrations of metals. Long term monitoring will be required to identify any changes that could have adverse effects on Smallwood Lake.

- Several small piles of low grade ore have been left lying on top of the waste rock. Field observations, sampling and testing indicate that this material has higher metal concentrations than most of the other rock stored at the site.

6.5.2 Potential Remedial Methods

The remediation methods that were considered for the Smallwood Mine waste rock are:

- Place soil covers on the rock;
- Relocate the rock under water;
- Segregate and relocate some of the rock;
- Leave the rock as it is; and,
- Improve drainage through grading and diversions.

Soil covers would be intended to reduce infiltration into the waste rock and reduce metal loadings to Smallwood Lake. The covers could be designed to shed some of the water as surface overflow, or temporarily store water in the soil pores for later release by evaporation. This method would require a large volume of natural soil to be taken from nearby borrow sources, which would create a new environmental disturbance. If all of the rock were to be covered, the pile would require extensive re-grading to create shallow side slopes, resulting in a larger footprint area. A soil cover would require occasional maintenance to remain effective.

Relocating the rock under water would be intended to prevent additional oxidation of metal sulphide minerals and could reduce the amount of metals released from the rock in the long term. There are two small lakes nearby that together may have sufficient capacity to allow the rock to be covered with water. The geochemical testing indicates that considerable oxidation has already occurred and some metals are relatively soluble. Placing the rock in a lake would release the soluble metals with an immediate negative effect on the lake water quality. The water might have to be contained and treated before it is discharged to the environment. As such, this option was not considered further.

An important conclusion of the site inspections and geochemical assessment is that there are distinct stockpiles of material with higher metal content than the majority of the rock. This material was stockpiled as low-grade ore when the mine was operating. Since this small amount of material can be readily identified, it can be separated from other waste rock at the site and managed separately to reduce metal loadings to the environment. The separate management could involve relocation away from water bodies and measures to limit the amount of infiltration into the rock.

Another approach is to leave the rock as it is, as proposed for the other Silver Bear Mines. The current cadmium and zinc loadings do not pose any risk to the environment and even if the rock were to produce acidic drainage at some point in the future, the size and location of the pile suggest that metal loadings under acidic conditions would still be relatively small.

An alternative would be to leave the rock in place, but reduce the amount of drainage through the piles by grading and diverting freshwater away from the pile.

The pros and cons of the potential remediation methods are summarized in Table 6.5.1.

Table 6.5.1 Potential Remediation Methods for Waste Rock at Smallwood Mine

Remediation Method	Advantages	Disadvantages
Place soil covers	Reduces metal loadings to Smallwood Lake	Creates new disturbance in soil borrow areas Requires maintenance High cost
Improve drainage	Potentially reduce loadings to Smallwood Lake Low cost	Continued metal loadings to Smallwood Lake
Segregate and relocate some rock	May reduce metal loadings to Smallwood Lake Waste rock could be used as backfill in Graham Vein No new environmental impact	Continued metal loadings to Smallwood Lake
Leave as it is	No new environmental impact	Continued metal loadings to Smallwood Lake

Because the current metal loadings do not pose any risk to the environment, the advantages of soil covers appear to be outweighed by the disadvantages. Relocating some of the easily accessible rock with higher metals content has few disadvantages and would reduce the potential for future increases in metal loadings. The remediation of the Graham Vein trench requires backfill, and rock from Smallwood Mine would be useful for this purpose.

Based upon the evaluation by the communities, the preferred option was to improve drainage around the piles and selectively remove material for use as backfill in Graham Vein. For the latter alternative, the ore stockpiles and acid generating waste rock would be priority materials for relocation to Graham Vein trench.

6.5.3 Preferred Remedial Plan

Improving drainage and relocating portions of the Smallwood Mine waste rock to an area that requires backfill is the preferred remediation method. The recommendation recognizes that the waste rock currently has no significant impact on the environment, but that there is a potential for metal loadings to increase in future. The first point suggests that any remediation methods that would create additional disturbances elsewhere, for example constructing soil covers or relocating the entire pile, are not warranted. The second point suggests that it would be prudent to take measures to reduce the risk of future deterioration in water quality, where such measures do not lead to significant additional disturbances.

The trench provides a good disposal location for the Smallwood rock. The walls of the trench are close to the height of land in the immediate area, and it would not receive any significant runoff from surrounding land. The backfilled material would form a tall planar shape with a small surface area, effectively limiting the amount of infiltration. The confined nature of the space would also allow for effective future monitoring. Any drainage from the rock would either emerge on surface from the narrow mouth of the trench, or would drain through the backfilled stope underneath the trench into the Norex mine workings. Drainage from the Norex Mine would be monitored at the proposed new drainage channel at the main portal.

The trench has sufficient capacity to contain the estimated 1,600 m^3 of Smallwood rock requiring special management, as well as other material. Other waste rock could be used to fill the base of the trench to keep the Smallwood rock above the water table. Backfilling the trench would remediate another important concern, which is the physical hazard to humans and wildlife currently posed by the high and steep walls of the trench.

With these reclamation plans in place the following benefits are expected:

- Reduced contaminant loadings from the waste rock pile drainage to Smallwood Lake; and,
- Long term physical and chemical stability of the site.

6.5.4 Monitoring and Contingencies

Drainage from the Smallwood waste rock piles has the potential to become acidic in the future, and increases in metal releases are possible. Therefore, the water quality of Smallwood Lake will be monitored in the long term to determine if changes are occurring. If the monitoring indicates trends of increasing metal concentrations with the potential for unacceptable effects on aquatic life, targeted investigations will be implemented to determine if the changes are caused by increased loadings from the waste rock. The investigations will attempt to determine if particular zones of waste rock are causing increased metal loadings. Potential remedial actions could include covering or relocating some or all of the rock.

6.6 Mine Openings

6.6.1 Key Issues

The key issue concerning mine openings at all of the Silver Bear Mines is the risk of injury to humans and animals caused by falling into the openings or entering unsafe mine workings. Safety issues include falling rock and potential for hazardous air quality. Preventing inadvertent access to abandoned mine workings is standard industry practise and required by law in the Northwest Territories.

6.6.2 Potential Remedial Methods

The Northwest Territories Mine Health and Safety Regulations specify that all underground openings to surface must be sealed before a mine is permanently closed, and provide basic design criteria for the capping of shafts and raises. The selection of methods is primarily an engineering exercise to ensure that each opening is sealed in a manner that meets the regulations and achieves the requirements for strength and durability, while remaining cost-effective. The selected method must not risk the safety of workers installing the seal (physical and air quality hazards). The methods of permanently sealing mine openings that have been considered for the Silver Bear Mines are:

- Backfilling with waste rock;
- Controlled collapse by blasting; and,
- Installing concrete caps, plugs or pre-cast slabs.

These methods are discussed below. Several common variations on these methods are illustrated in Figure 6.6.1. Key features of the Silver Bear Mine openings and the proposed reclamation plans are presented in Appendix 2. Where complete sealing of the mine in not practical, fencing can be considered. The option of fencing was only considered to be acceptable by the communities when necessary to protect public health and safety.

Backfilling with waste rock would be suitable for all horizontal openings, such as the portals leading to adits and declines, and there is abundant rock available at all of the sites for this purpose. The rock would be placed and compacted in lifts in the mouth of the opening and immediately outside it. Where water is expected to drain from the opening, the bottom lift would be comprised of coarser free-draining rock. The depth of the plug, the size of the rock used and final slopes of the rock faces would ensure that the plug is stable in the long term.

Backfilling would normally be the best method for permanently sealing open or partially filled stopes, but may not be feasible in all cases. For example, if the physical stability of existing fill or new backfill cannot be assured because of the shape of the cavity, or because of unknown conditions underground, other methods of controlling access may be required. Backfilling may be possible and preferable for some vertical or steeply inclined openings, such as short vent raises of known geometry. This could only be done in situations where the extent and condition of the excavation can be determined and the stability of the backfill can be assured.

The main advantage of backfilling over other methods is that the resulting seal is usually very stable and requires no maintenance. When suitable material is available, backfilling can be less costly than other methods. A disadvantage of backfilling is that considerable effort could be required to remove the seal if underground exploration or mining were to be resumed.

Blasting can be used to collapse broken rock into a mine opening and could potentially be used to close some horizontal openings or partially filled stopes. This method could be attractive in situations where it may be unsafe to push backfill into an opening with heavy equipment. Blasting requires specialized equipment and supplies, and it can be difficult to control the results. Therefore, blasting would only be considered when other methods are considered impractical. Blasting does not appear to be necessary at any of the Silver Bear Mines.

Concrete seals are commonly used to close vertical or steeply inclined openings, such as raises and shafts, when backfilling is impractical or the stability of backfill cannot be assured. Concrete seals can be placed over or inside an opening, and are usually reinforced with steel. Several provincial jurisdictions in Canada provide detailed guidelines for the design of concrete caps. They specify that reinforced concrete caps overlying openings must be constructed directly on, or otherwise supported by sound bedrock surfaces around the opening. Where the bedrock around the opening is weak, due to heavy fracturing or weathering, a reinforced concrete bulkhead may have to be located some distance inside the opening, recessed into sound bedrock below the surface. These types of caps can be covered with soil and, since they are relatively impermeable, will normally be provided with a vent pipe to allow exchange of air between the mine workings and surface.

There are some small mine openings at the Silver Bear Mines that could be sealed effectively with steel-reinforced concrete slabs that are pre-cast on site, away from the mine opening, and then lowered into place. The slabs would be secured in place with steel pins cemented into sound bedrock surfaces around the opening. This method may be more practical and less costly than casting concrete caps in place, on uneven ground at the mine opening.

The advantage of concrete seals over other methods is that they can be designed and constructed to ensure an effective seal in the long term. In some situations, they may be more reliable and less costly than backfilling. A disadvantage of concrete seals is that they would not last indefinitely. Eventually, the reinforcing steel would corrode and the structure would lose its strength and require replacement.

6.6.3 Preferred Remedial Plan

The mine openings at all of the Silver Bear Mines will be permanently sealed with structures requiring minimal maintenance to remain stable and effective in the long term. At Terra Mine, backfilling is the preferred method for all of the horizontal openings and the open or partially filled stopes. The preferred method for the shaft and vent raises is to install cast-in-place concrete caps, or pre-cast concrete slabs. The possibility of backfilling raises (also a preferred alternative by the communities) will be assessed when final designs for the seals are prepared. In some locations at the Terra Mine, rock cuts leading to horizontal openings have steep walls and pose a hazard because they are difficult to see (Portals #3, #4 and #5). These rock cuts would also be backfilled to remove the falling hazard. The preferred methods for sealing the mine openings at each of the Silver Bear Mines are shown in Table 6.6.1.

The issues relating to mine openings at Northrim and the preferred methods for sealing them are similar to those at Terra. An exception could be the method used to seal the stope openings. The open stopes at Northrim are narrow and convoluted, and it could be difficult to ensure that backfill inside the stopes is stable. It could also be difficult or even hazardous to haul backfill on some of the steep rocky terrain. As an alternative, some of the Northrim stope openings may be sealed with pre-cast or cast in-place concrete slabs.

The only novel issue concerning mine openings at Norex is the relatively high flow of water out of the main portal (Portal #1), which is not found at any of the other sites. As discussed in Section 6.4, the use of a concrete hydraulic seal has been considered for this opening, although the preferred remediation method is to place waste rock in the portal, and allow the mine to continue to drain at this location. Large pieces of clean rock would be placed at the bottom of the backfill to ensure the plug has adequate porosity to conduct the flow, and to make the plug resistant to any stress caused by ice build-up in winter.

The Graham Vein trench presents a falling hazard to humans and animals because the opening is difficult to see. The preferred method for managing this hazard is to completely backfill the trench. The fill could include waste rock collected from the mouth of the trench or the Norex pile, but disposal of some rock from the Smallwood site in the trench is also a preferred remediation option. The need for this is discussed in Section 6.5. It may also be possible to backfill some decontaminated non-hazardous demolition waste in parts of the trench. The stability of the existing backfill at the bottom of the trench is unknown, and voids could remain in the stope underneath. To ensure the safety of equipment operators, the backfill would be pushed into the trench from the sides, and it may not be possible to compact the fill if it is unsafe to put heavy equipment on top of the fill. Acid generating rock should not be placed into any opening with flowing water. Where acid waste is placed into an opening, the rock should be covered with a low permeability soil to reduce infiltration.

Table 6.6.1 Preferred Methods for Sealing Mine Openings

Mine Site	Preferred Method	
	Backfilling	Concrete Seals
Terra	Portal #1 Portal #2 Portal #3 Portal #4 Portal #5 Open Stope #1 Open Stope #2 Open Stope #3	Shaft #1 Vent Raise #1 Vent Raise #2 Vent Raise #3 Vent Raise #4 Vent Raise #5
Northrim	Portal #1 Portal #2 Portal #3 Open stopes?	Vent Raise #1 Vent Raise #2 Vent Raise #3 Vent Raise #4 Vent Raise #5
Norex	Portal #1 Portal #2	Vent Raise #1 Vent Raise #2 Vent Raise #3
Graham Vein	Trench / open pit	
Smallwood	Portal #1 Portal #2	Vent Raise #1 Vent Raise #2 Vent Raise #3 Vent Raise #4

6.6.4 Monitoring and Contingencies

The condition of the seals on mine openings will be monitored with periodic visual inspections in the long term. The monitoring plans are described in Section 7. Any significant performance concerns identified by monitoring will be addressed with maintenance or replacement of the seal.

6.7 Buildings and Equipment

6.7.1 Key Issues

Key issues for remediation of the buildings and equipment at each of the mines are the risks of physical injury to humans and animals, and the risks of exposure to hazardous materials located inside the buildings or stored outside. Potential releases of contaminants from hazardous materials to the terrestrial and aquatic environments are also a key concern.

6.7.2 Demolition and Disposal of Non-Hazardous Waste

The primary concern in considering remedial action for buildings and equipment is the safety of people who may visit the sites, and INAC intends to eliminate risks to future site users whenever possible, and minimize any residual risks. For this reason, it is proposed that *all* buildings would be demolished and the waste materials would be disposed of in a manner that minimizes risks to people and the environment.

The first step of the remedial work would be the removal of hazardous building materials, and hazardous materials stored in the buildings. Most of the hazardous materials can be removed from the buildings before demolition takes place. Hazardous materials to be removed from buildings include asbestos containing materials, lead-amended paints, some PCB containing paints, some PCB containing light ballasts, mineral concentrate, reagent residues, and hydrocarbon products. Hazardous materials would be disposed of both on-site and off-site according to a detailed plan to be prepared specifically for this project (described in Section 6.7.3). Careful decontamination of the non-hazardous materials and equipment will minimize safety and environmental concerns for the demolition and waste disposal process. In some situations, it may be more efficient to leave hazardous materials in place during the demolition process. These could include some of the lead-amended paints on process equipment, and mineral concentrate or reagent residues contained in tanks.

The buildings would be demolished and any materials or equipment containing hazardous materials would be separated from the debris for decontamination. Clean wood and paper products would be separated from the other waste and burned. Burning wastes that could rot and decompose in a landfill would make it less prone to settlement, and reduce the size of the landfill.

It should be noted that sensitive bird species are present in the area. Recommendations are provided in Joachim Obst, 2006 regarding demolition timelines to minimize potential impacts to sensitive species.

Quantities of Non-Hazardous Wastes

The estimated quantities of non-hazardous waste as shown in Table 6.7.1 is about 27,000 m^3.

Table 6.7.1 Estimated Quantities Non-Hazardous Waste

Source	Estimated Quantity m^3
Demolition debris	
• Terra	16,250
• Northrim	750
• Norex	950
• Smallwood	150
• Subtotal	18,100
Terra Waste disposal sites (approx)	6,750
Miscellaneous refuse/scrap (assume)	2,000
Total	26,850

Disposal of Non-hazardous Waste at Terra Mine

EBA in SD F undertook a geotechnical assessment of potential sites for locating a non-hazardous landfill site. Based upon this geotechnical review, two alternatives have been considered for the location of a non-hazardous waste landfill at Terra Mine. Both sites have sufficient capacity to dispose of the waste generated at Terra, as well as all of the other Silver Bear Mines, if that option is chosen. The landfill location options are:

- Landfill in the open pit; and,
- Landfill on waste rock near Ho Hum Lake TCA.

The non-hazardous landfill options are described in the following sections. The pros and cons of each option are summarized in Table 6.7.2. The existing waste disposal sites are non-engineered and not located in areas suitable for long term waste storage. As such, these areas were not considered suitable for the future on-site landfill.

Landfill in the Open Pit

A landfill in the open pit would be constructed on the east side of the pit, away from the backfilled and partially backfilled stopes on the west side of the pit. These areas would be avoided in case of instability in the stope backfill, which could pose a safety risk to workers constructing the landfill, or cause subsidence in the landfill and exposure of the waste. The landfill would be constructed against the sloping bedrock walls on the south side of the pit, the waste rock pile in the southeast corner, and the natural cliff on the east side of the pit. Some of the waste rock in the pit would be used in the construction of the landfill. The location of the landfill is shown in Figure 6.7.1.

The landfill would lie directly above Portal #4 in the bottom of the pit. Before any waste material is deposited, a layer of coarse rock would be placed in a drainage zone leading up to the adit. The drainage zone would allow the small volumes of water that drain from the adit to flow out of the landfill area, underneath the waste. The waste would be placed and compacted in lifts of about two metres. Intermediate layers of waste rock would be placed and graded over each lift of waste to fill in the voids. These layers could be up to half a metre thick after grading. The intermediate layers of rock would provide a traffic surface and make the waste deposit physically more stable. The waste at the top of the landfill would be covered with a layer of rock thick enough to ensure that waste would not become exposed in the future as a result of settlement. A cover thickness of one metre would be adequate to achieve this objective. A final cover of local till borrow would be applied and vegetated to minimize infiltration and stabilize the surface.

The main advantage of the open pit as a landfill site is that the amount of runoff to the landfill area would be limited because the catchment area is small. Drainage from the landfill area could also be monitored relatively easily. The landfill would also fill part of the pit void and this may be considered an aesthetic advantage of this option. The main disadvantage is the distance over which material would have to be hauled from the primary demolition site, the mill complex (about 700 metres).

Landfill on Waste Rock near Ho Hum Lake TCA

A landfill near Ho Hum Lake TCA could be constructed above a storage yard just west of the main mine entrance (Portal #1). The storage yard sits on a base of waste rock. The location of the landfill is shown in Figure 6.7.1. The waste would be placed and compacted in lifts of about two metres. Intermediate layers of waste rock would be placed and graded over each lift of waste to fill the voids. These layers could be up to half a metre thick after grading. The intermediate layers of waste rock would provide a traffic surface and make the waste deposit physically more stable. The waste at the top of the landfill would be covered with a layer of waste rock thick enough to ensure that waste would not become exposed in the future as a result of settlement. A cover thickness of one metre should be adequate to achieve this objective.

The advantages of the landfill site beside Ho Hum Lake TCA are that it is close to the primary demolition site (about 250 metres) and it is located in an area that had already been used for tailings and waste rock disposal, which will be monitored closely in the long term. The natural slope above this landfill site would produce slightly more runoff than the pit site because the slope is steeper, although the catchment area is also small. Drainage from the landfill would be more difficult to monitor than at the open pit site because the waste will be underlain by porous broken rock, although groundwater wells could be installed through the waste rock at the toe of the landfill to collect water from the natural soil slope underneath.

Table 6.7.2 Potential Alternative Locations for a Non-Hazardous Waste Landfill at Terra Mine

Alternative Location	Advantages	Disadvantages
Landfill in open pit	Limited runoff to landfill area Easier monitoring of drainage from landfill	Longer waste hauling distance
Landfill on waste rock near Ho Hum Lake TCA	Limited runoff to landfill area Shorter waste hauling distance Located in existing tailings and waste rock disposal area	More difficult monitoring of drainage from landfill Possible aesthetic disadvantage

6.7.3 Preferred Non-hazardous Waste Landfill Location

The advantages and disadvantages of the two locations do not indicate a clearly better location. Based upon preliminary discussions with members of the local communities, the use of the pit was preferred as this area is already disturbed and requires reclamation to return the site to conditions similar to the pre-mining landform.

The potential need for additional non-hazardous waste landfills at the other mine sites will depend on the logistics involved in moving the waste to Terra Mine. A single non-hazardous waste disposal site at Terra is desirable, but may not be practical. Possible alternatives for moving waste include use of the all-weather road between Norex and Terra, after rehabilitation, use of an ice road on Rainy Lake in winter, or use of a barge on the lake in the open water season. The Graham Vein trench is also a potential site for non-hazardous waste. The existing area of exposed tailings beside Leachate Pond at Northrim is also a potential site for disposal as this area is to be capped with soil.

6.7.4 Disposal of Hazardous Waste

Hazardous materials not acceptable for on-site disposal would be disposed of off-site at facilities approved for that purpose. The primary hazardous materials that may be disposed of onsite are hydrocarbon contaminated soil/rock, asbestos containing materials, residual concentrate (unless economically valuable) and lead-amended paints with low concentrations of leachable lead.

The Government of the Northwest Territories (GNWT) has developed guidelines for the management of several hazardous waste materials regulated under the Northwest Territories Environmental Protection Act (GNWT 1998). These include asbestos containing materials, used batteries, and lead amended paints. Although the Act does not legally apply to federal lands within the territory, INAC intends to apply these guidelines to the management of waste at the Silver Bear Mines, whenever they can be practically applied at this remote site.

The estimated total volume of hydrocarbon or hydrocarbon contaminated liquid waste at all of the Silver Bear Mines is 139,000 litres. The majority of the waste meets all of the GNWT criteria for incineration (57%). About 35% of the waste exceeds at least one of the criteria for metals, typically the lead criterion. The remaining 8% of the inventory is primarily hydrocarbon products mixed with water. Due to the remoteness of the site, and the safety and environmental risks involved with transporting waste for disposal elsewhere, almost all of the hydrocarbon wastes will be incinerated on site. The oil and water mixtures will be treated on site to separate a burnable hydrocarbon product from a waste water product. The waste water will be treated to produce clean water that can be discharged on site. The water treatment typically involves a gravity separation process followed by filtration through absorbent media and activated carbon. The treated water could be discharged directly to a water body such as Ho Hum Lake TCA, or discharged onto vegetated land to provide additional natural treatment before reaching a water body.

The GNWT waste oil incineration criteria are intended to provide a high standard of environmental protection for population and industrial centres where large quantities of used oil would be generated continuously over extended periods. There would be no significant environmental effects caused by incinerating the relatively small amount of used oil above the GNWT criteria at the Silver Bear Mines. In contrast, transporting the waste to an alternative disposal site in Alberta would involve the real risks of traffic accidents and spills. Filtration technologies may be effective in removing lead from waste hydrocarbons before incineration and these treatment methods will be assessed for possible use at Silver Bear. Some small quantities of highly contaminated or untreatable hydrocarbon waste may be disposed of off-site.

Drums used to store hydrocarbon wastes will be thoroughly decontaminated by washing and steam cleaning, so that they can be crushed and disposed of as non-hazardous waste. Contaminated wash water from the process will be treated with the same system used to treat the oil and water mixtures. The clean treated water could be discharged directly to a water body or onto land.

Most of the liquid hydrocarbon wastes are located at Terra Mine (approximately 960 drums) and this would be the primary incineration site. Approximately 100 drums of liquid hydrocarbon wastes are located at Northrim Mine, and a further 35 drums are located at Norex and Smallwood Mines. The preferred approach would be to transport these drums for disposal at Terra, either by barge or winter ice road on Rainy Lake. Alternatively, an incinerator could be transported to the other sites for this purpose.

Asbestos containing materials would be disposed of on-site in a secure landfill. The secure landfill would also be used for the disposal of lead-amended paints with low leachable-lead content, either stripped from building and equipment surfaces, or as small pieces or shredded pieces of painted equipment. Mineral concentrates would be transported off-site only if their value makes this cost-effective, or otherwise they would also be disposed of in the secure landfill. The landfill would include an under-liner of low-permeability compacted fine-grained soil and a synthetic geomembrane, and a cover of compacted fine-grained soil and geomembrane. The cover liner would be keyed into native soil on the hillside, and shallow runoff diversion ditches would be excavated upslope to minimize runoff onto the landfill.

The potential location proposed for the secure landfill is on the east side of the mill complex, as shown in Figure 6.7.1. This site was selected because it was within the impacted Ho Hum Lake TCA watershed and contained deposits of low permeability soils. A conceptual design for the landfill is described in EBA 2006a and is shown in Figure 6.7.2.

Due to significant upfront costs and long term monitoring and care and maintenance requirements INAC is looking into all options for a secure landfill site in the Great Bear Lake Area as there are four other sites that have hazardous materials in the nearby area. The costs, health and safety and possible environmental occurrences will be assessed prior to confirming that a hazardous landfill will be constructed on site or on a nearby site.

The secure landfill at the Terra site would be the only location in the area where hazardous materials are stored. Hazardous materials removed from buildings and equipment at Northrim, Norex and Smallwood that are suitable for on-site disposal would be transported to the Terra secure landfill.

6.7.5 Monitoring and Contingencies

The water quality of lakes downstream of all waste disposal sites will be monitored in the long term. Additional monitoring facilities, including runoff collection systems and groundwater wells, may also be installed depending on the selected locations and final designs for the landfills. If the monitoring results indicate potential releases of contaminants from the landfills with potential effects on the quality of receiving water bodies, targeted investigations would be implemented in an attempt to determine the location and cause of the releases.

Careful decontamination of non-hazardous materials will make contaminant releases with significant environmental effects from the non-hazardous landfill very unlikely. Rigorous documentation of the decontamination work will provide confidence in the estimation of very low risk. In the very unlikely event that significant quantities of contaminants are released from the non-hazardous landfill, the remedial actions could include covering the landfill with a low-permeability cover, installing upstream runoff control facilities, or excavating part of the waste to be contained in a new landfill.

The potential for significant contaminant releases from the hazardous waste landfill are also unlikely if it is carefully designed and constructed. In the unlikely event that monitoring indicates problems with the landfill, remedial actions could include repairing or supplementing the low-permeability cover, repairing or supplementing the upstream runoff control facilities, or excavating part or all of the waste to be contained in a new landfill.

6.8 Roads

6.8.1 Key Issues

The key remediation issue associated with the roads is the potential for runoff to erode the construction material and cause sediment release to water bodies. Significant erosion has been noted at several locations on the road between the Terra and Norex Mines, and may have resulted in historical releases of sediment to Rainy Lake on the Camsell River.

6.8.2 Potential Remedial Methods

The remediation proposed for other site components will require that most of the site roads remain safe and at least passable for heavy equipment and pick-up trucks until the work is complete. Some roads may require upgrading to implement the remediation. For example, the roads needed to haul construction rock and demolition waste to the new non-hazardous waste landfill at Terra may require improvements to ensure the work is safe and efficient. The upgrading could include building up and levelling the road base, as well as re-surfacing with crushed rock.

The road between Terra and Norex may also be needed while the remediation work is in progress. The potential use of the road will be determined by the remediation contractor and INAC, based on logistical issues and the cost of repairs. Possible alternatives to the use of the all-weather road are a winter ice-road on Rainy Lake, or use of a barge on the lake in the open water season. Engineering recommendations for repairs to the all-weather road are provided in EBA 2006a. A representative of Fisheries and Oceans Canada inspected the road in August 2006, and provided further recommendations for rehabilitating and decommissioning the road (DFO 2007).

When remediation work requiring use of the roads by light trucks or heavy equipment has been completed, the roads will be permanently decommissioned. The options considered for reclamation of the roads were:

Leave to naturally vegetate:

- Remove culverts and leave to naturally vegetate;
- Scarify roads, remove culverts and reclaim former stream banks and leave to naturally vegetate; and,
- Scarify roads, remove culverts, reclaim stream banks and vegetate.

The alternatives were reviewed with the local communities and the preferred option was to remove the culverts and leave roads to naturally vegetate. The rationale for the selection included:

- the roads were not a hazard to animals and additional grading was not necessary;
- the roads were being reclaimed by natural vegetation and many of the roads were providing habitat and browse for animals; and,
- The primary concern was restoration of the former drainage by culvert removal.

6.8.3 Proposed Remedial Plan

The preferred remedial alternative was to remove culverts and allow roads to vegetate naturally. This will involve excavating the road embankments at all significant drainage crossings, so that culverts can be removed and runoff can flow over the ground surface without risk of eroding road materials. The road fill will be pulled back from the drainage path at a shallow slope on either side, forming a wide drainage swale. Any fine-grained material left in the excavated swales will be covered with riprap (coarse rock) to prevent erosion. Swales will be constructed at each of the eight drainage crossings on the road between Terra and Norex, identified in Figure 3.2.10, and any other locations where there is a risk of erosion leading to sediment release to water bodies. The recommendations provided by Fisheries and Oceans Canada for decommissioning will be implemented and all water courses potentially used by fish will be protected and rehabilitated, as necessary.

6.9 Airstrips

6.9.1 Key Issues

The concerns associated with decommissioning of the airstrip at Terra Mine are limited. There is some potential for runoff to erode airstrip construction material and possibly release sediment to Moose Bay. This issue will require further evaluation while the remediation of other site components is in progress. A concern relating to the current state of the airstrip is that it may pose health and safety risks to people driving on it, because of the undulating surface and generation of airborne dust by vehicle traffic.

6.9.2 Potential Remedial Methods

Similar to the site roads, the airstrip will play a key role in the site remediation. Most of the heavy equipment, fuel, and other bulk supplies required for the remediation will be brought to the site either on trucks in the winter or by barge in the open water season. Other equipment, supplies and workers will be mobilized by air. Float and ski planes cannot do this efficiently, so the Terra airstrip will have to be repaired to allow larger wheeled planes to service the site.

When the airstrip is no longer required to support remediation work the site can be reclaimed. Options for reclamation include:

- Closure as per Transport Canada requirements;
- Removal or disabling of the runway; and,
- Covering of the runway to limit infiltration and potential future leaching.

The Transport Canada guidelines for abandonment of aerodromes include removal of any markings indicating an active runway (i.e. beacons and wind socks) and listing the aerodrome in the Canada

Flight Supplement as closed and unserviceable. The normal requirement to maintain large, white "X" markings on the runway surface is typically waived for remote northern sites such as this.

As an alternative, the runway could be disabled to assure that it could not be used in future. Although this is a possible alternative, the runway is currently being used by several parties and its presence as is provides a valuable resource to servicing the area and for use as an emergency landing area, and implementation of such measures are not acceptable.

There remains a concern that leaching of waste rock in the runway could impact on Moose Bay water quality. Based upon monitoring data for Moose Bay at station T-10, levels measured in the bay by the airport are similar to background levels.

There no apparent concerns with the remains of the Smallwood Mine airstrip and no remediation is proposed. The airstrip was constructed with re-graded local soils, rather than mine waste rock, and the site is becoming vegetated naturally.

6.9.3 Proposed Remedial Plan

The community have reviewed the reclamation alternatives for the airport and preferred to have the Terra airport landing strip closed per Transport Canada requirements. This option has been selected for the RAP.

6.10 Old Waste Disposal Sites

6.10.1 Key Issues

The key issues associated with the historical waste disposal sites are the potential for injury to people or animals caused by exposed debris, and the potential for release of contaminants from any waste containing leachable toxic metals, or hydrocarbons.

Currently, the only concerns relating to contaminant release are associated with Waste Disposal Site #3 at Terra Mine (see Figure 3.2.11), where there is evidence from water sampling of releases of iron, copper and some arsenic, although the specific source locations are unknown. These loadings result in concentrations of iron and copper above the CCME-FAL guideline values in the pool to the west of the landfill, which is connected to Jackfish Bay and probably used by fish. The water quality may not present a real risk to fish, but some simple remediation measures could be taken to reduce the contaminant release.

6.10.2 Potential Remedial Methods

The first remedial action for the old landfills would be to collect exposed waste and dispose of it along with waste from the decontamination and demolition of buildings. Any hazardous materials recovered would be separated and disposed of either on-site or off-site, in accordance with the project-specific plan for these materials. Hydrocarbon contaminated soils would be excavated and remediated, or contained, along with the other hydrocarbon contaminated soils on the site. Decontaminated non-hazardous materials would be disposed of in the proposed on-site landfill for these materials.

The residual buried waste could be reclaimed by:

- Leaving in place and monitoring;
- Excavation and removal to the on-site landfills; and,
- Cover with low permeability soil.

Low-permeability covers would include a layer of low-permeability material, such as compacted fine-grained soil or a synthetic membrane. The low permeability layer would be protected with a layer of waste rock or soil. Low-permeability covers would reduce infiltration from precipitation that lands on the waste area, but may not be effective in preventing sub-surface water flow through the waste. These covers have the disadvantage of requiring borrow soil in varying qualities for the different cover designs, which would create a new disturbance at the borrow area.

The local community have reviewed the plans and prefer to have the sites cleaned up followed by excavation and removal of the waste to the new on-site hazardous or non-hazardous landfill.

6.10.3 Preferred Remedial Plan

Exposed and partially buried waste will be recovered from all of the disposal sites to be disposed of appropriately with other site waste. The remaining waste would also be excavated and the waste would be disposed of appropriately. The excavation would be backfilled with either clean waste rock or local borrow material.

6.10.4 Monitoring and Contingencies

No further monitoring is proposed as the sites will be relocated.

6.11 Docks

6.11.1 Key Issues

The key issue associated with the physical condition of the docks is the potential for collapse of the wooden retaining walls and subsequent release of fill material and sediment into the Camsell River. Concerns relating to hydrocarbon contamination of the fill are considered in Section 6.12.

6.11.2 Potential Remedial Methods

The remedial options considered for the docks include:

- Remove hazards and leave as is to naturally degrade;
- Remove hazards and support the dock with coarse fill; and,
- Remove dock and stabilize shoreline.

The methods of dock construction, condition of the retaining walls, and river bathymetry in the dock areas, will all affect the selection of remediation methods for the docks.

For all options exposed hazards (steel rods etc.) would be removed.

For removal of the docks, the docks would be excavated to the original shoreline and the new shoreline stabilized with rock fill. Hydrocarbon contaminated fill would be remediated along with other contaminated soils excavated on site. Steel and other waste material would be disposed in the on-site landfills. The excavation would be inundated with water from the river and rigorous methods would be necessary to prevent releases of sediment or hydrocarbons to the river. These would include silt curtains, and oil absorbent booms and curtains.

An alternative approach would be to permanently support the dock fill from the river bed by placing additional coarse rock fill outside the retaining wall. This could be practical in relatively shallow waters. It would be preferable to avoid placing new fill on the river bed, but the disruption to fish habitat would be less than may be caused by a complete collapse of the dock. Buttressing the dock fill from the river bed could be the best approach in some circumstances. For example, if the amount of fine-grained fill or hydrocarbon contamination of the fill made it difficult to prevent releases of sediment or hydrocarbons to the river.

The two dock remediation methods are shown conceptually in Figure 6.11.1.

Based upon discussions with the communities, the preferred remedial plan is to remove the docks.

6.11.3 Preferred Remedial Plan

An adaptive approach to the remediation of docks will be necessary at all of the Silver Bear Mines. As indicated, the preferred method is to remove the dock structures and stabilize shoreline. Further excavation is required to assess the sub-surface conditions and full extent of hydrocarbon contamination, which has only been possible at shallow depths to date.

Removing the dock fill if necessary is the preferred remediation approach at Northrim if it can be practically applied. However, test excavations are required to demonstrate the feasibility of this method, and a definitive remediation plan for the dock cannot be proposed with the existing information.

Remediation of the Northrim dock is complicated by several factors, including the fact that the dock is partly submerged when river levels are high, there is a relatively large amount of fine-grained material in the dock fill, and the extent of hydrocarbon contamination of the dock fill is greater than found at Terra. Even if standard methods of fugitive sediment and hydrocarbon control are carefully implemented, it may be very difficult to excavate the dock fill without releasing sediment and hydrocarbon contaminants to the river. Therefore, leaving the dock fill in place and buttressing it by placing coarse rock on the outside of the retaining wall would be considered as an acceptable alternative if removal proves to cause too much disturbance to the river. The latter would be assessed during the reclamation program.

If the best remediation of the docks requires placing new fill material in the river, an Authorization under the Fisheries Act would be sought from Fisheries and Oceans Canada for the proposed work.

6.12 Hydrocarbon Contamination

6.12.1 Key Issues

The key issue associated with hydrocarbon contaminated soils and fills at the Silver Bear Mines is the potential for ecological effects, either through direct contact between soils and terrestrial animals or birds, or effects on aquatic species if the contaminants reach water bodies in significant quantities.

6.12.2 Potential Remedial Methods

The variety of contaminants and ground conditions at the mine sites could require a variety of remediation methods. Potentially applicable methods and technologies are discussed in detail in EBA 2006b. Four general approaches have been considered for the contaminated soils and fills, which are:

- Excavate, relocate and bio-remediate (*ex-situ* remediation);
- Leave in place and bio-remediate or chemically oxidize (*in-situ* remediation);
- Excavate, relocate and contain; and,
- Leave in place and monitor.

For the lighter-fraction hydrocarbons in the F1 and F2 categories, typically found in areas where fuel was stored and handled, one of the cost effective remediation methods would be excavation and *ex-situ* bio-remediation on-site. This could be done with traditional "land-farming" techniques in a large flat area prepared to contain contaminated drainage, or a more intensive approach in a smaller space using bio-piles, with controlled supply of nutrients, water and air. The problem with bio-remediation is that this would require a very large on site storage area (perhaps for 25,000 m^3) and 5 or more years of active care and monitoring before the soil would be deemed acceptable for disposal. In addition, much of the contaminated material is waste rock, which is not well suited to bio-remediation. Issues include potential development of temporary permafrost which could last well into the active bio-remediation months and lack of moisture retention which is essential for biological activity.

In-situ remediation, including bio-remediation with soil amendments (nutrients, water or air), or more aggressive chemical oxidation (permanganate, or hydrogen peroxide), could be used in areas where excavation may risk increasing the release of contaminants to surface water or groundwater, particularly in areas close to water bodies, with a high water table. Chemical oxidation is particularly applicable to the treatment of higher molecular weight hydrocarbons in soils (F3 category). Chemical oxidants could be added to the soil through wells, or trenches upstream of the contaminated area.

Relocation and containment of some contaminated soils and fills in an area distant from valued ecosystem components has been considered. This approach is particularly appropriate for heavier-fraction contaminants which are resistant to bio-remediation but also slow to migrate. The slow migration would provide sufficient time for natural attenuation of the contaminants. A new containment area would be selected for its distant location from water bodies and limited runoff, and the waste material would be covered with a layer of compacted fine-grained soil to reduce infiltration.

Some of the contaminated areas with higher molecular weight hydrocarbons (F3 and F4 categories) located distant from water bodies and designated as "low priority" could be left in place and monitored. Natural attenuation would slowly reduce the risk of environmental effects. Covers could be applied to eliminate potential exposure to animals and reduce the infiltration into the contaminated waste rock and soil.

Another option is to relocate all hydrocarbon waste that cannot be managed *in-situ* to a disposal cell within the hazardous waste disposal area. This would allow the hydrocarbon contaminated waste to be contained to prevent any future release to the environment.

6.12.3 Preferred Remedial Plan

Preferred remediation methods have been tentatively selected for each of the contaminated areas identified on each of the mine sites. The preferred methods are shown in Table 6.12.1.

The preferred remediation method for the majority of the areas and greatest volume of contaminated materials is to cover the contaminated area with 0.5 m of till and to monitor the site to assure future off-site migration is not occurring. The cover will also eliminate direct exposure to the hydrocarbon contaminated waste rock and soil and will minimize infiltration and hydrocarbon runoff from these areas. The total estimated quantity of contaminated soil and waste rock to be left in place is about 27,500 m^3. At 0.5 m of cover, about 13,750 m^3 of till borrow would be required.

The second remedial option selected is to relocate contaminated soils which are not amenable to in-place monitoring and dispose of these soils within a dedicated cell in the hazardous waste disposal area. The estimated quantity of soil to be relocated is about 3,500 m^3.

Table 6.12.1 Remediation Methods for Hydrocarbon Contaminated Waste and Fills

Site	Code	Description	Types	Estimated Volume (m^3)	Remediation Options	Preferred Option
Terra	A	Main tank farm	F2, F3, some BTEX and F1	6,000	EX-R, IN-M	IN-M
Terra	B	Tank farm (large tank)	BTEX, F1, F2, F3	100	EX-R, IN-M	IN-M
Terra	C	Tank farm	BTEX, F1, F2, F3		EX-R, IN-M	IN-M
Terra	D	Dock tank farm	BTEX, F1, F2, F3	100	EX-R, IN-R	EX-C
Terra	E	Former kitchen area	F2	50	EX-R	EX-C
Terra	F	Drum storage area	F2, F3	500	EX-R	EX-C
Terra	G	Above ground storage tank	F2, F3	500	EX-R	EX-C
Terra	H	Garage	F3	50	IN-M, EX-C	IN-M
Terra	I	Mill/drum storage/machine shop	BTEX, F1, F2, F3	6,500	EX-R, IN-R, IN-M	IN-M
Terra	J	Mine adit	F2, F3	100	EX-R	EX-C
Terra	K	Drum storage	F3	2,000	EX-C, IN-M	IN-M
Terra	L	Above ground tanks	F2, F3, F4	1,500	EX-R, EX-C, IN-M	IN-M
Terra	M	Drum storage	F2, F3	50	EX-R, IN-M	IN-M
Terra	N	Drum storage	F3, F4	50	IN-M	IN-M
Terra	O	End of airstrip	F3, some F2	3,000	IN-M	IN-M
Terra	P	Waste rock	F2, F3	100	EX-R	EX-C
Northrim	A	Tank farm/drum storage	F2	1,000	EX-R	EX-C
Northrim	B	Southwest of tank farm	BTEX, F1, F2	100	EX-R	EX-C
Northrim	C	Drum storage	F3	2,500	IN-M, EX-C	IN-M
Northrim	D	Smelter building	F2, F3	200	EX-R	EX-C
Northrim	E	Smelter building shore	F1, F2	100	EX-R	EX-C
Northrim	F	Dock and adits	F2, F3	1,600	IN-R, IN-M, EX-R	IN-M ,EX-C
Northrim	G	Landfill	F2	200	EX-R, IN-M	IN-M
Northrim	H	Leachate Pond	F1, F2	200	EX-R, IN-M	IN-M
Norex	A	Tank farm/mine adit	F2, F3	1,500	IN-M, EX-C, EX-R	IN-M
Norex	B	Machine shop	BTEX, F1, F2, F3	100	EX-R	EX-C
Norex	C	Drum disposal	F3	200	IN-M	IN-M
Norex	D	Drum storage	F3 (one F2)	1,000	IN-M	IN-M
Norex	E	Edge of Xeron Pond	F3 (one F2)	1,000	IN-M	IN-M
Norex	F	Dock area, near shore	F2, F3	100	EX-R, EX-C	EX-C
Smallwood	A	Waste rock pile	BTEX, F1, F2, F3	500	EX-R	EX-C
Smallwood	B	Waste rock pile	F2, F3	300	IN-M	IN-M
Smallwood	C	Mine adit/shop/tank farm	F2, F3	2,000	IN-M, EX-R	IN-M
Smallwood	D	Unknown disposal	F2, F3	1,000	IN-M, EX-R	IN-M

Notes:

Remediation methods are ex-situ remediation (EX-R); in-situ remediation (IN-R); excavation, relocation and containment (EX-C); and leave in place and monitor (IN-M)

Although on-site treatment and remediation could be considered for some of this contaminated soil, on-site treatment could require many years of ongoing maintenance which would in turn require the site to remain under active decommissioning and care for many years.

Further tests will be completed prior to and during remediation to finalize the feasibility of remedial plans for each area.

6.12.4 Monitoring and Contingencies

Areas in which contaminated materials are left in place, remediated *in-situ*, or areas to which contaminated materials are relocated and contained, will be monitored. The monitoring could include sampling and analysis of surface runoff, or groundwater collected from wells. The monitoring systems and monitoring locations will be determined during the implementation of remediation.

Where there remains a potential for hydrocarbon contaminant releases, water bodies immediately downstream of these areas will be monitored for hydrocarbons. Any water quality concerns with the potential for significant environmental effects would be investigated, in an attempt to determine the contaminant source. Further remedial actions could include any of the remediation methods described above.

6.13 Summary of Remedial Action Plan

The preferred remediation methods for each site component, indicated in the preceding sections, are summarized in Table 6.13.1. The selected choices focus on remedial measures, methods to reduce risks and methods preferred by the communities.

Table 6.13.1 Summary of Preferred Remedial Plan

Site Component	Terra Mine	Northrim Mine	Norex Mine	Graham Vein	Smallwood Mine
Mine Openings	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill	• Backfill trench with waste rock • Use rock from Smallwood Mine as backfill	• Backfill open stopes and horizontal openings with waste rock • Seal vertical shafts and raises with concrete caps or slabs or backfill
Waste Rock	• Improve drainage • Monitor	• Relocate waste by the River to Leachate Pond • Leave main pile as is • Monitor	• Re-direct mine drainage away from waste rock pile with open channel • Monitor	• Leave as is • Monitor	• Relocate some problematic rock to Graham Vein trench • Monitor
Tailings	• Cover exposed tailings with waste rock • Lower Ho-Hum Lake level and outlet dyke; construct spillway • Use natural wetland to reduce arsenic in Ho-Hum Lake discharge	• Cover exposed tailings with waste rock • Cover smelter process waste • Partially backfill Leachate pond and re-direct Hermandy Lake outflow	n.a.	• Leave as is • Monitor	n.a.
Buildings and Equipment	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in new landfill • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons on-site •	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in leachate pond , or new landfill • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons on-site, or at Terra Mine •	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in new landfill • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons on-site, or at Terra Mine •	• Demolish all structures • Dispose of non-hazardous waste at Graham Vein or new landfill	• Demolish all buildings • Decontaminate non-hazardous waste and dispose of in landfill at Terra Mine • Dispose of hazardous materials in secure landfill • Incinerate most waste hydrocarbons at Terra Mine •
Roads	• Construct drainage swales at major drainage crossings on haul road	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary	• Construct drainage swales, as necessary

Table 6.13.1 Continued

Site Component	Terra Mine	Northrim Mine	Norex Mine	Graham Vein	Smallwood Mine
Airstrips	• Remove any markings • Advise Transport Canada of un-maintained status				• No action necessary
Waste Disposal Sites	• General cleanup of all rubbish for disposal in New Landfill	• General cleanup of all rubbish for disposal in leachate pond or New Landfill	• General cleanup of all rubbish for disposal in New Landfill	• General cleanup of all rubbish for disposal in open trench or New Landfill	• General cleanup of all rubbish for disposal in Graham Vein open trench or New Landfill
Docks	• Remove Docks and stabilize banks • Remediate contaminated soil or fill	• Remove Docks and stabilize banks • Remediate contaminated soil or fill	• Remove Docks and stabilize banks • Remediate contaminated soil or fill		
Hydrocarbon Contamination	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the Terra hazardous landfill site	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the Terra hazardous landfill site	• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the Terra hazardous landfill site		• Cover waste rock and contaminated soils suitable to be left in place and monitor • Remove from sensitive areas for disposal in a purpose built cell in the Terra hazardous landfill site

7 Monitoring

The remedial actions outlined in Section 6 will require a commitment to monitoring, both during the implementation phase of the project, and after the remediation is complete. Specific monitoring requirements will be included under the Water Licence for the project. The following section highlights areas where monitoring is proposed.

Monitoring during implementation will include water quality monitoring within the sites and in the environment around the sites. The potential impact of the remediation work on wildlife would also be monitored. A designated health and safety officer would be on site at all times during the implementation, with the primary role of assuring and monitoring the health and safety of site workers. The monitoring could include dust monitoring, when there is any risk of airborne dust affecting site workers, gas monitoring for access closed spaces such as mine adits and any other occupational monitoring required ensuring a safe work place.

Monitoring after remediation is completed will assess the performance of the remedial measures compared with the original objectives and will allow any necessary maintenance or corrective action to be taken in a timely manner. These sites are remote and difficult to access and therefore the design and construction of the remedial measures will be intended to minimize the need for maintenance and long term monitoring.

Two types of post-remediation monitoring are necessary; performance monitoring and environmental monitoring. These are discussed in the following sections.

7.1 Performance Monitoring

Performance monitoring will be required for all of the remediation measures that require construction, including the modified outlet of Ho Hum Lake TCA, covers for exposed tailings at Terra and Northrim, the potential new dyke and outlet channel at Hermandy Lake TCA, the Norex mine drainage controls, the landfills at various sites, the stabilized docks, and the seals on mine openings. The performance of these facilities will be measured in terms of physical stability, erosion and sedimentation, and nearby surface or groundwater quality. Performance monitoring will be undertaken on an annual basis for a period of at least five years following completion of the remediation works. The monitoring will continue in the long term, but the results of monitoring in the immediate post-implementation phase will determine the frequency and scope of the longer term requirements.

The performance monitoring will include annual inspections by an appropriately qualified engineer of all civil works, including the remaining low dykes, spillways, channels, landfills and mine seals. The inspections will assess the physical stability of the structures and the performance with respect to erosion. The results of all inspections will be documented in annual reports to INAC, including any recommendations for maintenance or corrective actions.

Water quality in the area of new landfills and old waste disposal sites will be monitored. At a minimum, this would involve surface water monitoring in lakes or streams immediately downstream of the landfill close to the point where surface or sub-surface drainage would be expected to enter the water body. The landfill monitoring could also include surface or groundwater monitoring close to the disposal site, depending on the design of the landfill, the nature of materials disposed of and site conditions.

Monitoring of the effects of waste rock drainage will include water quality monitoring in the water body that would receive the drainage. In situations where the drainage would be expected follow a definable flow path, or where dilution would be expected to rapidly reduce contaminant concentrations in water, the monitoring would include lake sampling locations close to the point where the effect could be expected to occur. This approach would be applicable to the situations at Northrim, Norex and Smallwood. Groundwater monitoring within and adjacent to waste rock piles may also be continued.

7.2 Environmental Monitoring

Monitoring of environmental quality around the mine sites and at the reference sites in the area will continue in conjunction with the performance monitoring of remediation measures. Environmental monitoring will be undertaken on an annual basis during the implementation phase, and for a period of at least five years following completion of the remediation works. Surface water quality will be the primary target of the monitoring, but hydrological measurements may be included.

Environmental monitoring will continue in the longer term, but the frequency and scope of the work will be reduced.

8 Remediation Schedule

The draft plan will be submitted for screening by regulatory authorities, to determine the permits or licences that may be required to implement the plan. Assuming that agreement on the Remedial Action Plan can be achieved by the end of 2007, the following general project activities and milestones are anticipated:

2007/08: Complete final site inspections required to prepare detailed plans, engineering designs, specifications, cost estimates and contract tender documents. Begin contract tendering process. Make application for necessary permits.

2008: Award contract(s). Mobilize equipment to site, set up new camp, and begin remediation.

2010/11: Complete final remediation work. Demobilize remaining remediation equipment in 2010 or early 2011. Begin post-remediation monitoring.

9 References

AED Consulting 2007. Summary Report of a Questionnaire on Cultural Land Use, Wildlife Use and Observations in the Silver Bear Mines Area before 1970. Report to Contaminants and Remediation Directorate, INAC, January.

Canadian Council of Ministers of the Environment (CCME) 2006. *Canadian Environmental Quality Guidelines.* July. Includes updates to the original version (1999).

Canadian Council of Ministers of the Environment (CCME) 2001. *Canada-wide Standards for Petroleum Hydrocarbons (PHC) in Soil - Technical Supplement.* January.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2007. *Canadian Species at Risk.* 11 September 2007.

Contaminated Sites Management Working Group (CSMWG) 2002. *A Federal Approach to Contaminated Sites.*

Department of Fisheries and Oceans (DFO) 2007. *Access Road, Terra to Norex / Smallwood Mine Sites, Silver Bear Mines, NT.* Letter to Lisa Dyer, INAC. January 26, 2007.

EBA Engineering Consultants Ltd. 2006a. *Geotechnical Evaluation for Remediation of Silver Bear Mines.* Prepared for Indian and Northern Affairs, Yellowknife, NT, Canada. February. (Previously referred to as Supporting Document F).

EBA Engineering Consultants Ltd. 2006b. *Overburden Assessment Silver Bear Mines Northwest Territories.* Prepared for Public Works and Government Services Canada. April. (Previously referred to as Supporting Document G).

Elbow Creek 2005. *Laboratory Water Treatability Test Results, Silver Bear Mine Site, Draft Progress Report.* March 2005.

Environment and Natural Resources (ENR) 2007. *NWT Species 2006-2010. General Status Ranks of Wild Species in the Northwest Territories.* 26 February 2007. Version 2007.2. GNWT, Yellowknife, NT.
(searchable database: www.nwtwildlife.com/monitoring/speciesmonitoring/default.htm).

Environment Canada. Species at Risk website. Last updated May 8, 2006. (www.speciesatrisk.gc.ca/default_e.cfm).

Golder Associates 2006. *Drum Sampling and Product Inventory Program.* Prepared for Public Works and Government Services Canada. March. (Previously referred to as Supporting Document E2).

Government of the Northwest Territories (GNWT) 2000. *Environmental Protection Act.* "Used Oil and Waste Fuel Management Regulations (Draft)." Regulation 037. March 16, 2000.

Government of the Northwest Territories (GNWT) 1998. *Guideline for the General Management of Hazardous Waste in the NWT.* February 1998.

Indian and Northern Affairs (INAC) 2007. *Silver Bear Mines Remediation Plan – Hydrologic Monitoring Program 2006.* 28 June. (Previously referred to as Supporting Document H).

Indian and Northern Affairs (INAC) 2006a. *Mine Site Reclamation Guidelines for the Northwest Territories.*

Indian and Northern Affairs Canada (INAC) 2006b. *New Corporate Procedures Manual (Management Framework).* Northern Affairs Contaminated Sites Program.

Indian and Northern Affairs (INAC) 2006c. *Interview with 12 Elders from Gamètì*. By G. J. Lafferty, December.

Indian and Northern Affairs (INAC) 2006d. *Silver Bear Mine Sites, Northwest Territories Water Quality Monitoring Program - 2006.* Final Report. Prepared by Laurie McEachern, Water Resources Division, INAC. April. (Previously referred to as Supporting Document B2).

Indian and Northern Affairs Canada (INAC) 2005a. *Abandoned Military Site Remediation.*

Indian and Northern Affairs Canada (INAC) 2005b. *Traditional Environmental Knowledge- Silver Bear Properties, Great Bear Lake, NWT, July-August 2005*. Report to Contaminants and Remediation Directorate, INAC, for the Sahtu Land and Water Board. By J. Vandermeer.

Indian and Northern Affairs Canada (INAC) 2005c. *Silver Bear Mine Sites, Northwest Territories Water Quality Monitoring Program.* Final Report. Prepared by Laurie McEachern, Water Resources Division, INAC. February. (Previously referred to as Supporting Document B1).

Indian and Northern Affairs Canada (INAC) 2002a. *Northern Affairs Program Contaminated Sites Management Policy*. August.

Indian and Northern Affairs Canada (INAC) 2002b. *Mine Site Reclamation Policy for the Northwest Territories.*

Indian and Northern Affairs Canada (INAC) 1993. *Sahtu Dene and Metis Comprehensive Land Claim Agreement.*

Joachim Obst, AED Consulting 2007. *Summary Report of a Questionnaire on the Cultural Land Use, Wildlife Use and Observations in the Silver Bear Mines Area Before and After 1970.* Prepared for Indian and Northern Affairs Canada (INAC). January. (Previously referred to as Supporting Document N).

Joachim Obst, AED Consulting 2006. *Field Report on a Reconnaissance Survey of Birds Nesting in Abandoned Structures and Waste Sites at the Silver Bear Mines, Northwest Territories, in July 2006.* Prepared for Indian and Northern Affairs Canada (INAC). October. (Previously referred to as Supporting Document L).

Lorax Environmental Services Ltd. 2006. *Silver Bear Mines Geochemical Assessment.* Prepared for Indian and Northern Affairs (INAC). February. (Previously referred to as Supporting Document A).

Northern Environmental Consulting 2007. *Assessment of Plant Community Composition and Metal Concentrations in the Ho Hum Lake – Moose Bay Wetland at Silver Bear Mines in the NWT, in August 2006.* Draft Report. Submitted to SRK Consulting and SENES Consultants. February. (Previously referred to as Supporting Document C).

NWT Mining Heritage Society 2006. *Equipment at the Mine Sites.* August. (Previously referred to as Supporting Document O).

Rescan™ Environmental Services Ltd 2005a. *Demolition Assessment.* Prepared for Indian and Northern Affairs Canada (INAC). March. (Previously referred to as Supporting Document D).

Rescan™ Environmental Services Ltd. 2005b. *Hazardous Materials Survey.* Prepared for Indian and Northern Affairs Canada (INAC). March. (Previously referred to as Supporting Document E1).

Rescan™ Environmental Services Ltd. 2005c. *Aquatic Pre-Remediation Studies 2004.* Prepared for Indian and Northern Affairs Canada (INAC). March. (Previously referred to as Supporting Document I).

Rescan™ Environmental Services Ltd. 2005d. *Terrestrial Wildlife Assessment.* Prepared for Indian and Northern Affairs Canada (INAC). March. (Previously referred to as Supporting Document J).

Rescan™ Environmental Services Ltd. 2005e. *Vegetation Assessment.* Prepared for Indian and Northern Affairs Canada (INAC). March. (Previously referred to as Supporting Document K).

SENES Consultants Limited 2007. *Site-Specific Human Health and Ecological Risk Assessment for the Silver Bear Mines.* Final Report prepared for Public Works and Government Services Canada. September. (Previously referred to as Supporting Document M).

SENES Consultants Limited 1999. *Report on Technologies Applicable to the Management of Canadian Mine Effluents.* Report to Environment Canada.

SRK Consulting (Canada) Inc. 2006. *Assessment Processing Facilities.* (Previously referred to as Supporting Document E3).

Stottmeister, U. 2006. *Constructed Wetlands and their Performance for Treatment of Water Contaminated with Arsenic and Heavy Metals.* In: Soil and Water Pollution Monitoring, Protection and Remediation, Springer Netherlands.

Tłįchǫ Land Claim and Self-Government Agreement, August 25, 2003.

Treasury Board 2002. Treasury Board Federal Contaminated Sites Management Policy. June.

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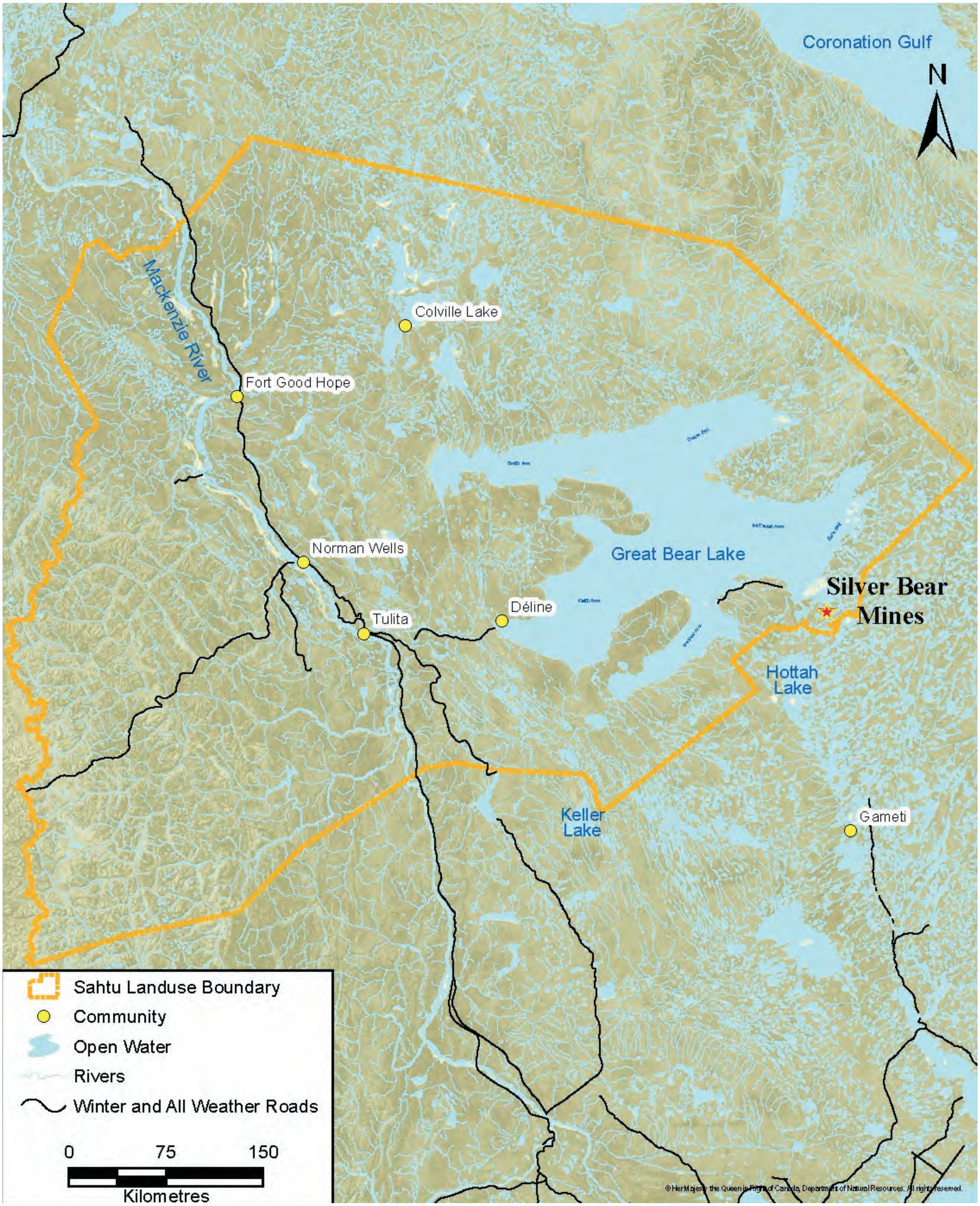
Appendix O-1

Report: Silver Bear Mines Remedial Action Plan with Project Update – PART 2

Canada

10 Figures



Note: Original figure prepared by Rescan Environmental Services Ltd., March 2005.

SRK Consulting Engineers and Scientists VANCOUVER

SENES Consultants

Indian and Northern Affairs Canada

Site Location and Access

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Filename: Figure1.1.1_SiteLocation.ppt

Silver Bear Mines Remedial Action Plan

Date:	Approved:	Figure:
Mar. 2007		1.1.1

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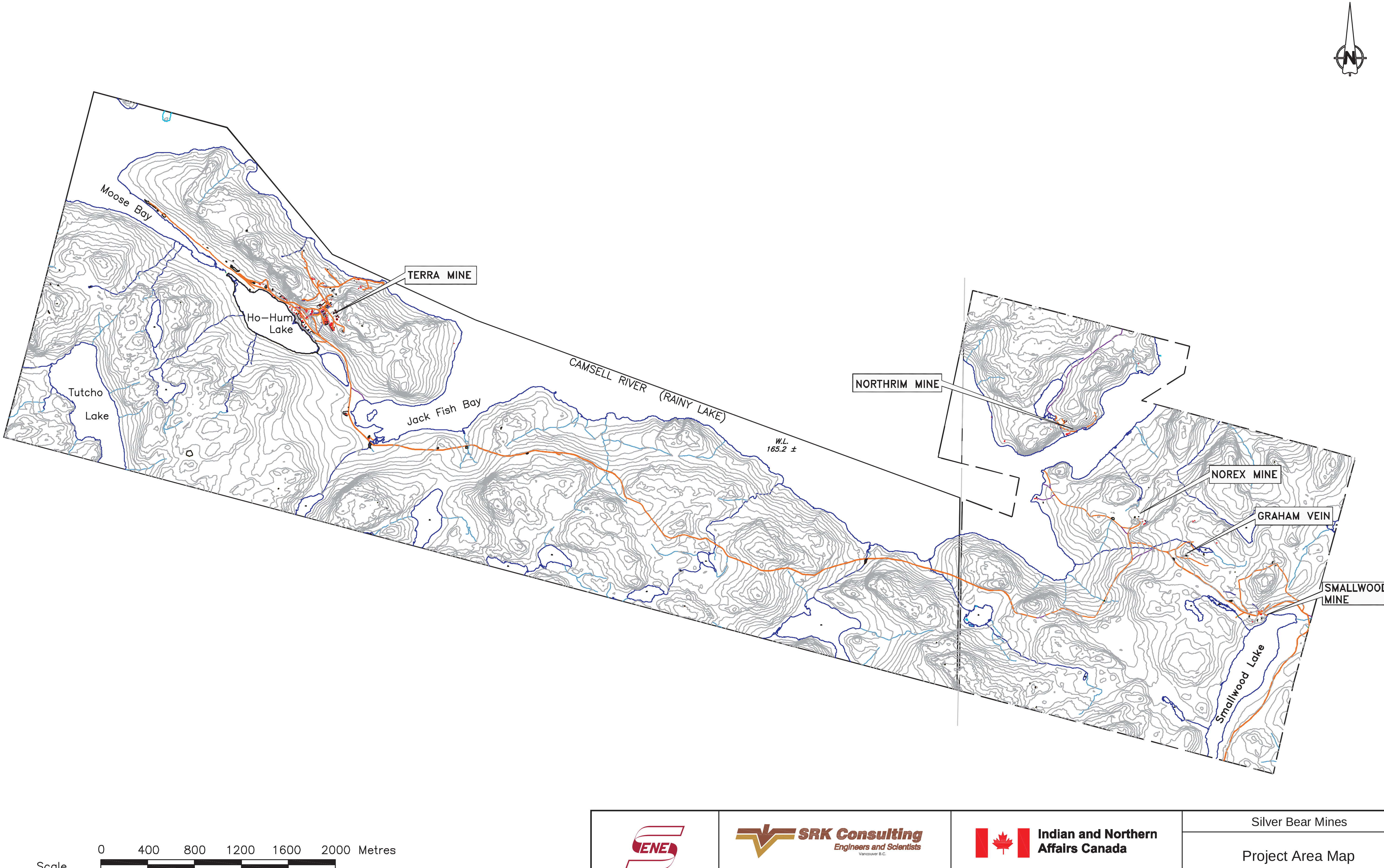
Historic Winter Road From Yellowknife

SOURCE: Mineral information Maps and Tgit Geomatics Ltd., January 2007

Silver Bear Mines Remedial Action Plan

Date:	Approved:	Figure:
Dec. 2007		1.1.2



File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.1.1.dwg

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SRK JOB NO.: 1CP001.506
FILE NAME: Figure 3.1.1.dwg

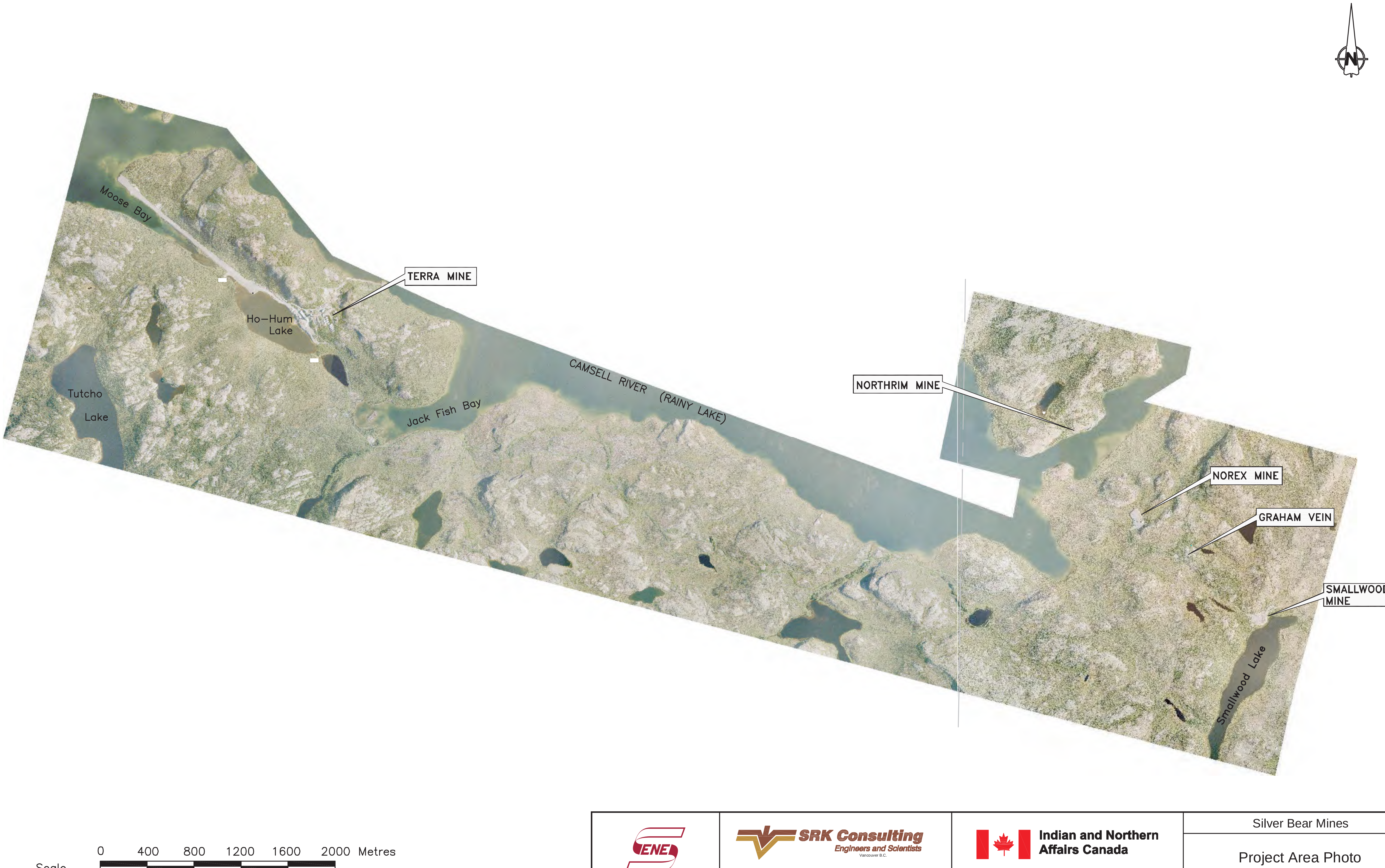
Indian and Northern Affairs Canada

SILVER BEAR MINES
REMEDIAL ACTION PLAN

Silver Bear Mines

Project Area Map

DATE:	APPROVED:	FIGURE:
Mar. 07	SRS	3.1.1



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Indian and Northern Affairs Canada

Silver Bear Mines

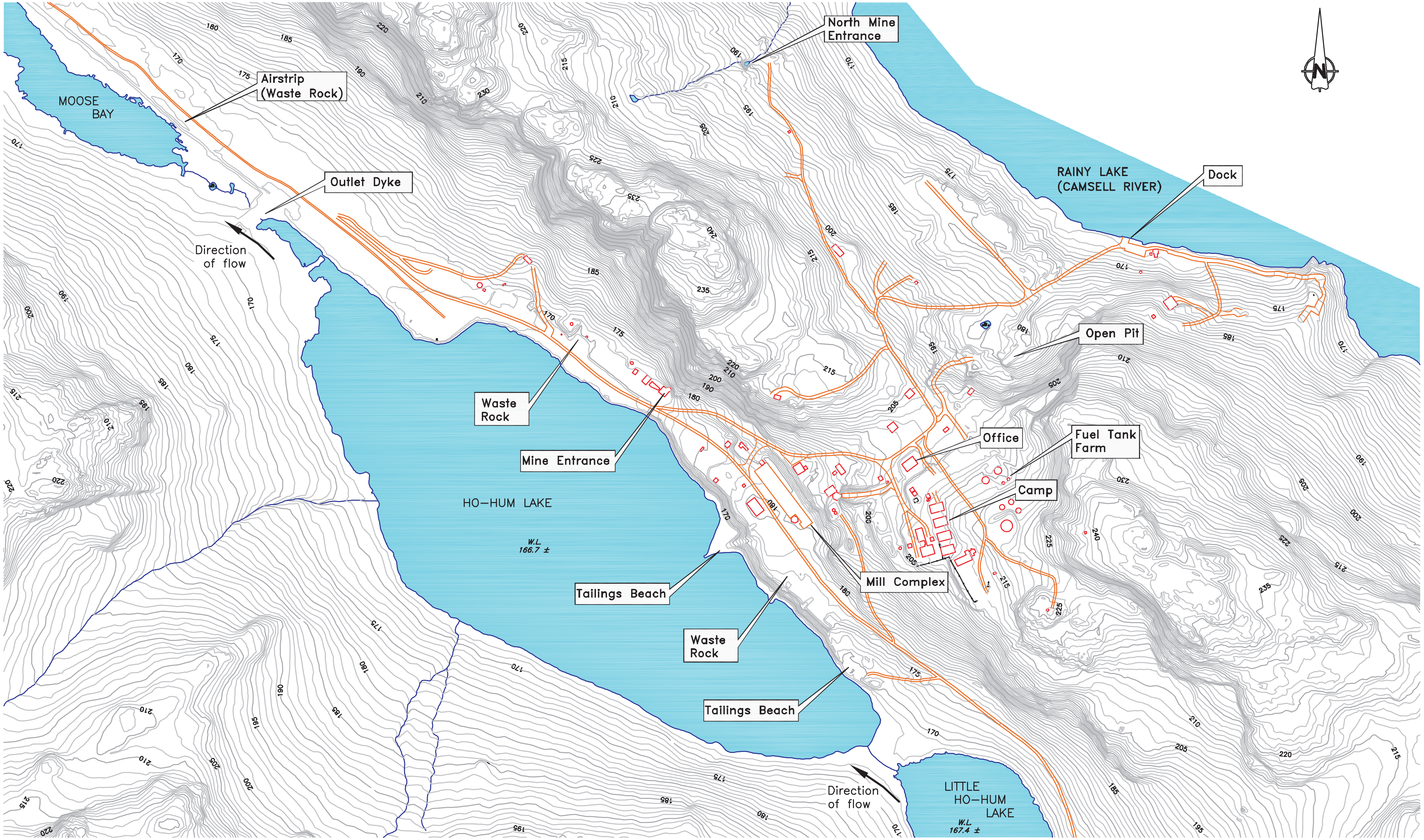
Project Area Photo

SRK JOB NO.: 1CP001.506
FILE NAME: Figure 3.1.1.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

DATE:	APPROVED:	FIGURE:
Mar. 07	SRS	3.1.2

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.1.1.dwg



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SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.2.1.dwg

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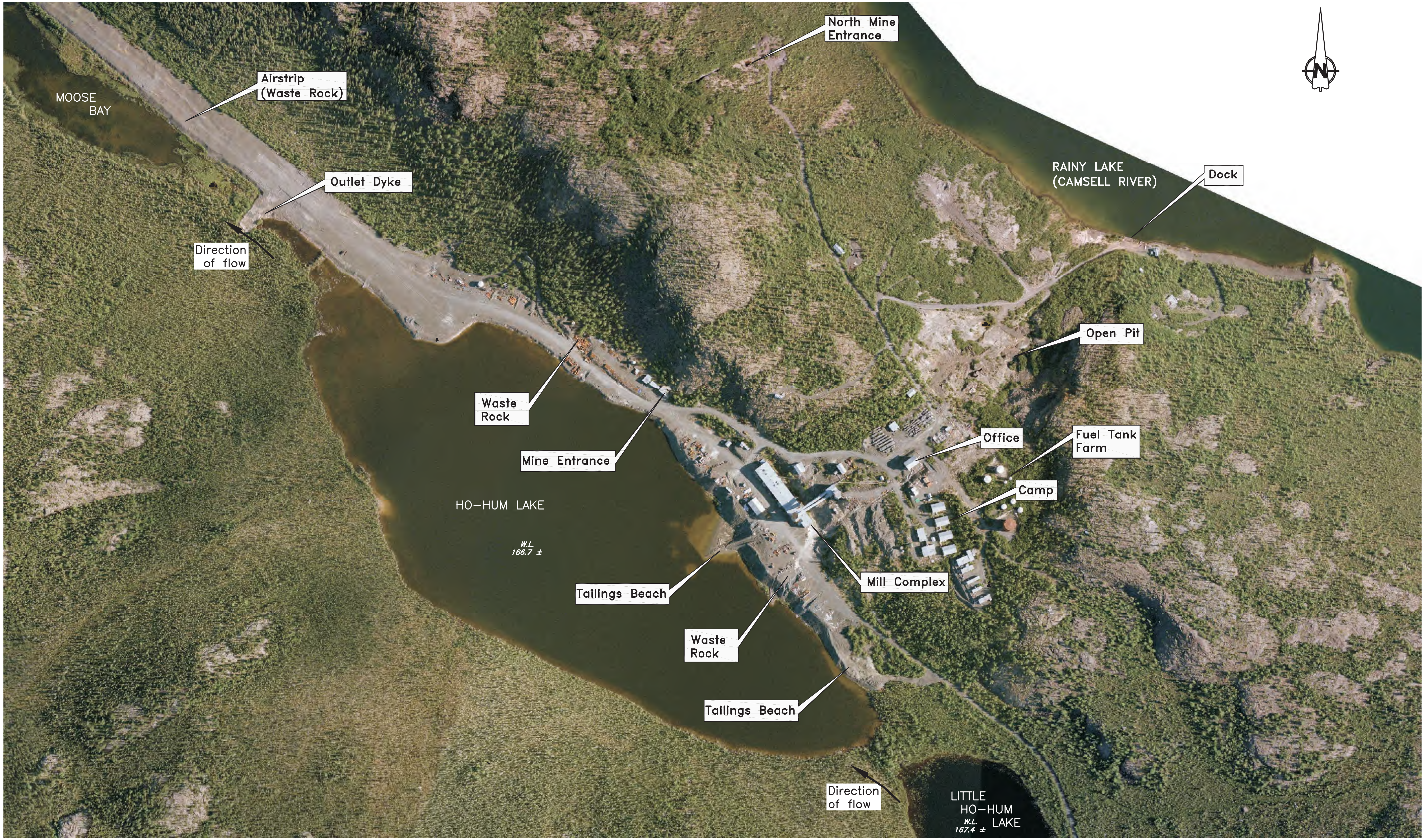
SILVER BEAR MINES
REMEDIAL ACTION PLAN

Terra Mine

Site Plan

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.2.1

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.1.dwg



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SRK JOB NO.: 1CP001.506
FILE NAME: Figure 3.2.1.dwg

Indian and Northern Affairs Canada

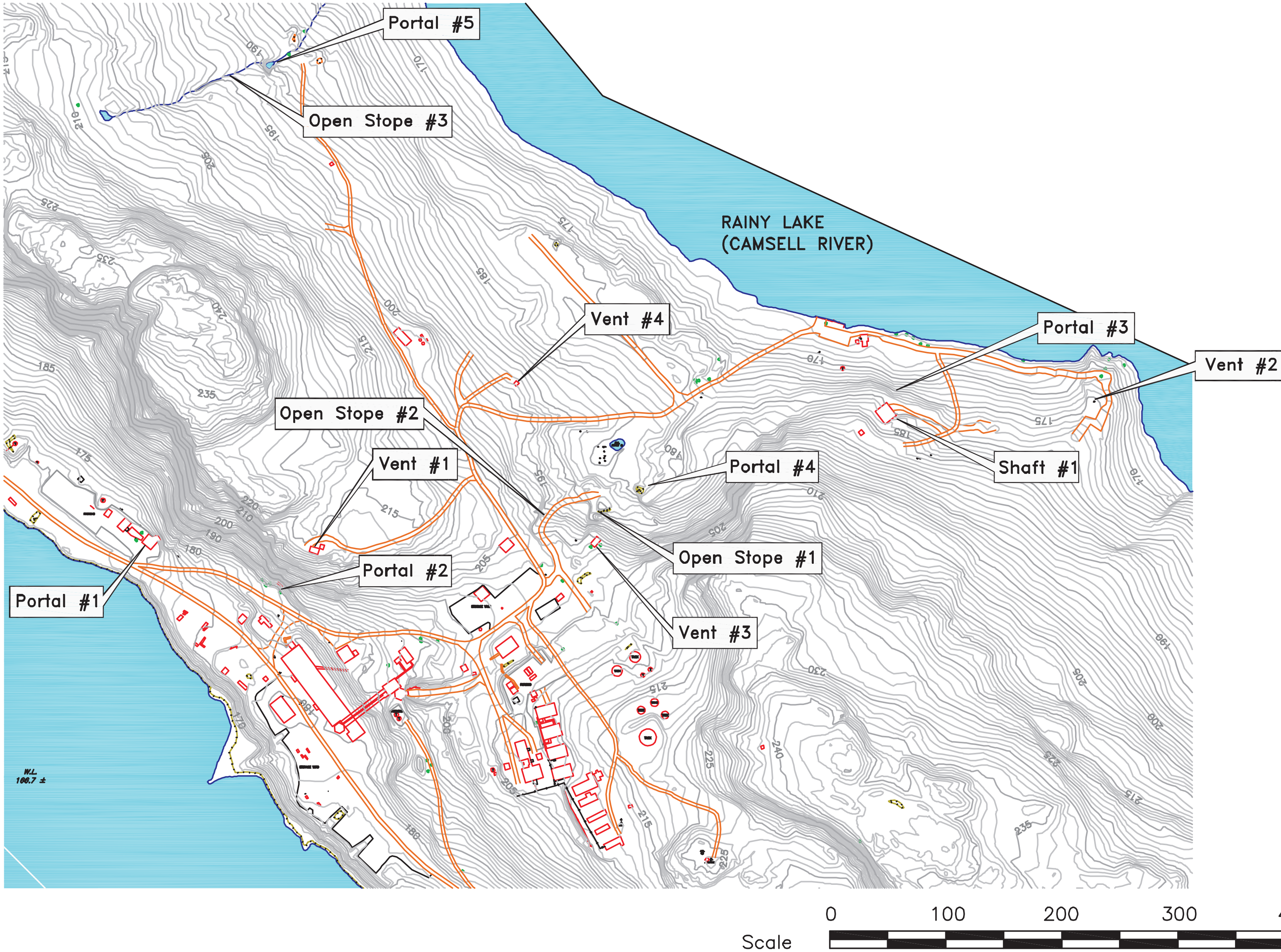
SILVER BEAR MINES
REMEDIAL ACTION PLAN

Terra Mine

Aerial Photo

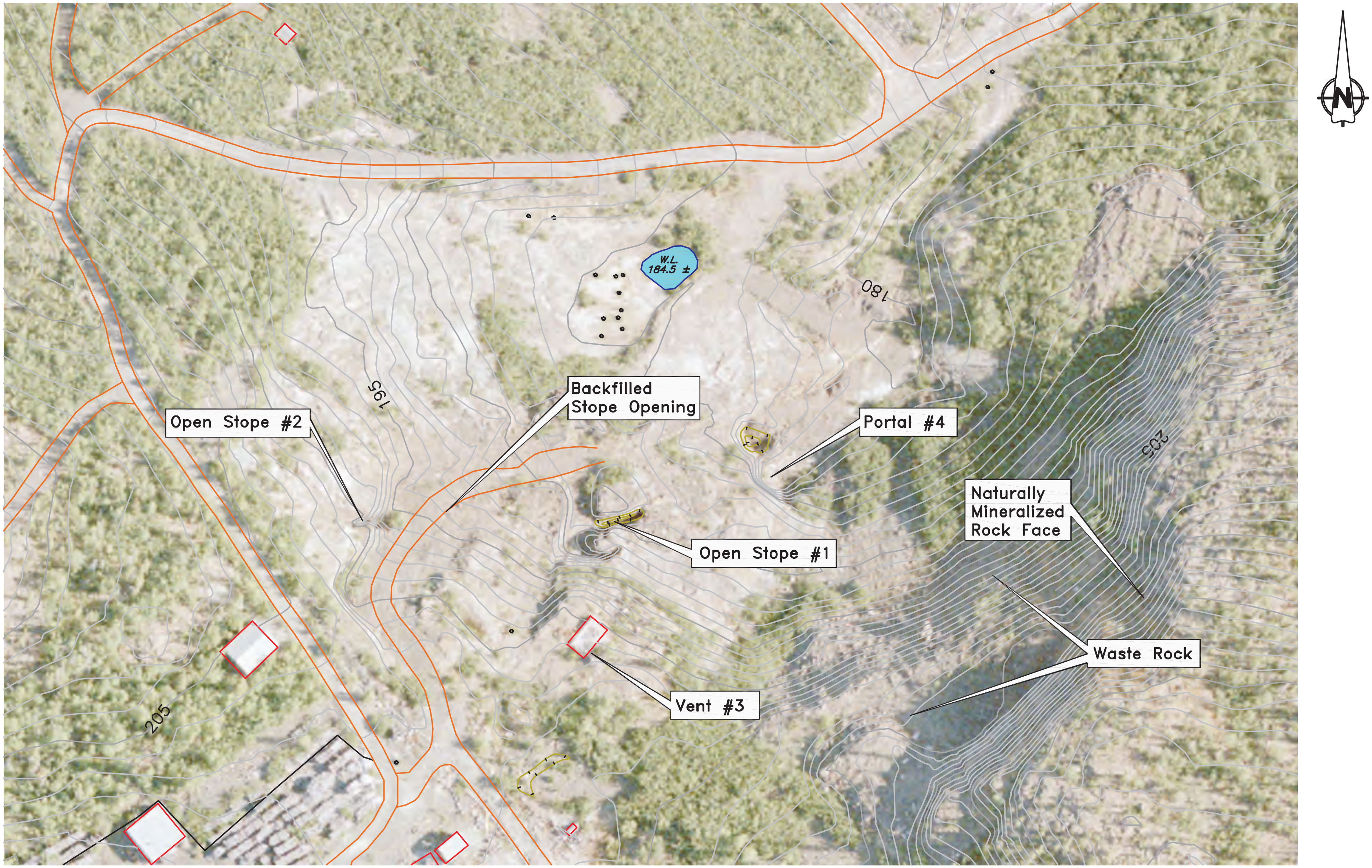
DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.2.2

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.3.dwg



SENES Consultants	SRK Consulting Engineers and Scientists Vancouver B.C.	Indian and Northern Affairs Canada	Terra Mine
	SRK JOB NO.: 1CP001.506	SILVER BEAR MINES REMEDIAL ACTION PLAN	Mine Openings
	FILE NAME: Figure 3.2.3.dwg		DATE: Mar. 2007 / APPROVED: SRS / FIGURE: 3.2.3

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.4.dwg



0 25 50 75 100 Metres

Scale

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SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.2.4.dwg

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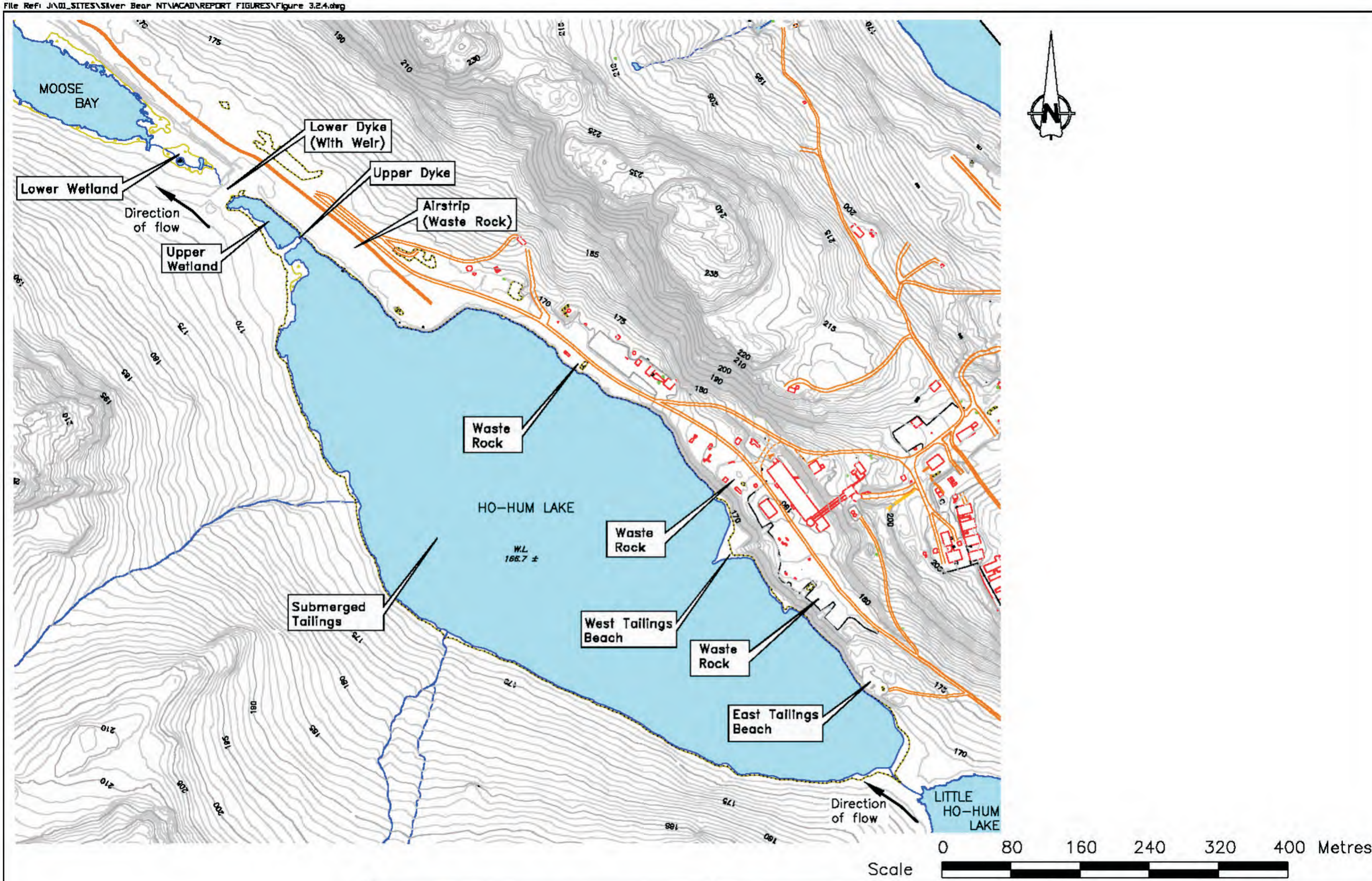
SILVER BEAR MINES
REMEDIAL ACTION PLAN

Terra Mine

Open Pit

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.2.4

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.4.dwg



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Terra Mine

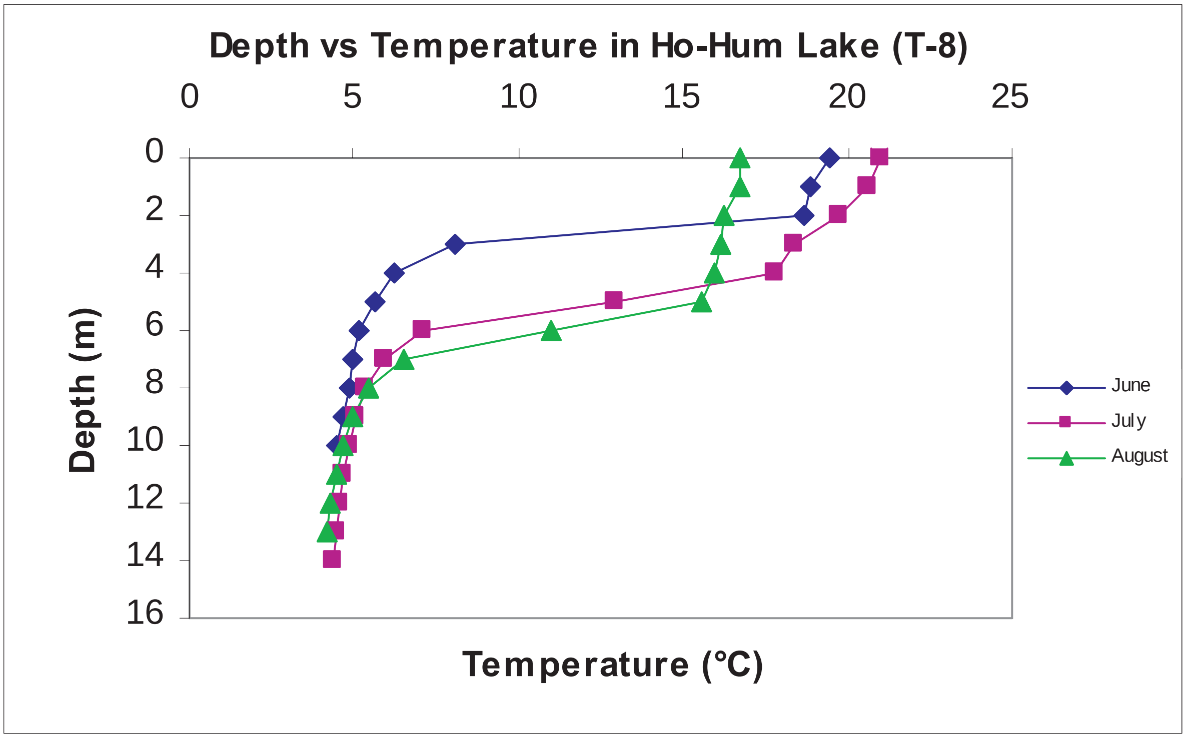
Tailings And Ho-Hum Lake

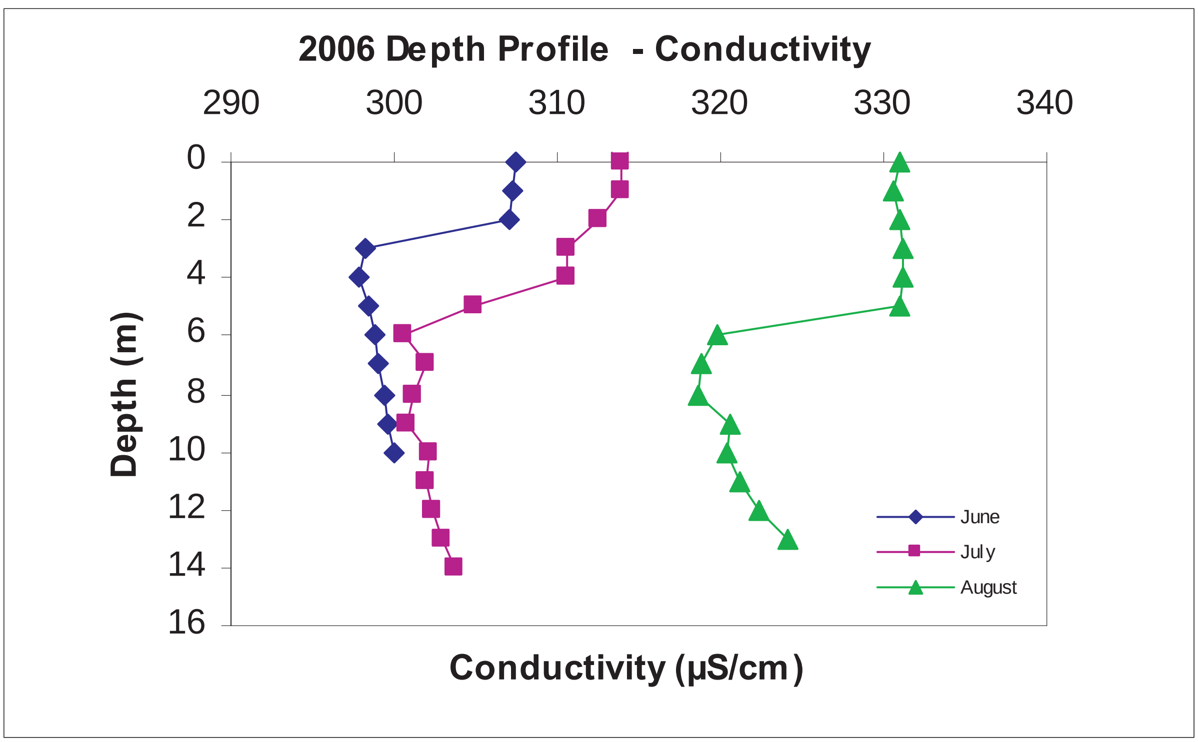
SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.2.4.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.2.5





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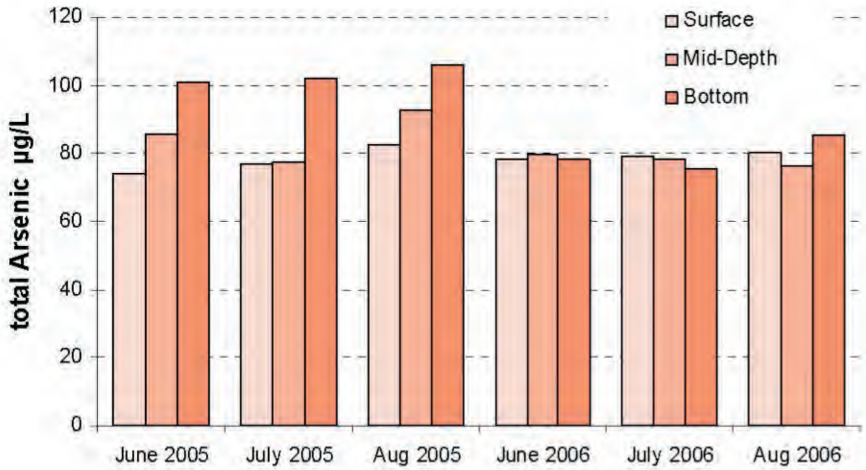
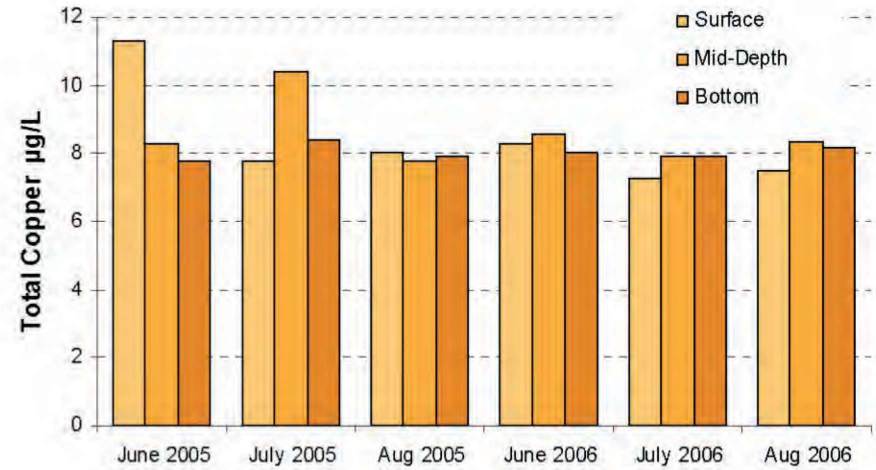
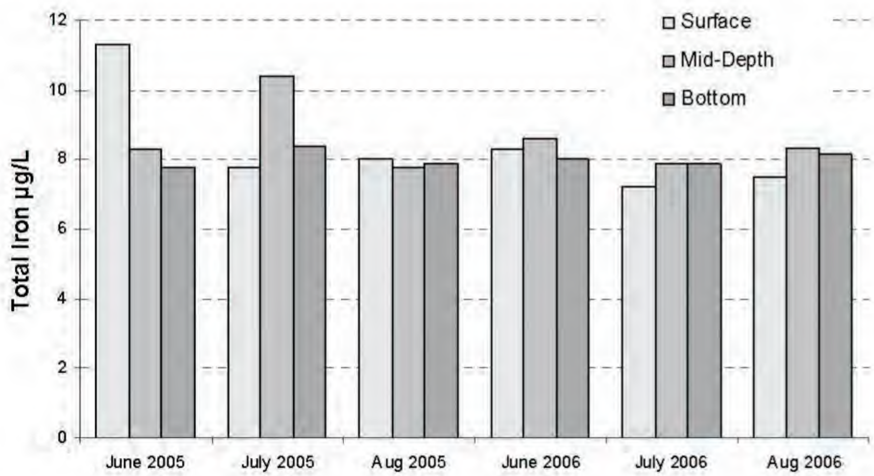
Stratification Effects
Ho-Hum Lake

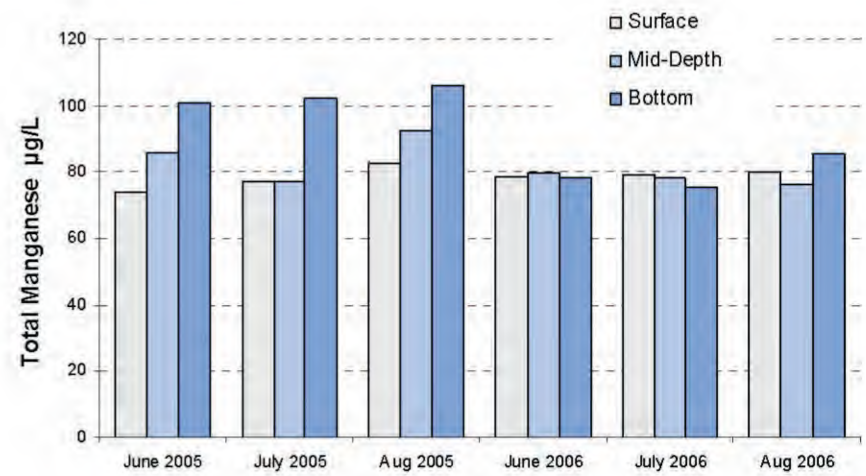
Silver Bear Mines Remedial Action Plan

Date:	Approved:	Figure:
Sep. 2007		3.2.6









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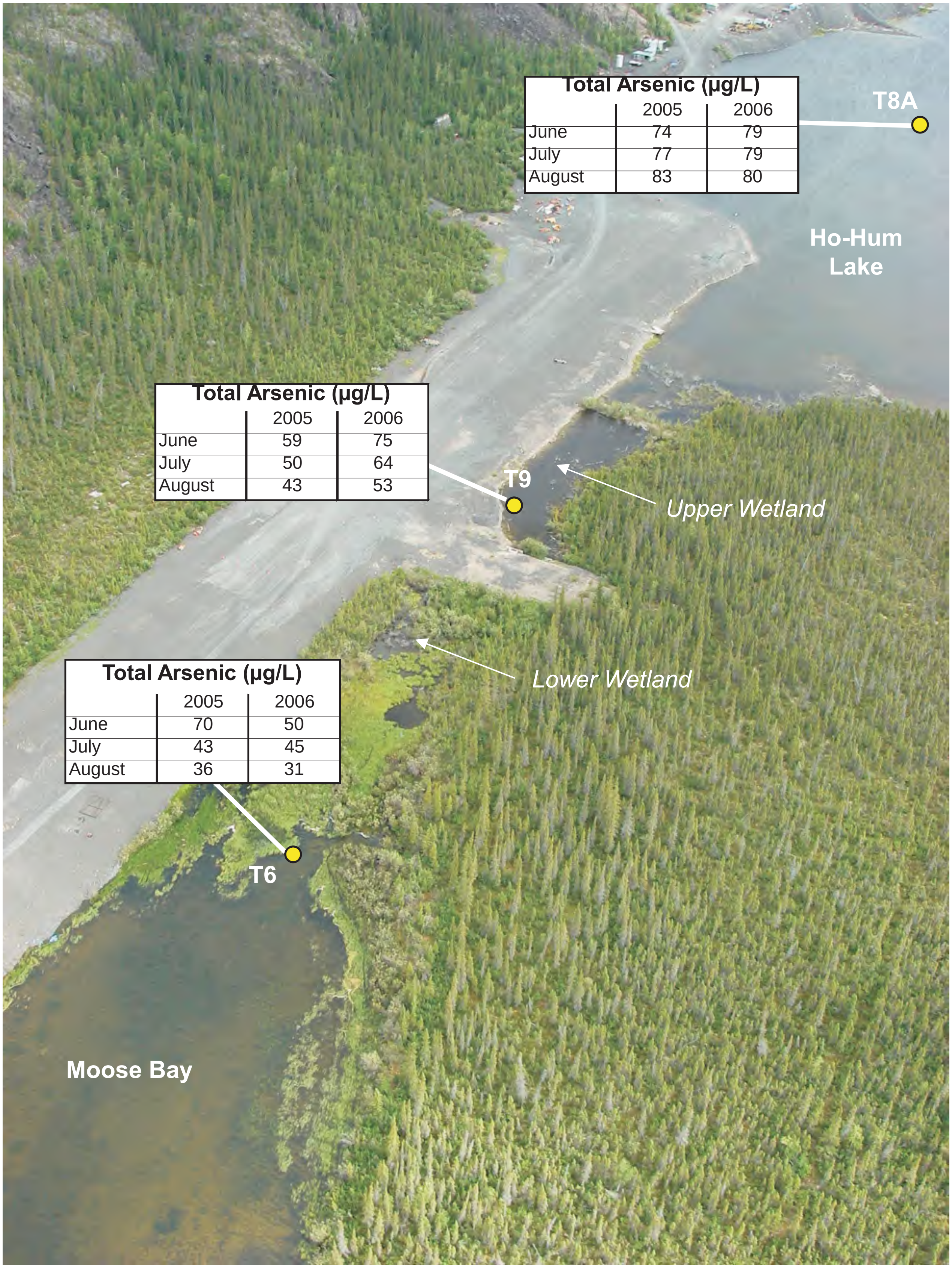
Metal Concentrations with Depth in Ho-Hum Lake

Job No: 1CP001.506
Filename: Figure 3.2.7_3.2.6.ppt

Silver Bear Mines Remedial Action Plan

Date: Feb. 2007
Approved:
Figure: 3.2.7



Total Arsenic (µg/L) (T8A)

	2005	2006
June	74	79
July	77	79
August	83	80

Total Arsenic (µg/L) (T9)

	2005	2006
June	59	75
July	50	64
August	43	53

Total Arsenic (µg/L) (T6)

	2005	2006
June	70	50
July	43	45
August	36	31

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Arsenic Concentrations in Ho-Hum Lake Discharge to Moose Bay

Job No : 1Cp001.506

Filename: Figure 3.2.8_Discharge_20070208.ppt

Silver Bear Mines Remedial Action Plan

Date:	Approved:	Figure:
Feb. 2007		3.2.8

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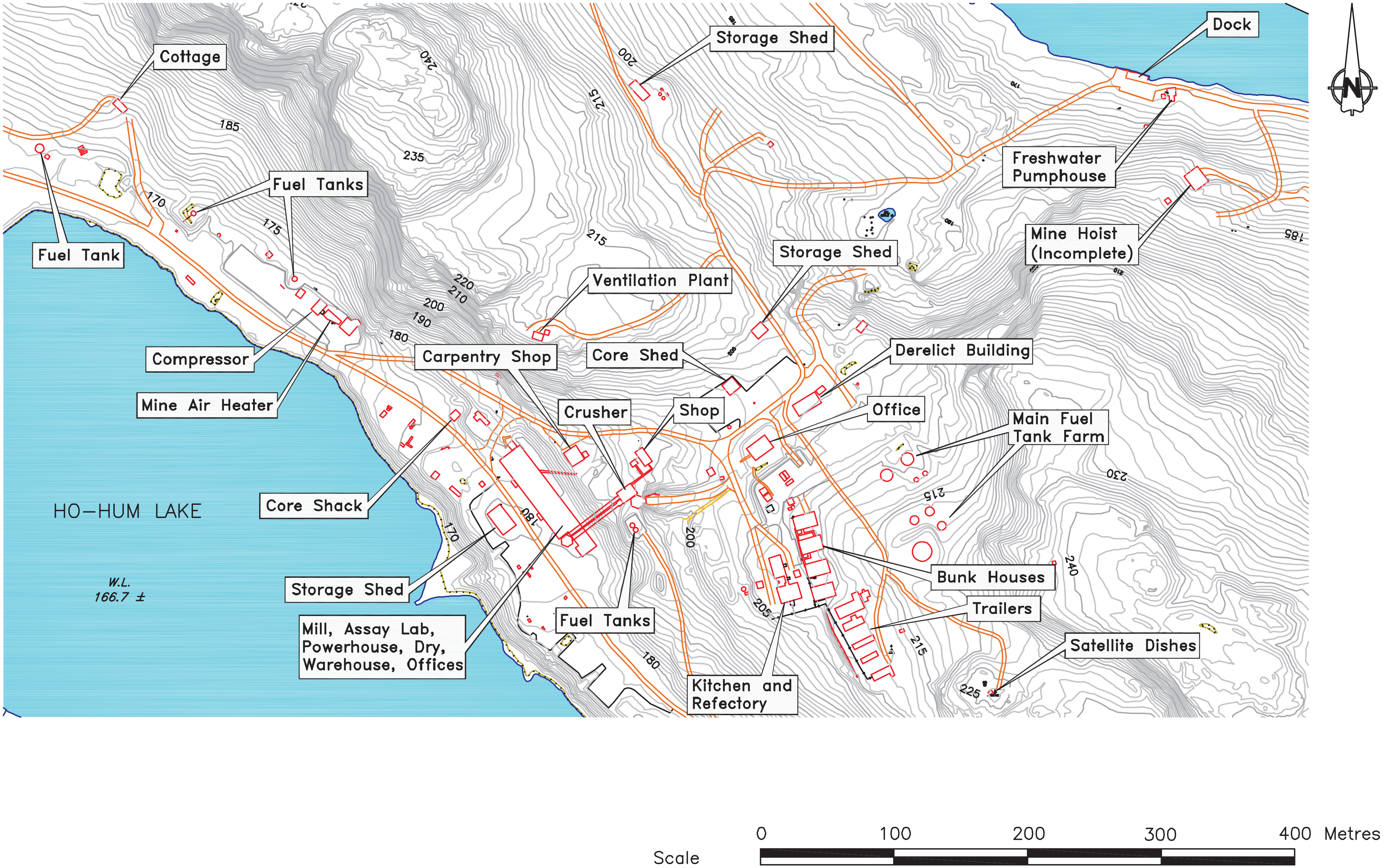

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SRK JOB NO.: 1CP001.506

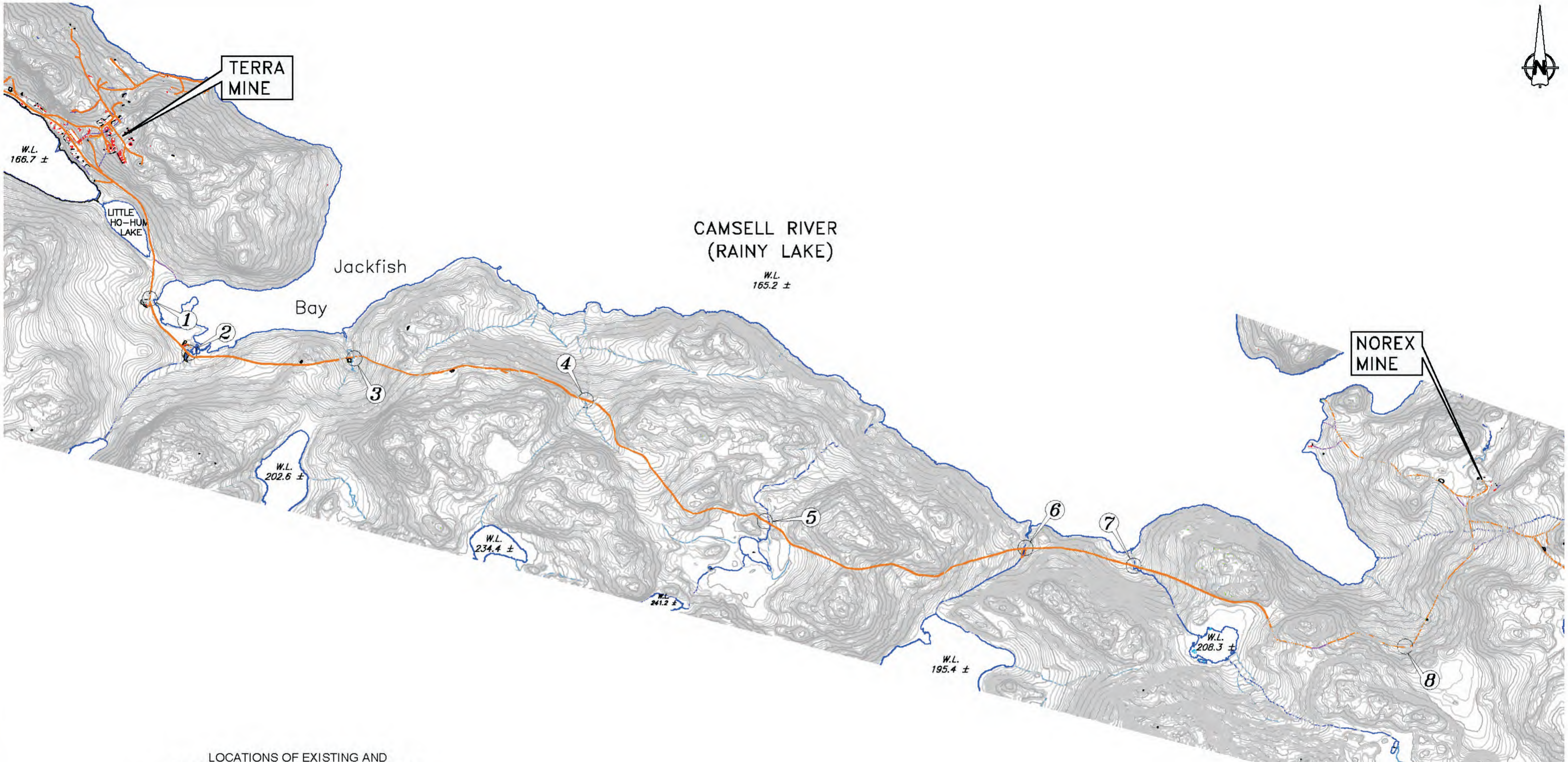
FILE NAME: Figure 3.2.4.dwg

SILVER BEAR MINES REMEDIAL ACTION PLAN

Terra Mine

Buildings and Equipment

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.2.9



Scale 0 500 1000 1500 2000 Metres

LOCATIONS OF EXISTING AND
POTENTIAL NEW DRAINAGE STRUCTURES

No.	Station (km)	Status
1	00+900	Existing culvert
2	01+200	Existing culverts, potential fish use
3	02+000	Existing culvert, damaged
4	03+200	Existing culvert
5	04+300	Existing culvert
6	05+700	Existing culvert, (ineffective), potential fish use
7	06+300	No structure, culvert required, potential fish use
8	07+700	Existing culvert

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Silver Bear Mines

Haul Road from Terra to Norex

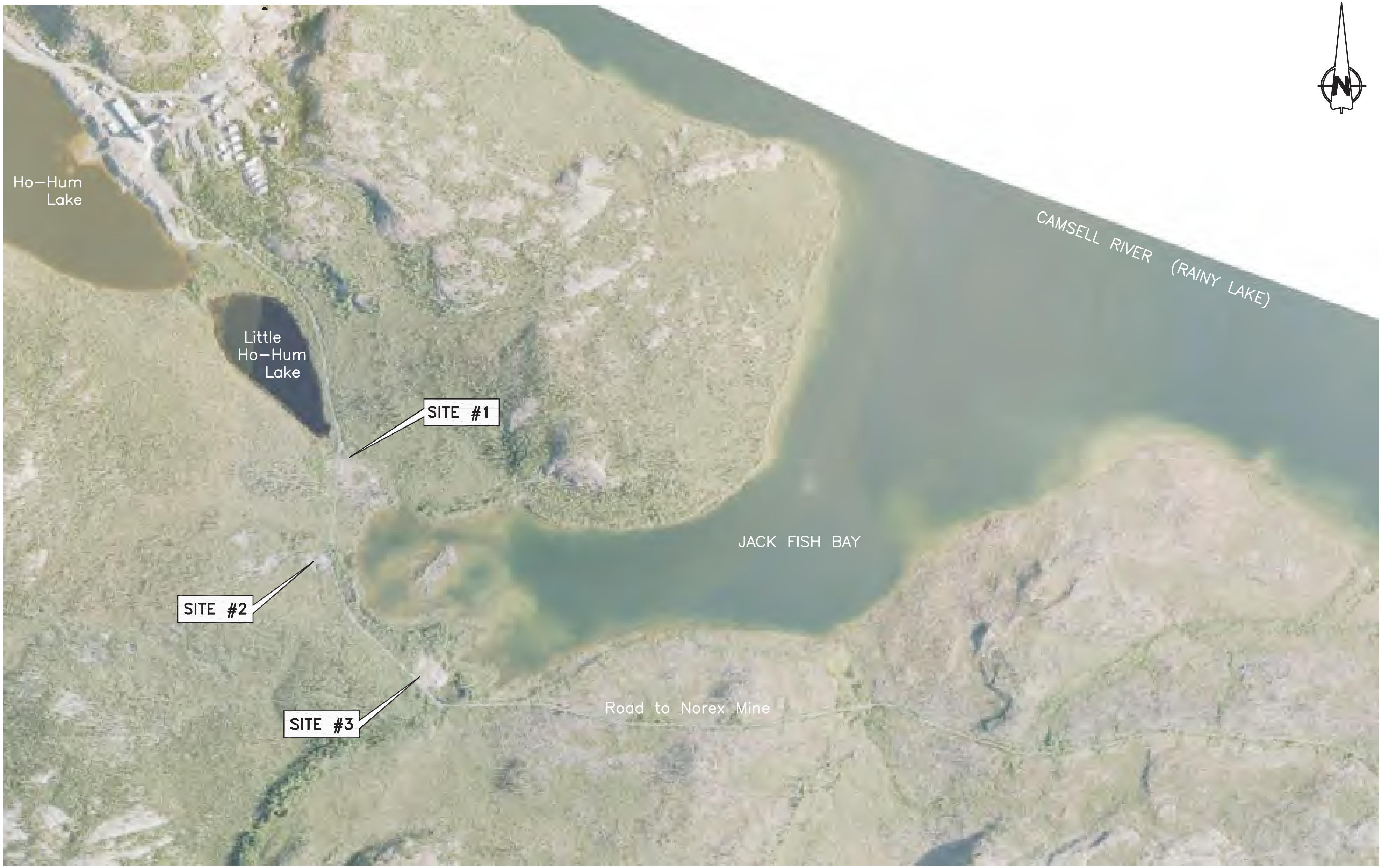
SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.2.10.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

DATE: Mar. 2007 | APPROVED: SRS | FIGURE: 3.2.10

File Ref: J:\01 SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.11.dwg



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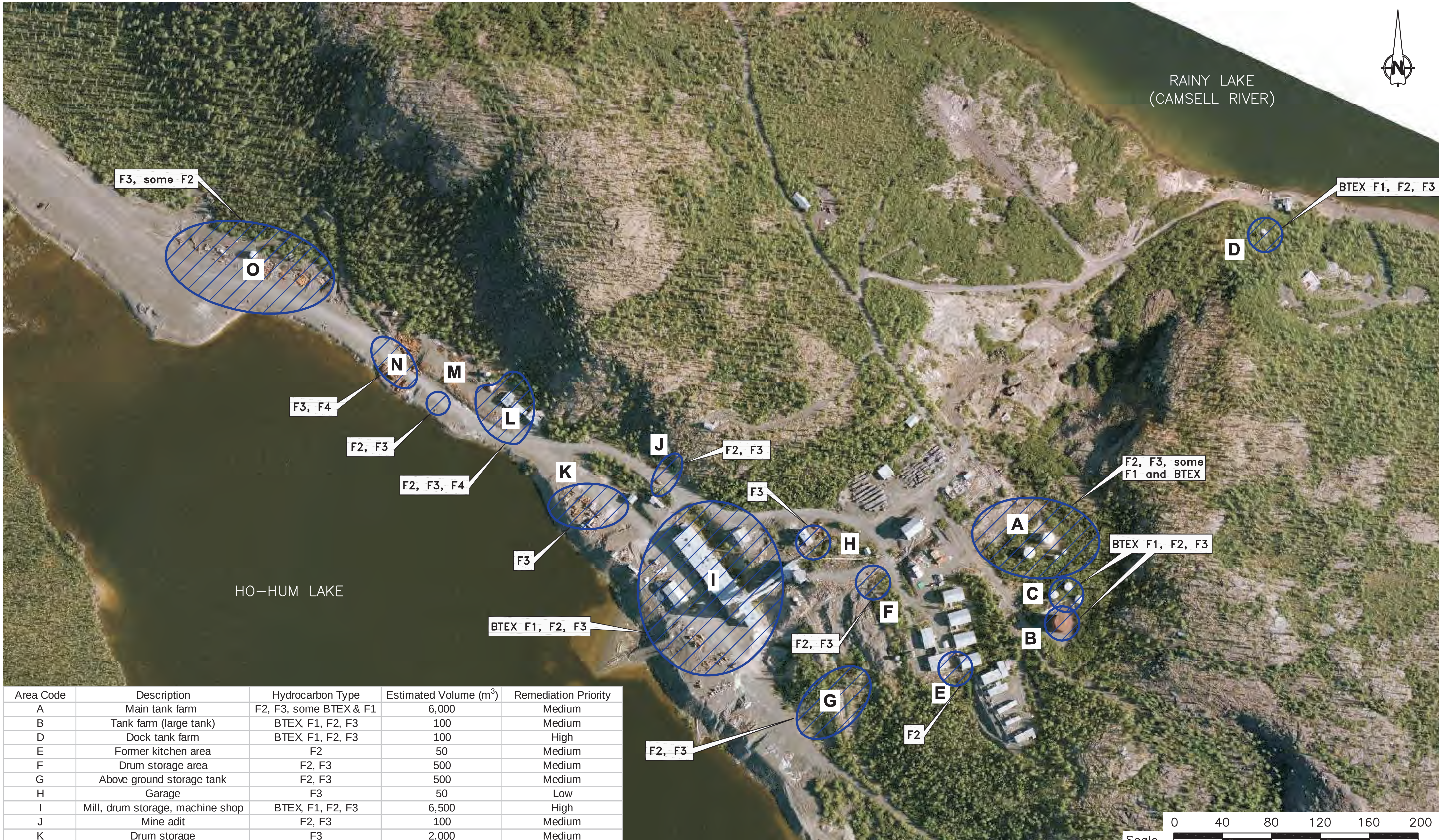
SRK JOB NO.:	1CP001.506
FILE NAME:	Figure 3.2.11.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

Terra Mine

Old Waste Disposal Sites

DATE:	APPROVED:	FIGURE:
Mar. 07	SRS	3.2.11



Area Code	Description	Hydrocarbon Type	Estimated Volume (m^3)	Remediation Priority
A	Main tank farm	F2, F3, some BTEX & F1	6,000	Medium
B	Tank farm (large tank)	BTEX, F1, F2, F3	100	Medium
D	Dock tank farm	BTEX, F1, F2, F3	100	High
E	Former kitchen area	F2	50	Medium
F	Drum storage area	F2, F3	500	Medium
G	Above ground storage tank	F2, F3	500	Medium
H	Garage	F3	50	Low
I	Mill, drum storage, machine shop	BTEX, F1, F2, F3	6,500	High
J	Mine adit	F2, F3	100	Medium
K	Drum storage	F3	2,000	Medium
L	Above ground storage tanks	F2, F3, F4	1,500	Medium
M	Drum storage	F2, F3	50	Medium
N	Drum storage	F3, F4	50	Low
O	End of airstrip	F3, some F2	3,000	Low
P	Waste rock	F2, F3	100	Medium

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Terra Mine

Hydrocarbon Contamination

SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.2.12.dwg

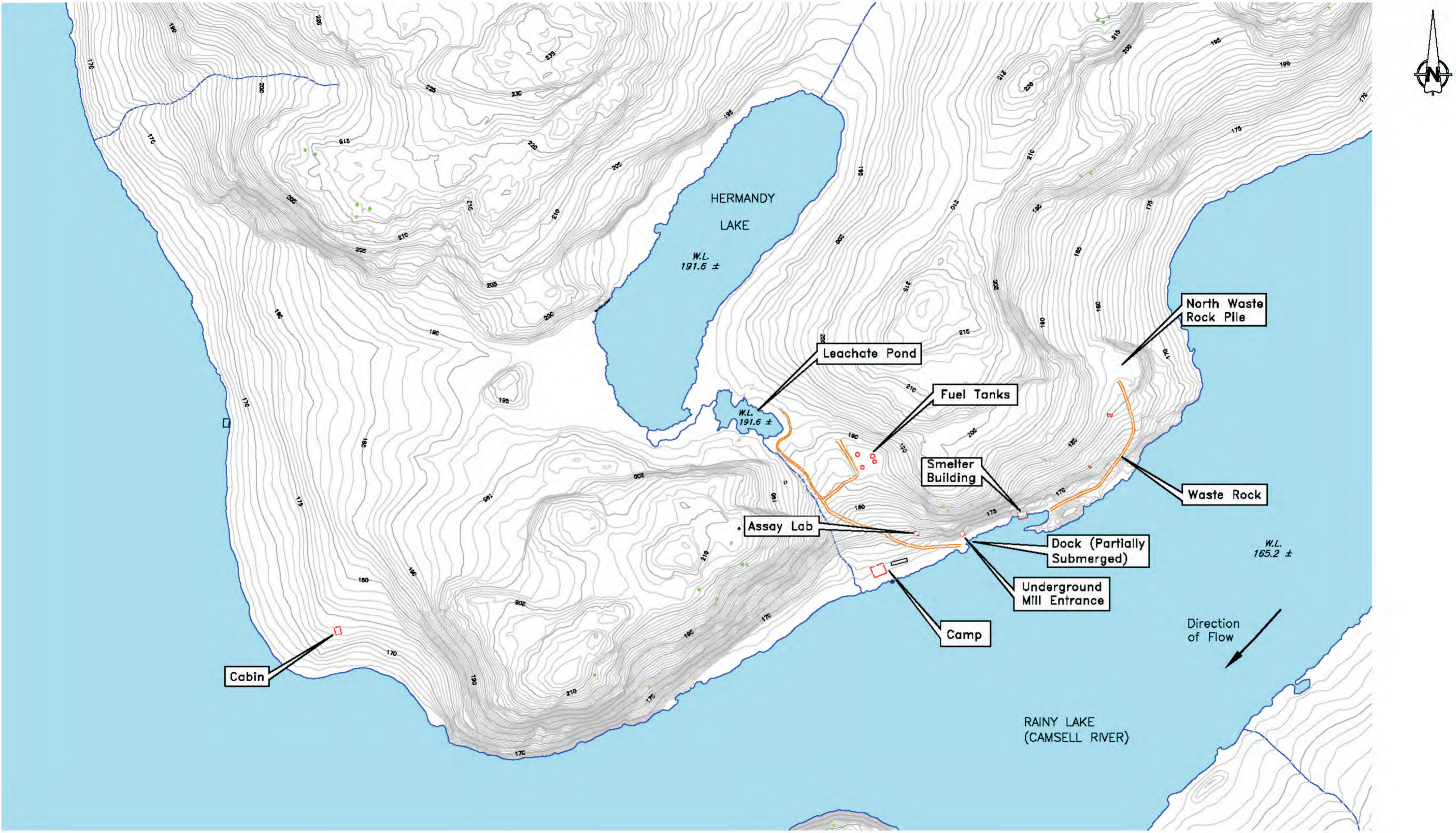
SILVER BEAR MINES
REMEDIAL ACTION PLAN

DATE: Mar. 2007

APPROVED: SRS

FIGURE: 3.2.12

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.2.11.dwg



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Northrim Mine

Site Plan

SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.3.1.dwg

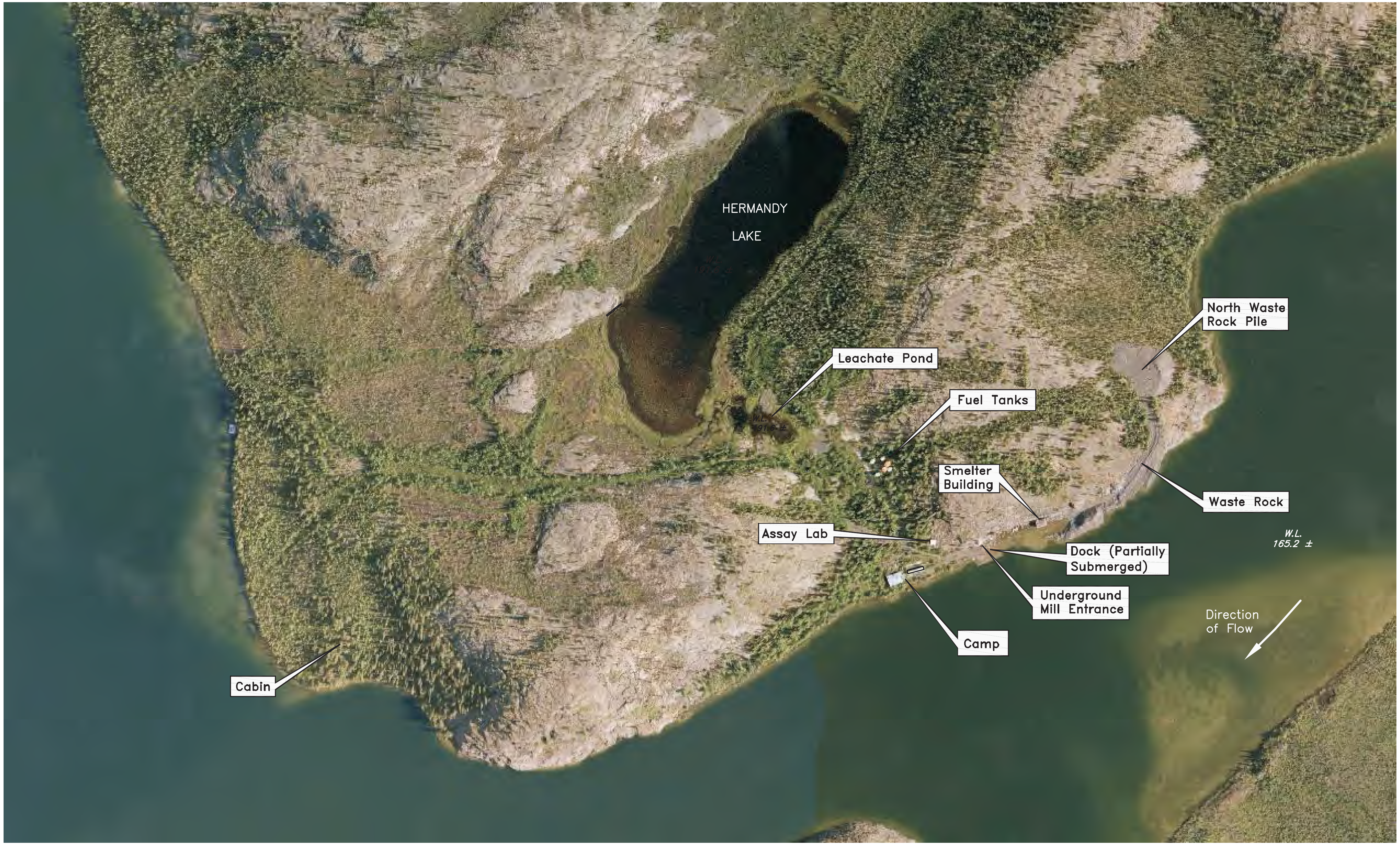
SILVER BEAR MINES
REMEDIAL ACTION PLAN

DATE: Mar. 2007

APPROVED: SRS

FIGURE: 3.3.1

File Ref: JAOL_SITES\Silver Bear NT\CAD\REPORT FIGURES\Figure 3.3.1.dwg

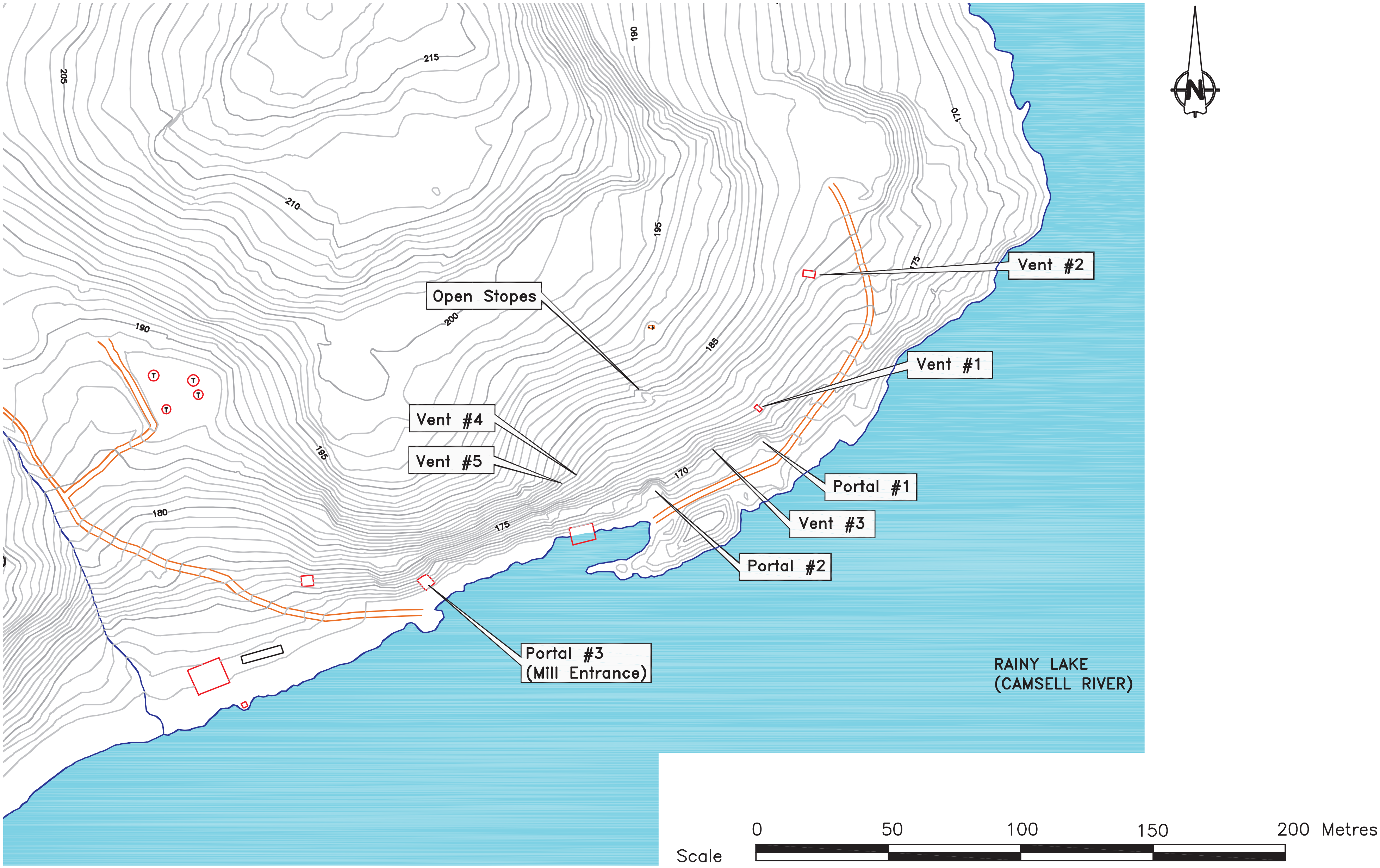


Scale 0 100 200 300 400 Metres

SENES Consultants	SRK Consulting Engineers and Scientists Vancouver B.C.	Indian and Northern Affairs Canada	Northrim Mine
	SRK JOB NO.: 1CP001.506	SILVER BEAR MINES REMEDIAL ACTION PLAN	Aerial Photo
	FILE NAME: Figure 3.3.1.dwg		DATE: Mar. 2007 APPROVED: SRS FIGURE: 3.3.2

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.3.1.dwg

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.3.3.dwg



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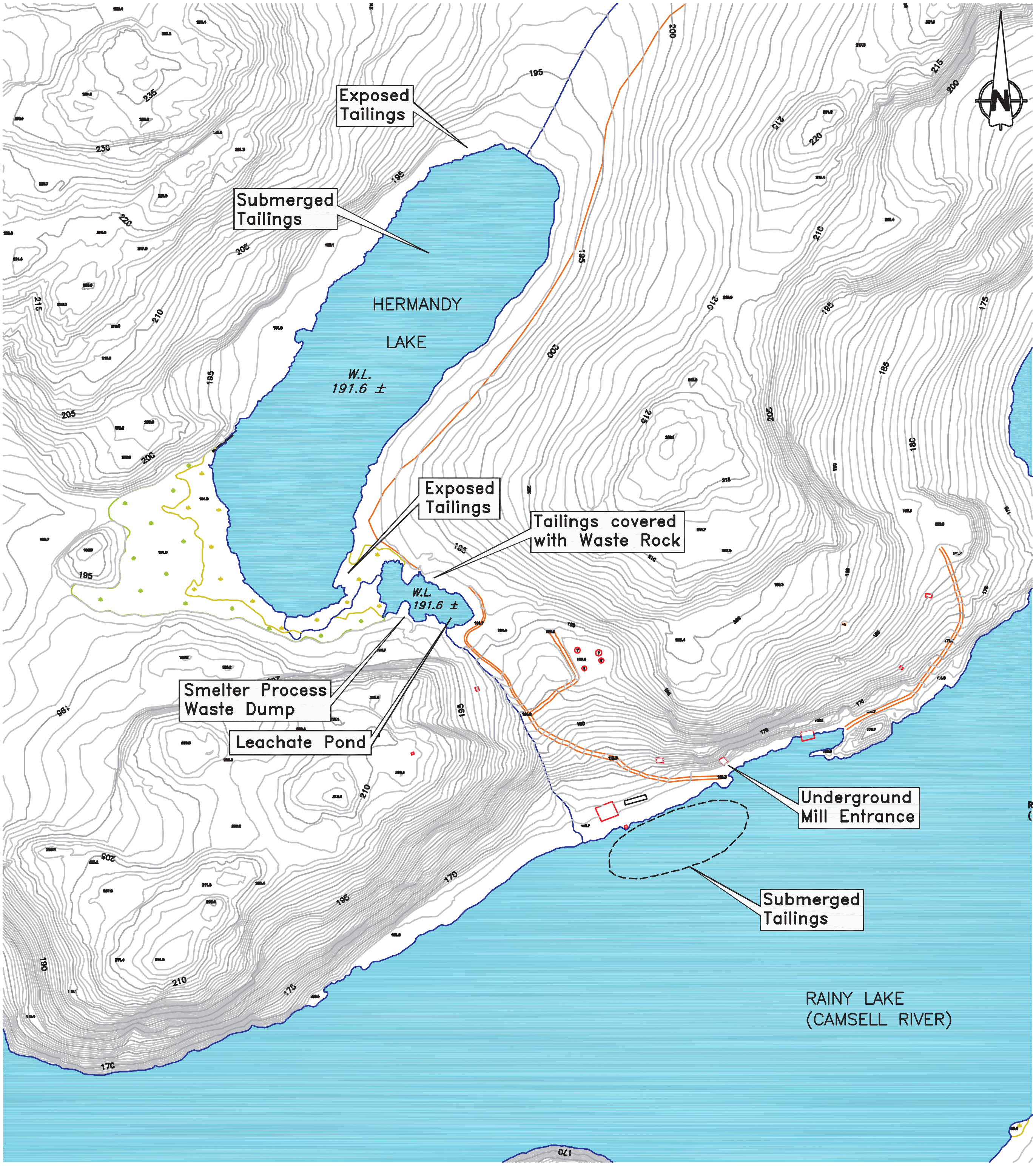
SRK JOB NO.:	1CP001.506
FILE NAME:	Figure 3.3.3.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

Northrim Mine

Mine Openings

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.3.3



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Northrim Mine

Tailings And Hermandy Lake

SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.3.3.dwg

SILVER BEAR MINES
REMEDIAL ACTION PLAN

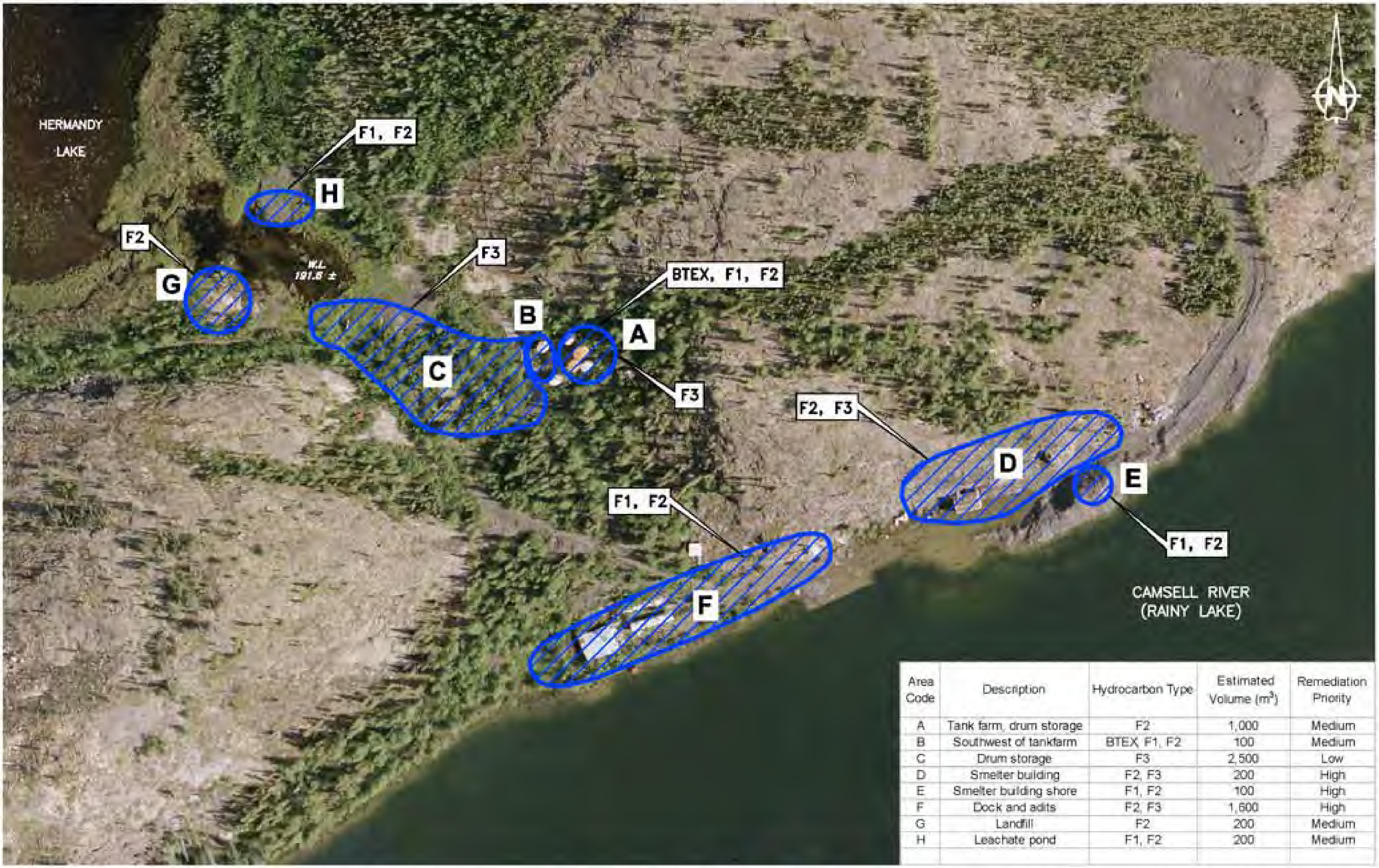
DATE: Mar. 2007

APPROVED: SRS

FIGURE: 3.3.4

File Ref: JA\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.3.3.dwg

File Ref: J:\01_SITES\Silver Bear NT\ACAD\REPORT FIGURES\Figure 3.3.5.dwg



Area Code	Description	Hydrocarbon Type	Estimated Volume (m^3)	Remediation Priority
A	Tank farm, drum storage	F2	1,000	Medium
B	Southwest of tankfarm	BTEX, F1, F2	100	Medium
C	Drum storage	F3	2,500	Low
D	Smelter building	F2, F3	200	High
E	Smelter building shore	F1, F2	100	High
F	Dock and adits	F2, F3	1,600	High
G	Landfill	F2	200	Medium
H	Leachate pond	F1, F2	200	Medium

Scale 0 50 100 m

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SRK JOB NO.: 1CP001.506

FILE NAME: Figure 3.3.5.dwg

SILVER BEAR MINES REMEDIAL ACTION PLAN

Northrim Mine

Hydrocarbon Contaminated Areas

DATE:	APPROVED:	FIGURE:
Mar. 2007	SRS	3.3.5