Mine Closure and Reclamation Plan

Doris North Project, Nunavut

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1.0 BACKGROUND

1.1 Scope

Miramar Hope Bay Ltd. (MHBL) owner and operator of the Doris North Project, is proposing to develop an underground gold mine at Doris Lake, Nunavut, located about 125 km southwest of Cambridge Bay. The centre of the Project is 160 km north of the Arctic Circle at latitude 67^{o} 30' N and longitude 107^{o} W (see Figure 1.1 and 1.2).

MHBL has prepared this Mine Closure and Reclamation Plan (Closure Plan) for inclusion in the Water License Application Support Document to facilitate public review by the Nunavut Water Board (NWB). It should be noted that the Doris North Project has not yet been constructed. This Closure and Reclamation Plan is intended to outline how this mine will be closed and reclaimed should construction proceed. This exercise is intended to ensure that issues associated with the effective closure and reclamation of the site are considered in sufficient detail at the earliest possible stage in the mine development process thereby influencing mine design to take into account environmental issues related to mine closure and reclamation.

The Closure Plan is considered to be a "living" document. It is anticipated that the Plan will undergo further revision over the next 3 years. It will continue to be updated and refined as the Doris North Project moves through construction, commissioning, into operation and approaches final closure in 2010. The level of detail of closure and reclamation planning contained within the Plan will continue to increase with subsequent revisions. Those revisions will incorporate the lessons learnt at each phase of the mine development process. Moreover, the revisions will also reflect the input form the Kitikmeot Inuit Association as representative of the land owner (the Inuit), local communities, Nunavut Tunngavik Incorporated (NTI) and other stakeholders who have an interest in how the Doris North Project is ultimately reclaimed. This document provides a basis for continuing discussions with stakeholders regarding closure and reclamation that were initiated during the Environmental Assessment and Water License permitting process.

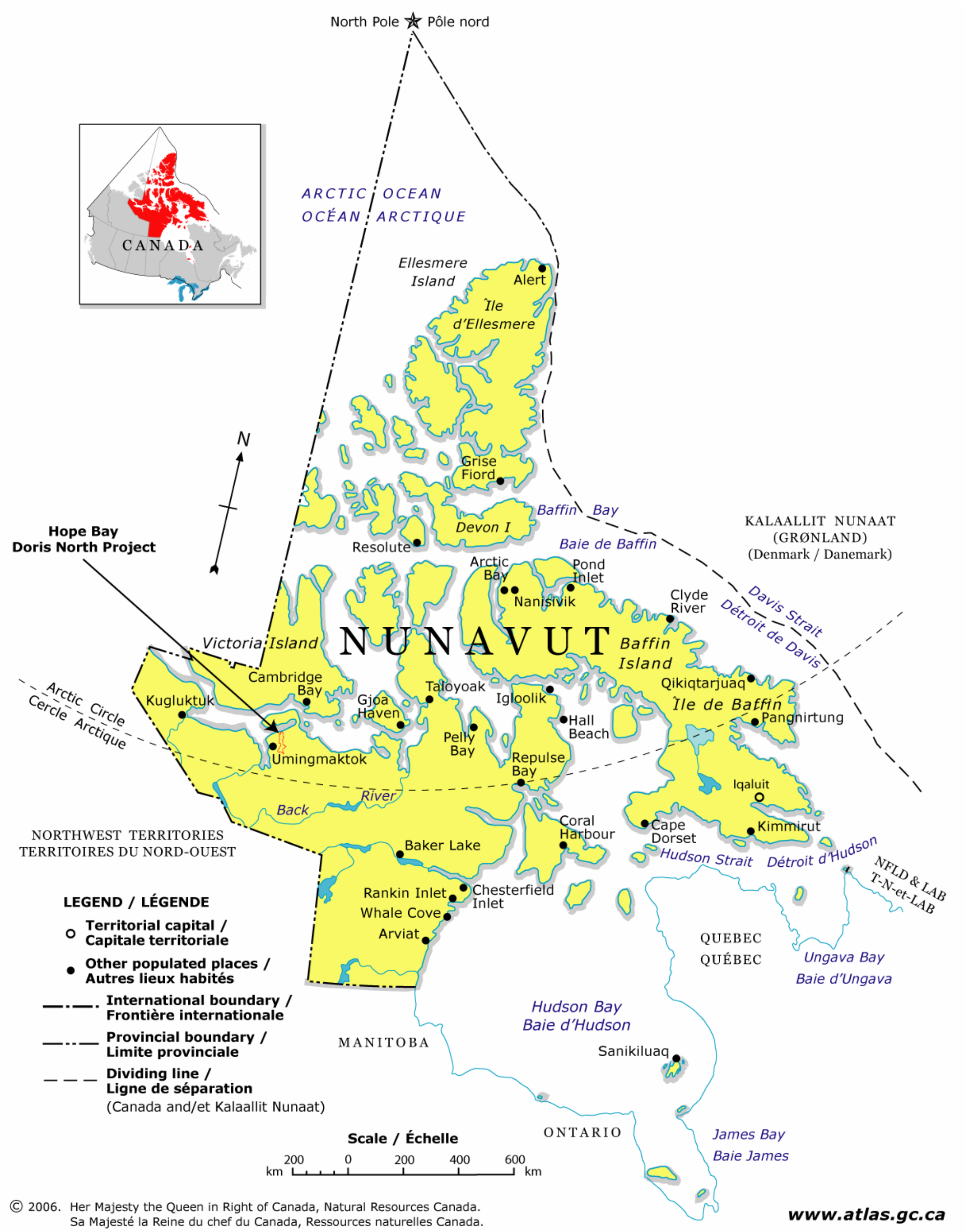

Figure 1.1: Project Location Plan

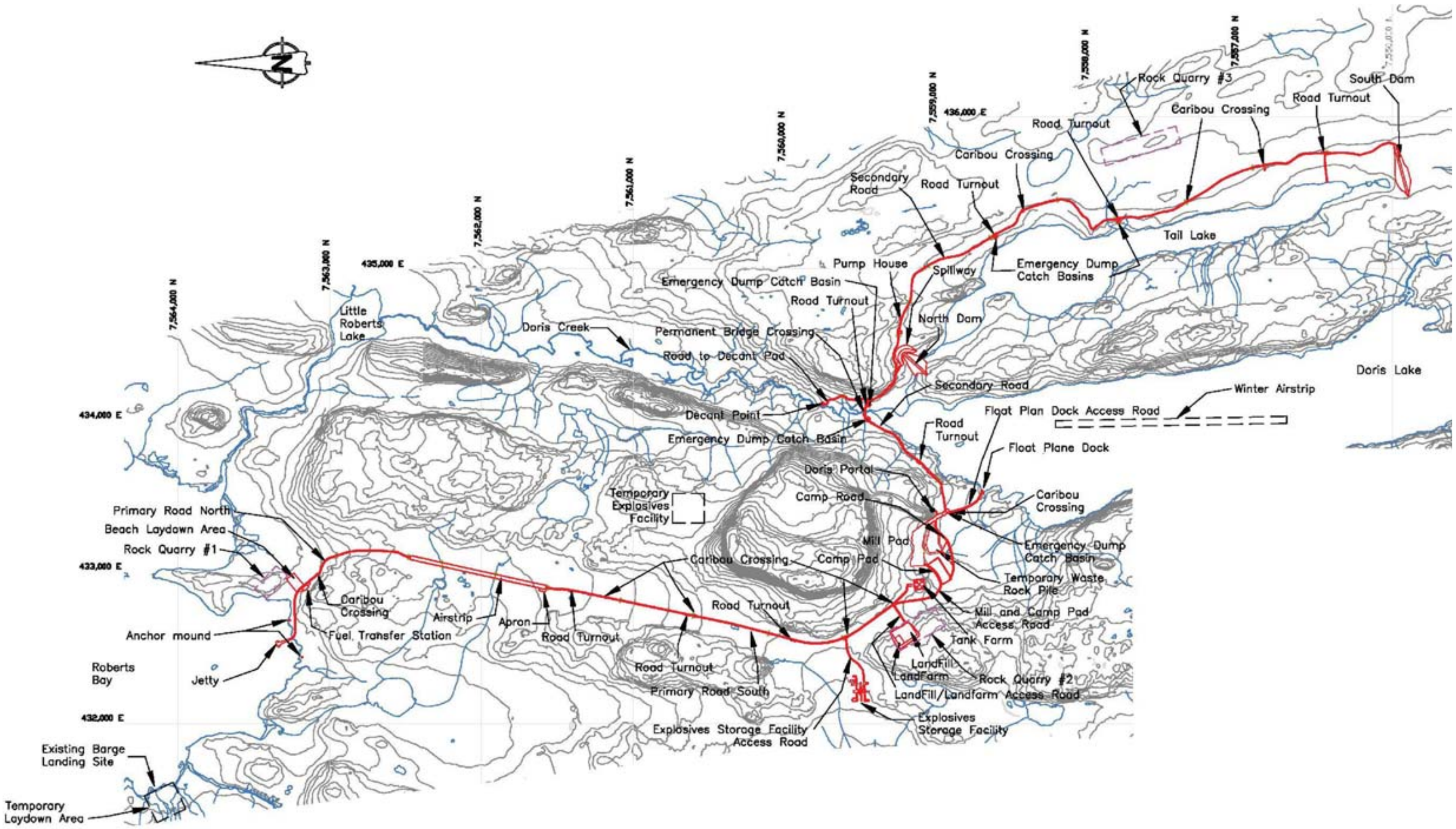

Figure 1.2: Overall Site Infrastructure Layout

1.2 Objectives

In 2002 the Department of Indian and Northern Affairs Canada (DIAND) published a "Mine Site Reclamation Policy for Nunavut" – "*A policy for the protection of the environment and disposition of liability relating to mine closures in Nunavut*". This policy sets out the principles and objectives that guide how DIAND will apply its authority in matters relating to the management of the environmental and liability issues relating to mine closure and reclamation in Nunavut. The policy sets out what is expected from project proponents in relation to reclamation planning in project design and what proponents can expect from regulatory decision makers, thereby "fixing the goal posts" and thereby reducing ad hoc, case-by-case interpretation. MHBL have incorporated, wherever possible, the principles and guidelines as set out in this policy into it's planning for the abandonment and restoration of the Doris North Project.

In January of 2006, the Water Resources Division of Indian and Northern Affairs Canada issued "*Mine Site Reclamation Guidelines for the Northwest Territories*". The guidelines are intended to assist proponents of mining projects in understanding the expectations of DIAND for closure and reclamation planning in the Northwest Territories and Nunavut. The guidelines acknowledge that there are also land owners and other agencies, such as First Nations, Environment Canada, Fisheries and Oceans Canada, Natural Resources Canada, Government of Nunavut and various co-management boards who play a role in the reclamation of lands and waters which are affected by mining activities.

The Mine Reclamation Policy for Nunavut was developed for the protection of the environment and the disposition of liability relating to mine closures. The policy states that all mines in Nunavut should be planned, operated, closed and decommissioned in an environmentally sound manner in accordance with current mine closure and reclamation practices.

These practices include:

- Submission of a mine reclamation plan to regulators and landowners, approval of the plan before the commencement of mine production, regular plan updates, and annual progress reclamation reports;
- Progressive mine reclamation, consistent with the approved plans and current mine reclamation practices;
- Financial assurance that fully covers the outstanding liabilities at any period of the mine operations; and
- Sites are reclaimed and monitored at the financial expense of the mining company.

Mining is considered to be a temporary use of the land. At closure, the mine site and the land affected by the mining operations are to be reclaimed to achieve the following objectives (listed in order of priority):

- Protection of public health and safety through the use of safe and responsible reclamation practices;
- Reduction or elimination of environmental effects once the mine ceases operation;
- Re-establish conditions that permit the land to return to a similar pre-mining land use; and
- Reduce the need for long-term monitoring and maintenance by establishing physical and chemical stability of disturbed areas.

These broad reclamation objectives are drawn from the Mine Site Reclamation Guidelines for the NWT that were issued by Indian and Northern Affairs Canada (INAC) in 2006. Miramar Hope Bay Ltd has adopted these objectives as the basis for establishing site specific reclamation objectives for the Doris North Project.

The goal of reclamation is to prevent progressive degradation of a closed mining site, and to enhance natural recovery of areas affected by mining. Landscape reclamation is driven by the following specific objectives:

- To establish stable landforms;
- To protect the water resources in the local area;
- To facilitate natural recovery of areas affected by mining and the mining related activities at the Project site; and
- To re-establish productive use of the land and water in the vicinity of the mine site for future generations in a manner that is consistent with the pre-development use of the land and water. In this case, productive use refers to use of the area by wildlife and for traditional activities as practised by the local communities and First Nations prior to the development of the mine.

This does not mean that the mine will not result in a permanent change to the landscape. Certain features of the mine, such as the quarries, will become permanent changes to the current landscape. Other features, such as roads, airstrips and building pads, will alter the landscape for many years (perhaps centuries) until natural forces obliterate or disguise their presence even after they are reclaimed. In other words, reclamation cannot totally remove the entire disturbance caused by development and operation of the mine.

Reclamation cannot return the site to a pristine condition. Reclamation can however ensure that these disturbances are not causing degradation of the surrounding water, air and land after the mine no longer continues to operate.

The establishment of stable landforms (primarily establishment of stable slopes and drainage pathways) through proper engineering practises will reduce the requirements for prolonged maintenance of the mine site after reclamation is complete. It is MHBL's intention to create a stable site where long term care and maintenance is reduced to the minimal practical extent. In other words, it is MHBL objective that reclamation be completed at the Doris North Project in a manner where future maintenance requirements are minimal, limited to periodic site visits, inspections and periodic maintenance of erosion damage and cleaning of drainage pathways. No long term maintenance presence on site is a key objective of reclamation planning for the Doris North Project. The objective is to get as close as possible to a "maintenance free" site through proper reclamation techniques, in other words to strive for a "walk away" reclaimed site. This means that drainage pathways, such as drainage swales and ditches, will be designed wherever possible and practical to be self-cleaning or immune to erosion problems that could otherwise require an ongoing maintenance requirement.

The targeted post-closure land use for the Doris North Project is wildlife habitat. This end land use is a reflection of the current use of the tundra area surrounding the Project site by wildlife (both resident and migratory). It is acknowledged that local communities and First Nations make use of the surrounding area for traditional activities and reclamation of the Doris North Project will target leaving a reclaimed site that is protective of the surrounding water, air and land to enable such traditional activities to continue.

It is also recognized that aesthetics (how a reclaimed site looks) is of concern to the Inuit, local communities, and other stakeholders. This concern is acknowledged by MHBL and aesthetics have been considered in the design of the specific reclamation activities to be applied at the Doris North site. The first and foremost approach in this respect is to leave a "clean" site. In other words, all remaining potentially hazardous materials (chemicals, reagents, hydrocarbons, explosives, etc.) will be removed from the site after mining ceases. These products will be transported south for use elsewhere (re-cycling) or for appropriate disposal in a licensed disposal facility. All non-hazardous materials such as buildings, demolition debris, steel, vehicles, general garbage and debris will be removed from the surface and disposed of in the appropriate non-hazardous landfill site to be constructed within Quarry 2. This landfill will then be closed out and covered with a "clean" cap of quarried rock. It is expected that permafrost will become established within the closed out landfill in a short time frame after closure. Precipitation runoff will be directed away from the reclaimed landfill by a series of upslope berms. All building foundations and above ground concrete structures will be demolished and removed so that only rock fill pads remain as evidence of the existing use of the site as a mine. There will be visual changes to the pre-development landscape primarily associated with the remaining remnants of the airstrip, site roads and building and laydown rock fill pads. Roads will be reclaimed to allow restoration of natural drainage pathways in a low maintenance fashion (i.e., no culverts, bridges or berms) but the gravels used to construct the roads, airstrip and building pads will largely remain in place and be evident for many years before natural processes obliterate or disguise their presence.

The Tail Lake tailings impoundment will be reclaimed as a lake similar in appearance to the pre-development lake however the South Dam and remnants of the North Dam will remain although they will no longer hold back any water (i.e., they will no longer function as dams). Tail Lake will return to its predevelopment water level with drainage flowing back through the original outflow channel into Doris Lake. The impounded tailings solids will be under a 4 metre cover of water and thus not visible on surface. Water quality will return to levels close to background. The water will not be harmful to aquatic life, wildlife or human consumption after reclamation. The lake will ultimately be able to support a fish population but it will take many years for sediment to cover the stored tailings and for benthic organisms and vegetation to re-establish on the lake bottom; both pre-conditions for the re-establishment of a fish population within the lake.

Figures 1.3 through 1.7 show the expected condition of the Doris North Project once reclamation has been complete. The jetty has been removed. The buildings and all other man made equipment and materials have been removed. The Tail Lake north dam has been breached and the lake allowed to return to its pre-development water level.

Figure 1.3 shows the mill and camp site after the buildings have been removed. Tail Lake is shown in the background once the North Dam has been breached. Figure 1.4 is a similar view looking towards the North (towards Roberts Bay). Figure 1.5 shows Tail Lake once the North Dam has been breached and the lake has returned to the pre-development elevation of 28.3 m leaving a permanent 4 m water cover over top of the tailings.

Figure 1.6 is a view of the Doris North Project after reclamation looking south from Roberts Bay towards Doris Lake. The jetty has been partially removed and is no longer visible as the remaining rockfill is submerged under 0.3 to 0.5 m of water.

Figure 1.7 is a close up of the plant site area once the buildings and fuel tank farm have been removed. The temporary waste rock stockpile has all been returned into the underground mine and the mine opening (adit) has been sealed.

Figure 1.3: View of Doris North Project Site Showing Expected Post-Closure Site Condition

Figure 1.4: View of Doris North Project Site Looking North After Reclamation

Figure 1.5: Tail Lake Looking North Showing Expected Post-Closure Condition

Figure 1.6: View of Doris North Site After Reclamation Looking South From Roberts Bay

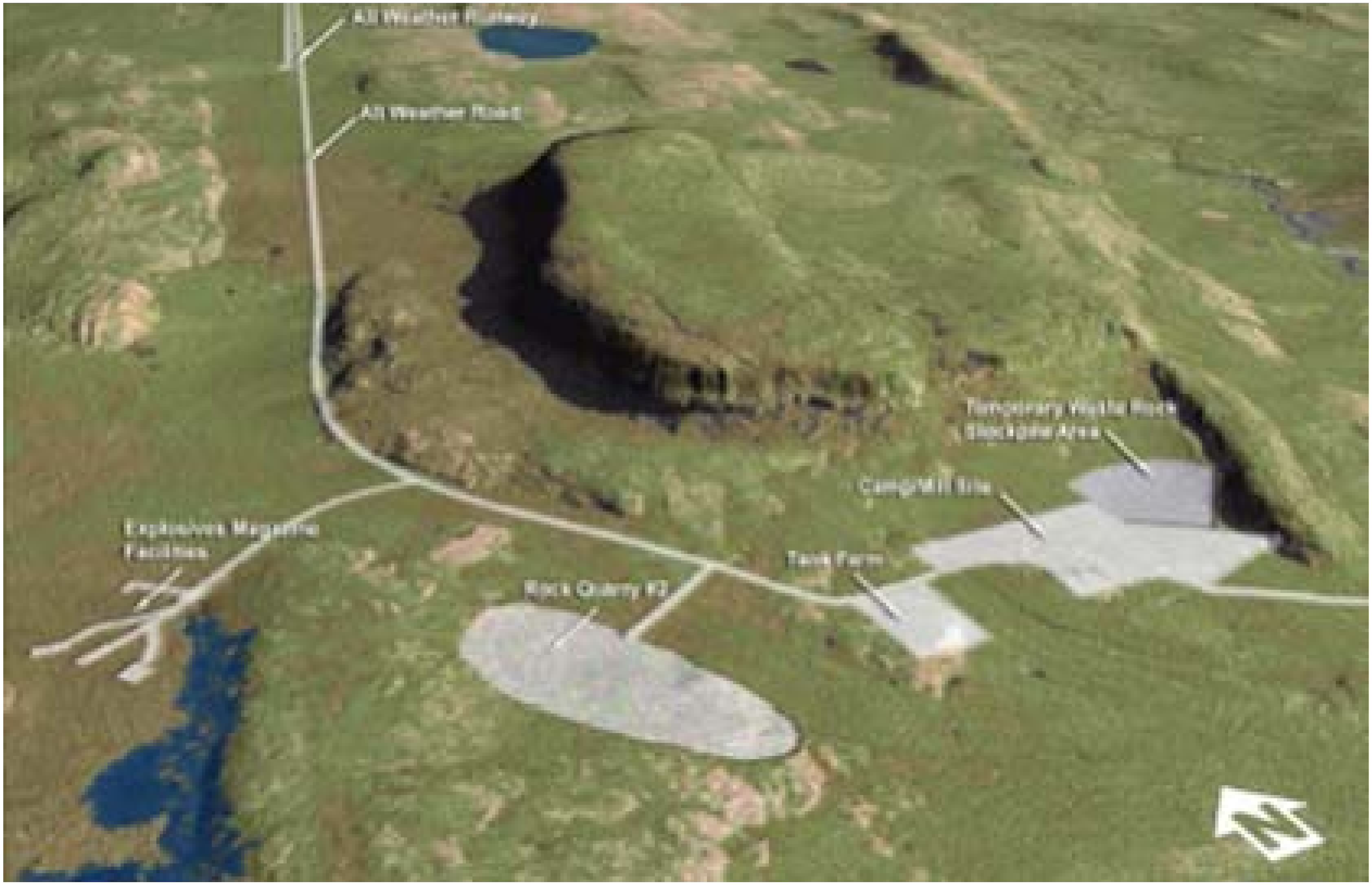

Figure 1.7: View of Post Closure Doris North Plant Site

1.3 Rationale and Approach

MHBL has incorporated, where applicable, the guiding principles, objectives and standards set out in the INAC guiding documents discussed in Section 1.2 in the preparation of the Closure and Reclamation Plan for the Doris North Project.

The Closure and Reclamation Plan will comply with the conditions of mining permits, regulations, and industry standards that are applicable to this Project. The following principles have been established to guide the development of the overall closure plan:

- Plan and implement in accordance with all applicable regulations;
- Apply cost effective and appropriate closure and reclamation practices to reduce environmental risks and allow traditional use of the land;
- Conduct studies to predict post-closure environmental effects;
- Maintain a program of progressive closure and reclamation as an integral part of project operations; and
- Incorporate new reclamation methods and procedures.

MHBL is committed to reducing the residual environmental effects at the site upon closure. Consequently, the mine plan has been developed in conjunction with the closure and reclamation plan. Reclamation work will form an integral part of the mine plan. Furthermore reclamation will be carried out progressively during the life of the Project where practical. All surface facilities have been designed to minimize restoration requirements following mine closure, and to enhance the natural recovery of the areas affected by mining.

Mine decommissioning and restoration will be carried out using conventional state-of-the-art, northern mine construction and reclamation techniques. MHBL plans to select closure technologies and design elements that not only comply with accepted protocols and standards, but will also use best available technologies that are practical for use at this site.

This report provides a description of the anticipated decommissioning and reclamation activities for the site, during and following completion of underground mining. This Closure and Reclamation Plan describes the areas of disturbance that require reclamation, summarizes the proposed strategy and schedule for decommissioning and reclamation of each area, and outlines the work to be carried out. The specific details of the mine reclamation plan are likely to evolve as mining progresses. Consequently, this plan will be updated during the mine life.

Key closure and reclamation issues for this Project are summarized as follows:

1. All buildings and equipment will be demolished and/or removed from the site as part of final reclamation. Demolition debris with no salvage value will be buried in an on-site non-hazardous waste landfill. All buildings and equipment will be cleaned of potentially hazardous materials prior to demolition. All remaining inventory of petroleum products, reagents, chemicals, etc. will be removed from the site as part of final reclamation. Consequently no buildings, equipment, hydrocarbons or chemicals will remain at the site once reclamation has been completed;

2. Potential acid rock drainage (ARD) and metal leaching (ML) will be minimized through the placement of all potentially acid generating waste rock into the underground mine where it will remain in a frozen state due to the presence of permafrost (or underwater should future global warming trends cause permanent thawing of the permafrost and subsequent flooding of the closed mine workings at some point in the future). Mill cyanide leach tailings will be filtered and placed underground as backfill. All mill flotation tailings will be permanently stored under a minimum 4 metre deep water cover in the reclaimed tailings containment area (Tail Lake). These actions will retard the rate of ongoing sulphide mineral oxidation and prevent the future release of contaminants into groundwater and surface water from these materials due to oxidation/weathering. Consequently no-long term water treatment requirements are envisioned once reclamation has been completed. The successful implementation of this strategy will minimize requirements for long-term post-closure water monitoring.

3. Fresh water use will be minimized during the mine's operating life by recycling as much water as practical from the tailings containment area for use as process water in the mill and by using a recycled brine solution underground for all drilling and mining activity. Consequently the volume of potentially contaminated water requiring management at closure will be kept to a minimum.

1.4 Land Use Objectives and Alternatives

The key objectives of the reclamation plan are to:

- Protect public health and safety through the use of safe and responsible reclamation practices;

- Reduce or eliminate environmental effects once the mine ceases operations;

- Re-establish conditions that permit the land to return to a similar pre-mining land use; and

- Reduce the need for long-term monitoring and maintenance by establishing physical and chemical stability of disturbed areas.

The Doris North Project is a remote site in an Arctic setting. Pre-development land use can be classified as wildlife habitat with occasional use by Inuit people for subsistence hunting and fishing. MHBL's closure objectives are to return the land after mining and reclamation have been completed to healthy, self-sustaining wildlife habitat suitable for use by Inuit people for subsistence hunting and fishing.

Alternative land use objectives considered include:

- Use of the site as a continued base for mineral exploration in the region. This may be viable in the short term but not sustainable over the long term. The viability of a local exploration base will diminish as the area is explored and the distance between prospective properties and the base camp becomes greater.

This closure and reclamation plan is predicated upon the objective of removing all facilities from the Doris North Project site and leaving the site in a chemically and physically stable condition so that wildlife and fish can safely reside in and use this area as habitat without adverse health impacts to themselves or to the Inuit people who may use this wildlife for subsistence purposes.

The present reclamation guidelines for Nunavut (Mine Site Reclamation Guidelines for the NWT, INAC 2006) provide direction on methodologies and reclamation procedures and provide broad reclamation objectives and criteria but there is still a need to establish site specific reclamation criteria for each mine site against which reclamation progress can be measured. In other words, there is need to develop site specific criteria that can be used by the mine owner, the land owner (Kitikmeot Inuit Association), regulatory agencies, the Inuit of the West Kitikmeot, local communities, and other stakeholders to know when each portion of the mine site has been successfully reclaimed to an acceptable standard (i.e., to provide a benchmark to allow all parties to know when reclamation has been successfully completed). To date, these site specific criteria have not been developed by the regulatory agencies.

MHBL acknowledges that such site specific reclamation criteria need to be developed in consultation with the Kitikmeot Inuit Association, local communities, and other stakeholders including the regulatory agencies. This section is thus intended to provide a starting point for the development of these site specific reclamation criteria for the Doris North Project. They were discussed with the Kitikmeot Inuit Association, local communities, and other stakeholders during the Nunavut Impact Review Board (NIRB) environmental assessment process. MHBL is committed to continue this process during the permitting phase so that the next refinement of the Mine Closure and Reclamation Plan is based on site specific reclamation criteria that have been developed in consultation with the Kitikmeot Inuit Association, local communities, and other stakeholders. This would then leave sufficient time prior to the planned mine closure in 2010 for detailed reclamation planning to be adjusted to meet these site specific reclamation criteria.

For this phase MHBL has put forward suggested site specific reclamation criteria for use at the Doris North Project that can act as a basis for future dialogue and consultation.

Reclamation criteria will be used to assess the final reclamation obligations for closure of the Doris North Project. These criteria will establish benchmarks that will be used to determine when decommissioning, reclamation and monitoring programs have been completed and remaining liability has been removed. The objective is to reach a “maintenance free” reclaimed site where minimal active management or maintenance is required.

Completion of reclamation is the time at which all reclamation criteria have been met. To facilitate this process, MHBL have adopted an approach similar to that used at Ekati that looks at three stages of reclamation:

- **Stage 1: Decommissioning Stage** – removal of contaminants, removal of buildings and structures, creation of a stable water management or drainage system across the reclaimed site and the creation of geotechnically safe landforms;

- **Stage 2: Reclamation Stage** – the return of the disturbed site to a form and productivity level that conforms to the defined end land use for each component of the mine site. Enhancement of natural revegetation and post-closure environmental monitoring programs are in place, as and where required; and

- **Stage 3: Completion Criteria Conformance** – reclamation is complete and environmental monitoring is in place to measure for reclamation success and to demonstrate that the site specific reclamation criteria have and will continue to be achieved in a sustainable fashion. At this phase the land owner (the KIA) and other regulatory agencies will be asked to confirm that the reclamation criteria have been met.

The proposed site specific reclamation criteria for the Doris North Project are set to ensure that closure and reclamation of the site meets the overall objectives for mine site reclamation in Nunavut as established in the Mine Site Reclamation Guidelines for the NWT put forward by INAC in 2006. The objectives of the site specific reclamation criteria can be considered under the following four categories:

- Physical stability;

- Chemical stability;

- Ecological sustainability; and

- Climate and geographic stability.

1.4.1 Physical Stability

Physical stability is ensured by protecting the surface against wind and water erosion, providing for surface drainage, minimizing hazardous conditions, and contouring the surface to meet land capability objectives. Physical structures such as underground mine openings, sedimentation ponds, drainage ditches, breached dams, spillways, quarry slopes, and rock pads will meet the following requirements:

- Be physically stable and designed in accordance with acceptable design criteria;
- Pose minimal hazard to the public and wildlife health and safety as a result of failure or physical deterioration;
- Continue to perform the function for which they were designed; and
- Have stable land surfaces with minimal surface erosion.

1.4.2 Chemical Stability

The reclaimed mine site at the Doris North site will be chemically stable. This means surface waters will be protected against significant adverse environmental effects resulting from discharges. In addition, discharges will not endanger public and wildlife health and safety, nor result in unacceptable deterioration of environmental resources.

Aspects to be monitored closely will include short-term and long-term changes in the geochemistry of quarried rock used in the construction of roads, dams and building pads, seepage and runoff from these facilities, and the chemistry of surface water draining from the site. Potential effects due to any acid rock drainage, metal leaching and flushing of other chemicals via surface runoff will be mitigated. Control and mitigation measures will be specific to the source and contaminant types. The success of physical reclamation at the Doris North site will influence chemical and physical stability.

1.4.3 Ecological Sustainability

The ecological sustainability of the reclaimed site and potential effects on the surrounding environment are closely related to methods of reclamation, the end land use, and the physical and chemical characteristics of the site. Ecological sustainability at Doris North is reached when mining related physical or chemical impediments to the establishment of natural ecological processes are removed thereby allowing the establishment of self-sustaining and productive ecosystem (including progressive natural changes in habitats) vegetation, aquatic and wildlife habitats to establish. Vegetation, aquatic and wildlife habitats would be stable, self-sustaining, and productive, and meet the agreed stakeholder requirements.

1.4.4 Climate and Geographic Stability

Regional and local climatic information will be used to resolve questions concerning aspects such as hydrology and permafrost growth. The effects of climate on mine closure measures include: precipitation and extreme events such as floods, freeze-thawing and aggradation of permafrost into mine infrastructure. Precipitation affects the overall water balance of the site and hence influences the chemical and physical stability of the site together with its contaminant transport parameters. Extreme events influence erosion and subsequently the physical stability of the site.

The effects of geography on mine reclamation include proximity of local populations and resource users downstream of the mine, the proximity of surface water which will influence their susceptibility to contaminants of concern released from the reclaimed mine components and the geographic location of reclaimed mine components in relation to watersheds.

1.5 Land Reclamation Units and Proposed Site Specific Reclamation Criteria

It is convenient to separate mining facilities into components (land reclamation units) to design and plan reclamation work. For the Doris North Project, mining facilities have been divided into the following five land reclamation units:

- The underground mine workings;
- The Tail Lake tailings containment area and site water management facilities;
- Buildings and equipment;
- Infrastructure such as the airstrip, site roads, and laydown areas; and
- The site non-hazardous waste landfill area and quarries.

Proposed site specific reclamation criteria for each of the six land reclamation units at the Doris North Project are presented in Table 1.1.

Table 1.1: Proposed Site Specific Reclamation Criteria for the Doris North Project

Land Reclamation Unit	Proposed Site Specific Reclamation Criteria			
	Physical Stability Requirements	**Chemical Stability Requirements**	**Ecological Sustainability Requirements**	**Climatic and Geographic Stability Requirements**
Underground Mine Workings	1) Salvageable equipment removed. All other equipment cleaned of hydrocarbons and other hazardous contaminants. 2) All mine entries sealed to prevent any future inadvertent access by humans or large wildlife using a combination of engineered concrete caps and/or backfill for raises and a backfilled rock plug in the adit portal.	1) All potentially hazardous materials removed from the UG mine; prior to waste rock deposition. 2) All chemical/hydrocarbon spills and contaminants remediated or removed; prior to waste rock deposition. 3) Placement of all potentially acid generating waste rock into the underground mine where it will remain in a frozen state due to the presence of permafrost. 4) Should future global warming trends cause permanent thawing of the permafrost, allow subsequent natural flooding of the closed mine workings to minimize ARD generation.	1) Wildlife unable to enter or come into contact with UG mine workings to protect wildlife health and safety.	1) Permafrost is not required to be sustained within the closed out underground mine workings. 2) Dry underground mine conditions are not required in the event of global warming.

Table 1.1: Continued

	Proposed Site Specific Reclamation Criteria			
Land Reclamation Unit	**Physical Stability Requirements**	**Chemical Stability Requirements**	**Ecological Sustainability Requirements**	**Climatic and Geographic Stability Requirements**
Tail Lake tailings containment area and site water management facilities	1) Stable dam side slopes with adequate geotechnical factor of safety for closure. 2) No significant wind or water erosion. 3) Dams in the water management pond breached to re-establish hydrologic flow. 4) Site drainage systems on the reclaimed site set to direct precipitation into the surrounding water courses under all precipitation events including extreme events without causing significant erosion or damage to the drainage structures left behind. 5) All non-required catch basins, sedimentation ponds and drainage structures removed or in filled so that no significant erosion occurs under all precipitation events including extreme events.	1) No significant level of contaminants in outflow from the reclaimed Tail Lake. 2) Water license discharge requirements are being met without ongoing active water treatment of seepage and drainage. 3) Site drainage consistently meets water discharge criteria and results in no significant adverse impact on water quality in the surrounding water courses and water bodies	1) Separation of wildlife and humans from contact with the underlying tailings deposited within Tail Lake. 2) No opportunity for significant transfer of contaminants to wildlife through water. 3) Water quality draining from the reclaimed site remains protective of aquatic life in the surrounding water bodies and presents no significant adverse risk to the health of wildlife.	1) Ability to shed all precipitation including extreme events without causing significant erosion or pickup of contaminants. 2) Hydrologic flow re-established under all precipitation conditions including extreme events without resulting in significant erosion.

Table 1.1: Continued

	Proposed Site Specific Reclamation Criteria			
Land Reclamation Unit	**Physical Stability Requirements**	**Chemical Stability Requirements**	**Ecological Sustainability Requirements**	**Climatic and Geographic Stability Requirements**
Buildings and Equipment	1) All potentially hazardous materials removed from the mine site and shipped south for re-cycling or proper disposal. 2) Buildings and equipment cleaned prior to demolition and all hazardous materials recovered, packaged and removed prior to demolition. 3) All equipment and buildings demolished and the demolition debris encapsulated within an appropriate landfill within Quarry 2. 4) Site clean of all equipment, steel, containers, debris and concrete. All removed and buried within the landfill. 5) All concrete foundations and slabs broken up and buried within the landfill or used as UG backfill. 6) All fuel storage facilities cleaned of hydrocarbons then demolished and removed for encapsulation within the landfill. 7) No significant erosion of rockfill building pads after removal of buildings.	1) All hazardous materials removed. 2) All chemical/hydrocarbon spills remediated or removed. 3) No significant adverse water quality in drainage across former building pads and areas. 4) All liners and berms from within fuel tank farms removed and buried within landfill. 5) All identified contaminated soils will be excavated and dependant on their level of contamination they will be either remediated on site, removed from site for off-site disposal in a licensed facility or disposed of in the underground mine or landfill so that no significant contaminant release occurs with future site drainage from these sources.	1) No contact of wildlife or humans with contaminated soils due to removal and/or placement of separation barriers. 2) No significant health risks to wildlife or humans from the reclaimed building areas. It may be desirable to leave the residual building pads in an un-vegetated state so that they do not attract wildlife for browsing for many years even centuries.	1) Site drainage restored across the remaining building pads through creation of permanent no maintenance swales or drainage channels to meet all precipitation events including extreme events without causing ponding or significant erosion in these areas.

Table 1.1: Continued

	Proposed Site Specific Reclamation Criteria			
Land Reclamation Unit	**Physical Stability Requirements**	**Chemical Stability Requirements**	**Ecological Sustainability Requirements**	**Climatic and Geographic Stability Requirements**
Infrastructure (airstrip, roads and laydown areas)	1) All culverts and bridges removed and new drainage swales or channels created that are maintenance free and will not result in significant erosion. 2) All side berms removed and shoulder slopes regraded to prevent erosion and allow safe wildlife passage.	1) No ARD or significant contaminant release from the rock fill left in place within the roads, airstrip and laydown areas. 2) All chemical spills and contaminants remediated or removed.	1) No contact of wildlife or humans with contaminated soils due to removal and/or placement of separation barriers. 2) No significant health risks to wildlife or humans from the reclaimed roads, airstrip and laydown areas.	1) Site drainage restored across the remaining roads, airstrip and laydown rock fill areas through creation of permanent no maintenance swales or drainage channels to meet all precipitation events including extreme events without causing ponding or significant erosion in these areas
Non-Hazardous Landfill Area and Quarries	1) Non-hazardous landfill site fully buried within Quarry 2. A separation barrier of quarried rock placed on top of the landfill to separate contact with the surrounding environment. 2) No significant wind or water erosion of the reclaimed landfill area. 3) Stable wall slopes within the reclaimed quarries.	1) No adverse drainage from the landfill area and quarries into the surrounding water courses.	1) No contact of wildlife or humans with the contents of the reclaimed landfill area due to the placement of a suitable stable separation barrier (cover). 2) No significant health or safety risks to wildlife or humans from the reclaimed landfill area and quarries.	1) Permafrost development and maintenance within the reclaimed landfill. 2) Ability to shed all precipitation including extreme events without causing significant erosion or pickup of contaminants.

1.6 Likely Effects of Continued Mining on the Hope Bay Belt on the Closure Plan

The reclamation plan assumes the worst case scenario specifically that at the end of the Doris North reserve there is no ongoing exploration or mining activity on the remainder of the Hope Bay belt. In the more optimistic scenario, MHBL will continue to develop additional reserves on the Belt which would continue the life of the Doris North site. MHBL has indicated that where possible from a practical and economic standpoint, the Doris North camp would continue to be used as the centre for mining other reserves found on the belt. In this case the reclamation plan will be adjusted as needed to accommodate the extended facility life. MHBL will remove all of the Doris North buildings and facilities once all further activity on the Hope Bay Belt was completed.

At some point continued use of Tail Lake to receive tailings from an expanded project (tailings from the processing of other ores on the Belt) will result in the deposition technique moving from sub-aqueous to sub-aerial as the full storage capacity of the lake was reached and tailings were deposited above the pre-development water level. Final closure of Tail Lake would then move from a water cover to the placement of a quarried rock separation barrier to isolate the dry tailings from the surrounding environment. This event will be addressed during the assessment and permitting of future development projects on the Hope Bay Belt.

2.0 SITE INFORMATION

2.1 Proponent Information

The Doris North Project, a resource component of the overall Hope Bay Belt, is owned by Miramar Hope Bay Ltd., a wholly owned subsidiary of Miramar Mining Corporation (MAE-TSE).

Project Operator:	Miramar Hope Bay Ltd. #300 – 899 Harbourside Drive North Vancouver, B.C., V7P 3S1
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Doris North Project:	Jim Currie Senior Vice President Operations and Project Manager Miramar Mining Corporation Tel. 604 985 2572 / Fax 604 980 0731
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2.2 Land Tenure Information

The proposed Doris North Project and all components of the supporting infrastructure will be constructed on Inuit owned land (with the exception of the jetty that extends into Roberts Bay and is thus on foreshore crown land. The Hope Bay mineral exploration rights property comprises an area of 1,078 km^2 and forms one large contiguous block that is approximately 80 km long by up to 20 km wide. The entire land package at Hope Bay has been maintained in good standing.

3.0 PRE-DEVELOPMENT ENVIRONMENTAL BASELINE

The following section provides a short summary description of the pre-development environmental condition and land use of the Doris North Project area. It is intended to provide the reader with an understanding or "snap shot" of; (i) the physical conditions at the Project site; (ii) of the aquatic, terrestrial and wildlife resource condition, use and habitat in the Project area; and (iii) a description of how the land and its resources are currently being used prior to project development. For additional information on the pre-development environmental conditions at the Doris North Project site, the reader is referred to the Final Environmental Impact Statement submitted to the Nunavut Impact Review Board in October of 2005 and available on the NIRB ftp site.

http://ftp.nunavut.ca/nirb/NIRB_REVIEWS/PREVIOUS_REVIEWS/02MN134-DORIS_NORTH_2004/118%20Final%20EIS/

3.1 Physical Environment

Environmental baseline studies in the Project area were carried out from 1995 to 1998 by the Project's previous owner, BHP and in 2000 through 2005 by MHBL.

3.1.1 Climate and Air Quality

MHBL, and others, have been collecting climate data in the Project area for its camps at Doris North and Boston since 1993. This site-specific climate data has been combined with data from three longer-term regional weather stations operated by Environment Canada (Lupin, Cambridge Bay, and Kugluktuk) to develop annual climate profiles for the Project planning process.

The Project area has a low arctic ecoclimate with a mean annual temperature or –12.1°C with winter (October to May) and summer (June to September) mean daily temperature ranges of -50°C to +11°C and -14°C to +30°C, respectively; and mean annual precipitation ranges from 94 mm to 207.3 mm. Annual lake evaporation (typically occurring between June and September) is estimated to be 220 mm. A precipitation and temperature profile for the area is taken from the baseline meteorology data compiled for the Doris North Project[1]. The average monthly air temperature is typically above 0°C between June and September with the peak in July, and below freezing between October and May with the coldest temperatures usually occurring in February. The mean annual precipitation adjusted for under-catch is approximately 207 mm with 41% occurring as rain between May and October and 59% as snow through the remainder of the year.

Air quality monitoring was initiated in the Project area site in May 2003. Total suspended particulate (TSP) measured in August 2003 indicated that ambient TSP concentrations were consistently low, ranging from 3.9 to 5.5 µg/m³, which is less than 5% of the federal objective (120 µg/m³) for TSP. These results are consistent with other particulate

[1] AMEC, 2003. Meteorology And Hydrology Baseline, Doris North Project, Nunavut, Canada, prepared for Miramar Hope Bay Ltd. November 2003, p.D-iii.

monitoring data gathered at remote sites in northern Canada. Concentrations of sulphur dioxide, oxides of nitrogen and fine particulates are also expected to be low in the Project Area.

3.1.2 Climate Change

The Department of Indian and Northern Affairs Canada (INAC) commissioned a technical report on the “Implication of Global Warming and the Precautionary Principle in Northern Mine Design and Closure” (BGC 2003). The Intergovernmental Panel on Climate Change (IPCC) concluded that the temperature trends indicate that some global climate change has already occurred (IPPC 1995). Their predictions for the year 2100 estimate a global mean temperature increase between 1.5^0C and 4.5^0C, with a “best estimate” of 2.5^0C. This translates into a predicted increase of up to 6^0C in the winter, 4.2^0C in the spring and about 1^0C in the summer and fall. These increases would raise the mean ambient temperature by 3.1^0C. The predictions advanced by IPCC show that climate change would eventually modify the thermal regime that currently exists in the Project area. Continuous permafrost in the Project area will remain, but the surface “active” layer (the surficial layer that thaws annually) may deepen in response to the milder mean annual temperature predicted. Inuit elders report longer summers and milder winters in recent years.

3.1.3 Geomorphology

The Project area is coastal lowland with numerous lakes and ponds separated by glacial landforms and parallel running geological intrusions of diabase dykes and sills. The drainage basins are generally long and narrow and predominantly oriented along the north-south axis. The local topography ranges from sea level at Roberts Bay to 158 m at the summit of Doris mesa, 3 km inland. The ridge separating Doris and Tail lake drainages rises to 70 m above sea level.

3.1.4 Surficial Geology, Permafrost Conditions and Seismic Risk

Bedrock ridges, oriented north/south parallel with the dominant strike of bedrock units, show the erosive effects of the northward flowing Pleistocene (Keewatin Lobe) continental glacier ice over 10,000 years ago. The surficial active layer over continuous permafrost is approximately 2 m thick. Drill core results indicate soils below the active layer contain interstitial and segregated ground ice. Most of the soils are marine in origin and include clay, silt and some sand. Drill core results along the proposed road corridor between Roberts Bay and Tail Lake shows bedrock as deep as 20 m below surface (Thurber Engineering, 2003). Surface materials include frost-churned mineral and organic soils mantled by a thin cover of tundra vegetation. Patterned ground masks the underlying soils. Small, frost-heaved clay-silt polygons are common. Linear frost cracks occur in raised marine spit deposits. Ice wedge polygons are common. The entire area lies below the post-glacial marine limit of 200 masl. Pleistocene deposits, including till, are buried beneath Holocene marine sediments deposited during the post-glacial marine emergence. Some glacial deposits show evidence of alterations by marine wave action.

Continuous permafrost extends to -560 m. (Heginbottom *et. al*., 1995). Ground temperature measurements in the Project area indicate an active zone thickness ranging between 1.5 to 2.6 m and the depth of zero annual amplitude varying between 11 and 17 m (Golder 2001; EBA 1996). The geothermal gradient measured at the Boston Camp is approximately 18°C km^{-1}, which also indicates a depth of continuous permafrost of approximately –560 m.

The Project area occurs in the seismically "Stable" zone of Canada. This region has too few earthquakes to define reliable seismic source zones.

3.1.5 Bedrock Geology

The Hope Bay Belt occurs in the Slave Structural Province, a geological sub-province of the Canadian Shield. The region is underlain by the late Archean Hope Bay Greenstone Belt. This geological formation ranges from 7 - 20 km in width and over 80 km in length. It is oriented in a north-south direction. The late Archean Hope Bay Greenstone Belt lies entirely within the faulted Bathurst Block forming the northeast portion of the Slave Structural Province. The belt is mainly comprised of mafic metavolcanic (mainly meta-basalts) and meta-sedimentary rocks that are bound by Archean granite intrusives and gneisses. Archean volcanic greenstone hosts many of Canada's precious and base metal mines (*e.g.*, Yellowknife, Timmons, Rouyn-Noranda).

3.1.6 Doris North Deposit Geology

The geology of the Doris North zone comprises a network of quartz veins more than 2 km in length. The Doris Hinge zone occurs where the Doris Central and Doris Lakeshore veins meet in a zone of mineralization 4 – 5 m wide and ranges in thickness for a few centimeters to over 40 m. It is visible at surface as a quartz outcrop at least 600 m long, plunging north at 10° and truncated by a cross cutting diabase dyke. The basaltic host rock is folded in shallow north-south trends, which also plunge north. Diabase dykes and sills of Proterozoic age in the basalt host rock range from 1 to 6 m thick. Most of the gold mineralization is hosted in quartz vein systems. Sulphide in these veins is low, averaging < 2% pyrite.

3.1.7 Geochemistry

Acid rock drainage (ARD) can occur when sulphide minerals contained in rock are exposed to air and water. It can cause environmental degradation if allowed to enter natural water bodies. Metal leaching can also occur under near neutral conditions if the rock contains readily soluble metals.

The following is a brief summary of the characterization work conducted on underground waste rock to date. The reader is referred to the following sources for additional information:

- ARD and Metal Leaching Characterization Studies in 2003 – 2005 Doris North Project, Nunavut Canada, prepared for MHBL by AMEC Earth and Environmental, dated October 2005 (Supporting Document B2 to the Final Environmental Impact Statement Technical Report submitted to NIRB in June 2005) – Section 2;

- Hope Bay Joint Venture Hope Bay Project Integrated ARD Characterization Report, prepared for MHBL by Knight Piesold, dated June 2002 (Supporting Document B4 to the Final Environmental Impact Statement Technical Report submitted to NIRB in June 2005) – Section 1 through 3; and

- Geochemical Characterization of Portal Development Rock, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007 (Supporting Document S8 to the Revised Water License Application Support Document, April 2007) – deals with additional characterization of drill holes along the upper portion of the underground decline.

Significant test work was completed to determine the acid rock generating and metal leaching potential of the rock to be disturbed by underground mining. Almost all of the rock outside the mineralized zones has low acid generating potential, and is not expected to be a source of acid rock drainage or other metal contaminants.

Samples of rock from the Doris North deposit as well as from adjacent areas around the mineralized zone were tested by acid-base accounting (ABA) analysis. In general, all waste rock extracted from outside the mineralized zone such as from the development of the underground access ramp will have low acid generating potential. All of the rock types identified as having high or uncertain acid generating potential are either from the mineralized zone or from areas immediately adjacent to the mineralized material, with one minor exception. The exception is a possible small dyke of mafic volcanic rock in the path of the proposed access decline. This intrusion has a total sulphur concentration in excess of 1% and is identified as potentially acid generating.

Characterization of the portal development rock (rock to be encountered in developing the access ramp from surface to the ore body), based on an additional 125 samples taken from a geotechnical drilling program conducted in 2006, are presented in the SRK report "Geochemical Characterization of Portal Development Rock[2]. This report concluded that the diabase and gabbro rock has low NP and low AP limiting the potential for acid production (total S generally less than 0.30 wt%) and the basalt appears to be strongly net acid consuming. In general, rock excavated for the underground access ramp outside the mineralized zone will have low acid generating potential.

MHBL will segregate all waste rock brought to surface from the underground mine workings and return this rock into the mine as backfill during the mine's operating life.

ABA testing indicates that mill tailing will have low acid generating potential.

Tests on potential quarry rock showed it is not likely to be acid generating or a source of metal leaching and so provides a clean, chemically stable construction rock. Metal Leaching/Acid Rock Drainage (ML/ARD) characteristics of rock at the proposed quarry locations were the focus of a series of investigations carried out by MHBL and AMEC Earth

[2] Geochemical Characterization of Portal Development Rock, Supporting Document S8 to the Revised Water License Application Document, April 2007.

and Environmental during 2002 through 2005[3]. The results of these investigations were summarized in a supporting document to MHBL's Final Environmental Impact Statement for the Doris North Project. The following briefly summarizes the findings of AMEC's work and provides the rationale and context for the recent 2006 investigations carried out by MHBL and SRK Consulting (Canada) Inc. (SRK). The reader is referred to the AMEC report for detailed description of methods, and for results and analysis.

Evaluation of static geochemical characteristics, consisting of metal analysis and determination of ABA parameters, was carried out on samples collected during two rounds of surface grab sampling in 2002 and 2003, as well as during a round of chip sampling in 2003. Results of these analyses showed that exposed bedrock at the proposed quarry locations had neutralization potential ratios (Sobek NP:AP and carbonate NP:AP) greater than 3:1. Rock with NP:AP>3 is generally considered to be unlikely to generate acid.

Trace element leaching was evaluated by subjecting surface chip sample composites to shake flask extraction tests. Leachates from samples from all three quarry locations were alkaline (pH 8.58 to 9.52). Metal concentrations in shake flask leachate indicated that aluminium and copper leached at concentrations exceeding CCME guidelines for protection of aquatic life. However, aluminium concentrations in leachate were likely elevated due to alkaline test conditions that resulted from exposure of fresh silicate mineral surfaces by crushing and grinding during sample preparation. Under site conditions, excess alkalinity in rock contact water would be consumed by reaction with carbon dioxide in the atmosphere, a process which is incomplete under test conditions. In addition, the particle size of the samples tested was small in comparison with quarry rock. Further, as CCME guidelines are receiving environment water quality objectives, concentrations exceeding CCME guidelines in shake flask leachate indicate only potential elements of concern, and can not be taken as indicative of metal concentrations in any receiving water as a result of seepage or runoff inputs from quarry rock.

Kinetic geochemical characteristics were evaluated with three humidity cell tests (HCTs) conducted on chip sample composites from each of the three proposed quarry locations. Kinetic test results showed that the three samples tested did not generate acidic conditions over the duration of testing, and that the rates of NP and AP depletion were consistent with generation of neutral to alkaline drainage in the long term.

A number of follow-up tests were carried out on HCT residues following the completion of kinetic testing to provide a better understanding of the mineralogical form of measured neutralization potential. These tests included determination of neutralization potential via a method designed to correct for NP generated by siderite (iron carbonate), determination of total inorganic carbon (TIC), and determination of mineralogy by quantitative x-ray diffraction (QXRD).

Results from the siderite-correction method of NP determination were inconclusive. Siderite was not identified in any of the HCT residues through QXRD, yet the siderite correction procedure indicated that siderite was present and represented up to a third of the measured

[3] ARD and Metal Leaching Characterization Studies in 2003 – 2005 Doris North Project, Nunavut Canada, prepared for MHBL by AMEC Earth and Environmental, dated October 2005 (Supporting Document B2 to the Final Environmental Impact Statement Technical Report submitted to NIRB in June 2005) – Section 2.

Sobek NP. As a result, a need for further characterization of carbonate mineralogy was identified.

In the winter of 2006, a geotechnical drilling program was conducted at all four quarry sites to better define and characterize subsurface rock conditions (2 holes per quarry site). The data obtained from this program has been used in the design and operational planning for the four proposed quarry sites. The quarry outcrops are 15 to 20 m in height and will not be mined below grade to prevent creating permanent ponds at closure. Given the nature of the bedrock geology in the area it is unlikely that the rock types seen at surface will significantly change as the quarries are developed given the relatively shallow depth of the proposed quarries (maximum of 20 m in depth). This was validated during the 2006 geotechnical drilling program.

MHBL commissioned SRK Consulting (Canada) Inc. to conduct a study on the samples derived from this drilling program to provide the geochemical characterization required to proceed with detailed project engineering for this Project. A total of 157 samples were taken from this drill program and subjected to conventional acid base accounting analysis. The data verified that the construction rock from these four quarry sites will be non-acid generating rock[4].The following is a brief summary of the results.

- To improve the understanding of the ML/ARD characteristics of rock at the proposed quarry locations, supplementary laboratory and field investigations were conducted. These investigations consisted of additional analyses on the remaining residues from prior humidity cell tests, and of additional sampling of diamond drill core at each of the four proposed quarry locations. The following points summarize the conclusions from the SRK study regarding the geochemical characteristics at the four proposed quarry locations for the Doris North Project.

- Quarry rock is not potentially acid generating, based on static and kinetic test results from analysis over the period from 2002 through 2006. Diamond drilling in 2006 expanded the lateral sample coverage, and tested the vertical dimension with two drill holes at each of the proposed quarry locations. Uniform geology was intersected at each location and geochemical parameters showed no obvious vertical patterns.

- Most of the neutralization potential measured in standard acid-base account testing is in the form of calcite and dolomite (calcium and magnesium carbonates). Quantitative x-ray diffraction analysis did not identify any siderite (iron carbonate) in the three humidity cell residues tested.

- Electron microprobe analysis of carbonate grains supported the findings that calcite and dolomite were the host minerals for all inorganic carbon in the samples tested. Calcite was found to contain trace to no iron, manganese or magnesium. Dolomite was found to contain up to 0.22 mole fraction iron and manganese, with calcium and magnesium making up the balance.

[4] Additional information on this sampling program is attached as Geochemical Characterization of Quarry Materials, Supporting Document S7 to the Revised Water License Application Support Document, April 2007.

- The mineralogy and carbonate speciation data show that most analytically-determined NP is hosted by calcium and magnesium carbonates. These minerals are sufficiently abundant and reactive to neutralize any acid that forms during the weathering of sulphide minerals from the proposed quarry rock fill.

3.1.8 Groundwater Conditions

The permafrost underlying the Project area is generally impervious to groundwater movements. Groundwater movement will only occur in the shallow active layer (to a depth of between 1.5 to 2.6 m) during its seasonal thaw period. The mining design for the Doris North deposit will not encroach on the Doris Lake talik (the area underneath the lake that thaws or is not frozen) so groundwater from that source is not expected to report to underground workings.

3.1.9 Hydrology

The Project area is located primarily in the Doris Lake outflow drainage basin. The Tail Lake basin, part of the Doris basin, is the Project's planned tailings containment area. Peak flows typically occur in June during snowmelt. A second smaller peak may occur from rainfall in late August or early September. The streams in the study area are usually frozen with negligible flow from November until May. The mean flow from June to October for Tail, Doris, and Little Roberts Lake outflows are approximately 0.03, 0.85, and 1.73 m^3/s, respectively.

3.1.10 Water Quality

Water quality samples were collected from Project area lakes, streams, and the nearby marine environment between 1995 and 2006. The lakes in the area are soft water lakes with neutral to slightly acid pH and low to moderate acid sensitivity. Total phosphorous levels were low, indicating oligotrophic to mesotrophic conditions. Chloride, sodium, and potassium concentrations were elevated compared to typical lakes in the Slave Structural Province. Some metal levels (*i.e.*, total aluminum, iron, copper, cadmium, chromium, lead and manganese) in certain lakes exceed Canadian Water Quality Guidelines (CWQG) on a seasonal basis (Table 3.1). Metal concentrations were generally representative of lakes in undisturbed northern regions. In summer, the lakes were generally well mixed. Wind likely played an important role in maintaining well-mixed conditions. In shallow lakes, wind appeared to cause complete lake turnover. Winter data generally indicated a shallow upper layer of water at or near 0°C, with constant temperatures, not exceeding 2 to 3°C, throughout the remaining water column. The lakes were typically well aerated during the summer; depressed dissolved oxygen (DO) concentrations were recorded near-bottom in winter. With the exception of Ogama Lake, this DO depression occurred in lakes with relatively high total organic carbon (TOC) levels in sediments. This suggested that sediment oxygen demand (SOD) was the underlying cause.

Marine baseline water quality sampling was conducted in Roberts Bay between 1996 and 1998. The Roberts Bay baseline data indicated a thermally stratified and well aerated water column in shallow water during summer, temperatures near 9°C and DO concentrations greater than 11 mg/L. Turbidity and total suspended solids (TSS) levels were low during summer (1.4 NTU and 11 mg/L, respectively). Most median total metal concentrations in Roberts Bay were below detection limits and below the CWQG; exceptions were cadmium and chromium (0.0035 and 0.0026 mg/L, respectively).

Table 3.1: Baseline Water Quality Parameters That Exceeded Canadian Water Quality Guidelines in the Lakes of the Doris North Project Area

									Water Quality Guidelines[b]	
Parameter (units)	**Ice Covered (April to June)**				**Open Water (July to Sept)**				**Drinking**	
	Med	**Min**	**Max**	**n**	**Med**	**Min**	**Max**	**n**	**Water**	**Aquatic Life**
Doris Lake (1995 - 2003)										
pH (units)	7.06	6.47	7.66	11	7.19	**5.90**	7.80	33	6.5 - 8.5	6.5 - 9.0
Total Suspended Solids (mg/L)	4	<1	11	11	4	<1	11	33		Short-term increase, 25; long term increase < 5
Turbidity (NTU)	**4.4**	**3.0**	**10.3**	7	**4.8**	**2.1**	**8.0**	20	1	long term increase <2
Total Aluminum (ug/L)	**9**	5	19	8	40	18	**120**	27		100
Total Arsenic (ug/L)	0.40	0.30	0.62	8	0.5	<0.1	**15.0**	27	25	5
Total Cadmium (ug/L)	<0.2	<0.05	**0.42**	12	<0.05	<0.05	<0.20	31	5	0.016
Total Chromium (ug/L)	<1	0.4	<1	8	0.5	<0.5	**3.5**	27	5	1
Total Copper (ug/L)	**3.0**	**2.0**	**5.0**	12	1.3	<0.5	**2.3**	31	≤1000	2
Total Iron (ug/L)	20	<10	40	8	90	40	**720**	27	≤300	300
Total Lead (ug/L)	<1	0.12	**4.00**	12	0.26	<0.05	**1.00**	31	10	1
Total Manganese (ug/L)	<5.0	1.8	<5.0	8	12.0	5.2	**191.0**	27	≤50	
Total Selenium (ug/L)	<0.50	<0.05	<0.5	8	0.50	<0.50	**4.00**	27	10	1
Total Zinc (ug/L)	12	2	**118**	5	2.5	<1	19.0	31	≤5000[d]	30
Tail Lake (1995 - 2003)										
pH (units)	7.15	6.94	7.39	4	7.31	**5.50**	7.90	17	6.5 - 8.5	6.5 - 9.0
Total Suspended Solids (mg/L)	2	<1	3	4	2	<1	7	17		Short-term increase, 25; long term increase < 5
Turbidity (NTU)	**3.8**	0.8	**6.7**	4	**2.1**	0.3	**5.5**	14	1	long term increase <2
Total Aluminum (ug/L)	**110**	47	**170**	3	31	19	**309**	15		100
Total Cadmium (ug/L)	<0.2	<0.2	**0.2**	3	<0.10	<0.05	0.12	15	5	0.016
Total Chromium (ug/L)	**2**	<1	**3**	3	<0.5	<0.5	**2.3**	15	5	1
Total Copper (ug/L)	**4.8**	**4.0**	**7.0**	3	1.2	<0.5	**3.8**	15	≤1000	2
Total Iron (ug/L)	213	120	**300**	3	60	40	**300**	15	≤300	300
Total Lead (ug/L)	<1	<1	**1**	3	0.11	0.05	0.50	15	10	1
Total Selenium (ug/L)	<0.5	<0.5	<0.5	3	0.5	<0.5	**4.0**	15	10	1
Total Zinc (ug/L)	6	<5	7	3	<1	<1	**85**	15	≤5000[d]	30
Ogama Lake (1995 - 2000)										
pH (units)	6.94	**6.43**	7.38	7	7.10	6.64	7.35	6	6.5 - 8.5	6.5 - 9.0

									Water Quality Guidelines[b]	
Parameter (units)	**Ice Covered (April to June)**				**Open Water (July to Sept)**				**Drinking**	
	Med	**Min**	**Max**	**n**	**Med**	**Min**	**Max**	**n**	**Water**	**Aquatic Life**
Total Suspended Solids (mg/L)	2	<1	12	7	5	4	7	6		Short-term increase, 25; long term increase < 5
Turbidity (NTU)	**8.8**	**4.1**	**13.2**	5	**9.5**	**6.3**	**12.1**	4	1	long term increase <2
Total Aluminum (ug/L)	**261**	**216**	**300**	5	**425**	**334**	**452**	5		100
Total Cadmium (ug/L)	**0.4**	<0.2	**0.8**	7	<0.20	<0.05	<0.20	7	5	0.016
Total Chromium (ug/L)	**1.8**	1.5	**2**	5	**1.7**	<1	**2.3**	5	5	1
Total Copper (ug/L)	**5**	**2**	**12**	7	**2.0**	<1	**3.9**	7	≤1000	2
Total Iron (ug/L)	**435**	200	**650**	5	**435**	270	**580**	5	≤300	300
Total Lead (ug/L)	**1.5**	<1	**3**	7	<1	0.2	<1	7	10	1
Total Manganese (ug/L)	**170**	17	**329**	5	17	8	25	5	≤50	
Patch Lake (1995 - 2000)										
pH (units)	7.13	**6.10**	7.52	11	7.10	**6.10**	7.82	13	6.5 - 8.5	6.5 - 9.0
Total Suspended Solids (mg/L)	1	<1	4	11	1	<1	12	13		Short-term increase, 25; long term increase < 5
Turbidity (NTU)	0.9	0.5	**4.4**	7	**3.0**	**2.5**	**4.0**	7	1	long term increase <2
Total Aluminum (ug/L)	30	7	99	8	69	22	**182**	10		100
Total Cadmium (ug/L)	<0.2	<0.05	**0.2**	12	<0.2	<0.05	<0.2	14	5	0.016
Total Chromium (ug/L)	**1**	0.7	**2**	8	<1	0.5	**2.4**	10	5	1
Total Copper (ug/L)	**3.0**	1.0	**7.0**	12	1.0	<0.5	**2.7**	14	≤1000	2
Wolverine Lake (1995 - 2000)										
Total Suspended Solids (mg/L)	2	1	5	4	2			1		Short-term increase, 25; long term increase < 5
Turbidity (NTU)	**2.0**	**1.1**	**2.9**	4	**2.7**			1	1	long term increase <2
Total Copper (ug/L)	**3.0**	**2.0**	**3.0**	4	<1			1	≤1000	2
Total Iron (ug/L)	**360**	**300**	**400**	4	280			1	≤300	300
Total Manganese (ug/L)	42	26	**58**	4	12			1	≤50	
Windy Lake (1995 - 2000)										
pH (units)	7.52	**6.33**	7.73	5	7.58	6.90	8.00	13	6.5 - 8.5	6.5 - 9.0
Total Suspended Solids (mg/L)	<1	<1	2	5	2	<1	19	13		Short-term increase, 25; long term increase < 5

Parameter (units)	Ice Covered (April to June)				Open Water (July to Sept)				Water Quality Guidelines[b]	
	Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Turbidity (NTU)	**1.2**	0.3	**2.1**	3	**1.8**	0.6	**5.0**	10	1	long term increase <2
Total Aluminum (ug/L)	14	9	19	4	42	12	**147**	11		100
Total Arsenic (ug/L)	0.40	0.20	0.6	4	1.0	0.1	**5.0**	11	25	5
Total Chromium (ug/L)	<1	<1	<1	4	**1.8**	<0.5	**5.3**	11	5	1
Total Copper (ug/L)	<2	<1	**2.0**	6	1.0	0.8	1.4	13	≤1000	2
Total Lead (ug/L)	**1**	<1	**1**	6	0.64	0.07	<1	13	10	1
Total Selenium (ug/L)	<0.50	<0.50	<0.50	4	**2.0**	<0.5	**5.0**	11	10	1
Little Roberts Lake (1995 - 2003)										
Total Suspended Solids (mg/L)	-	11	21	2	3	<1	11	9		Short-term increase, 25; long-term increase < 5
Turbidity (NTU)	-	-	-	0	1.9	0.8	**5.8**	7	1	Long-term increase <2
Total Aluminum (ug/L)	-	-	-	0	**209**	**53**	**343**	5		100
Total Chromium (ug/L)	-	-	-	0	<1	<1	**2.7**	5	5	1
Total Copper (ug/L)	-	**3**	**9**	2	**2**	1	**3.4**	7	≤1000	2
Total Lead (ug/L)	-	<1	**1**	2	0.50	0.15	**4.0**	7	10	1
Total Selenium (ug/L)	-	-	-	0	0.25	<0.2	**2.80**	5	10	1
Total Zinc (ug/L)	**169**	10	**327**	2	<5	<5	8	7	≤5000[d]	30
Pelvic Lake (1995 - 2000)										
Total Suspended Solids (mg/L)	3	<1	5	3	7	4	10	6		Short-term increase, 25; long-term increase < 5
Turbidity (NTU)	**6.1**	**6.0**	**6.3**	3	**8.3**	**5.3**	**11.7**	6	1	Long-term increase <2
Total Aluminum (ug/L)	-	93	95	2	**147**	66	**338**	6		100
Total Copper (ug/L)	-	**13.0**	**14.0**	2	1.4	1.0	**2.0**	6	≤1000	2
Total Iron (ug/L)	-	80	110	2	298	170	**430**	6	≤300	300
Total Lead (ug/L)	-	**1**	**2**	2	**1.50**	0.08	**5.00**	6	10	1

Results listed in this table represent values measured outside the Canadian Council of Ministers of the Environment (CCME) guidelines. All other parameters measured were within the guidelines.

[a] Values in bold are equal to or greater than guidelines

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from US EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water 10.3 °C) periods were used to assess ammonia concentrations.

[d] Aesthetic Objective

Additional water quality sampling was conducted by MHBL during 2003 and 2004[5]. These programs have added data to the data base presented in Table 3.1. This additional data is reported in the following reports:

- Doris North Project Aquatic Studies 2003, prepared by Golder Associates (Report 03-1370-007, dated November 2003;
- Doris North Project Aquatic Studies 2004, prepared by Golder Associates (Report 04-1373-009, dated February 2005.

Sediment samples were collected in the lakes in the Project area. Metal concentrations in sediments were compared with the Canadian Interim Sediment Quality Guidelines (CISQG) for the Protection of Aquatic Life (CCME 1999). The CISQG recommends using two guidelines in assessing sediment quality: the Threshold Effect Level (TEL) – the concentration below which adverse effects are rare; and the Probable Effect Level (PEL) - the concentration above which adverse effects are likely. Most lake sediment metal levels fell below the CISQG. The exceptions were total chromium, total copper, total arsenic and total cadmium. Of these, total chromium values exceeding the guidelines were the most widespread geographically and temporally, with concentrations exceeding the CISQG PEL in three of the eight lakes (Doris, Tail and Patch). Overall sediment metal concentrations remained within the range of natural variability for the Slave Structural Province. Sediment TOC levels varied between lakes. For lake sediments with relatively elevated TOC (Doris and Tail Lakes), colour and mineralogy indicated that reducing conditions were predominant in the surface layer as well as underlying sediments. For lake sediments with relatively low to moderate TOC concentrations, colour and mineralogy indicated a strong redox gradient between an oxic surface layer and reducing underlying upper layer.

Roberts Bay sediment samples were primarily clay-sized. The exception was the shallowest station (Station S5) sample that consisted of primarily fine sand. TOC ranged from <0.05 to 0.72% dry weight, with no apparent relationship between water-column depth and TOC content. Total metal concentrations in Roberts Bay seabed sediments were, for the most part, within the sediment quality guidelines. Total chromium (66 mg/kg) and total copper (26 mg/kg) exceeded the CISQG TEL at two sites.

3.2 Biological Environment

3.2.1 Marine Biota and Marine Habitat

Marine biology studies conducted by MHBL and others provide descriptions for benthic invertebrates, fisheries resources, marine mammals, avifauna, and shoreline habitats. The benthic communities in Roberts Bay are dominated by Polychaeta, Nematodes, Pelecypoda, Cumacea and Amphipoda. Polychaeta (lugworms, tube worms and marine bristle worms) contributed to more than 50% of benthic community total numbers. The

[5] MHBL also collected baseline water samples throughout 2005 and 2006. These results have not been incorporated in Tale 3.1. Water quality from this additional sampling yielded background concentrations equivalent to those measured in 2004.

composition of benthic communities was found to be typical for Arctic and Antarctic regions. Ringed seals were the only marine mammal species identified during 1996 spring marine aerial surveys (Rescan, 1996). Marine habitat characterization along the shoreline of Roberts Bay was mapped (based on aerial observations). The southern shoreline around the mouth of Glenn and Little Roberts outflows was classified as good to excellent habitat for anadromous fish, such as Arctic char. Coastal surveys for birds and bird colonies were flown in August 2000. No colonies were found in Roberts Bay. Numerous flocks of waterfowl, mostly molting eider and Canada geese were observed along the coast.

3.2.2 Freshwater Biota and Habitat

Aquatic biota was sampled in Doris, Tail, Ogama, Patch, Wolverine, Windy, Little Roberts, Roberts, and Pelvic lakes. A comparison of periphyton abundance among the study streams suggested that Doris, Ogama, and Windy outflows were highly productive and that Tail Outflow, closely followed by Pelvic Outflow, were the least productive. Phytoplankton chlorophyll *a* samples were collected to assess the productivity of lakes in the Project area. Tail Lake was the least productive of the lakes sampled with a mean chlorophyll a value of 0.75 mg/m^3, while Doris Lake had a mean value of 7.71 mg/m^3. The benthic communities of the lakes sampled are similar in many respects to the communities of other small lakes in the Canadian Arctic and sub-Arctic.

Seven fish species occur in the Doris North Project area: Arctic Char, broad whitefish, cisco, lake trout, lake whitefish, least cisco, and ninespine stickleback. Lake whitefish and cisco accounted for approximately 90% of the fish sampled in Doris, Ogama and Pelvic Lakes. Lake trout were more dominant in Patch and Windy Lakes. Only lake trout and ninespine stickleback inhabit Tail Lake. Fish populations in Little Roberts Lake included Arctic char, broad whitefish, least cisco, cisco, lake trout, lake whitefish, and ninespine stickleback. A waterfall (approximately 4.3 m in height) between Doris and Little Roberts lakes prevents passage of diadromous fish species such as Arctic char and broad whitefish into the Doris Lake drainage. Little Roberts Lake is used by Arctic char during their movements between Roberts Lake and the ocean.

Fish assemblages in streams in the Project area were dominated by Arctic char, ninespine stickleback and lake trout. Arctic char were the most common (61% of total catch); most of these fish were captured at a fish fence installed in Roberts Outflow during 2002 and 2003 to monitor the number of migratory Arctic char from Roberts Bay to Roberts Lake. Ninespine stickleback was second in abundance (23%) and was the most widely distributed species and encountered in each of the 14 streams sampled. Lake trout was third in abundance (13% of the total catch) and second in distribution (encountered in 10 of 14 streams). Juveniles and adults were present in the catch, suggesting that the larger streams provide both rearing and feeding habitat.

Baseline metal concentrations in fish tissue (dorsal muscle, liver, and kidney) were analyzed from lake trout, lake whitefish, and cisco sampled from Doris, Tail, Ogama, Patch, Windy, and Pelvic Lakes, from Arctic char in Roberts outflow and lake trout from Roberts

Lake. In general, low levels of metal concentrations were documented, with the exception of arsenic and mercury. The highest mean concentration of arsenic (1.95 µg/g dry weight) was recorded in a lake trout liver from Windy Lake. Similarly, the highest mean mercury concentration (3.31 µg/g dry weight, was recorded in a lake trout liver from Patch Lake. Metal concentrations in fish tissues from Pelvic Lake (as selected as a control basin for long term monitoring) were similar or intermediate to corresponding levels from other study lakes. A small proportion of lake trout muscle tissue samples (8 of 113) from the study area lakes exceeded the Health Canada food consumption guideline of 0.5 µg/g wet weight (roughly equivalent to 2.5 µg/g dry weight) for mercury (6 fish from Patch Lake, 1 from Doris Lake, and 1 from Roberts Lake). The maximum mercury concentration was 0.68 µg/g wet weight. Older and larger lake trout had greater concentrations of mercury in their tissues and these fish were most likely to have muscle mercury concentrations above the Health Canada guideline. All lake whitefish and Arctic cha muscle tissues contained mercury levels that were below Health Canada guidelines; the maximum concentrations were 0.22 µg/g and 0.036 µg/g wet weight, respectively.

The shoreline or littoral zones of Doris, Tail, Roberts and Little Roberts lakes were assessed for habitat characterization by aerial and ground surveys. Doris and Roberts lakes had the highest diversity and highest quality of littoral substrate types, based on the presence of sand, cobble, and boulder substrates that provide fair to high quality habitats (spawning, rearing, and feeding) for lake trout, Arctic char, and coregonid species. The littoral zone of Tail Lake was rated as poor to fair habitat for lake trout because of the predominance of bedrock substrates. Little Roberts Lake has the least diverse littoral habitat with silt and sand dominating the substrate; the entire shoreline was rated as fair quality fish habitat because these fine substrates provide some feeding habitat. Despite the rating of only fair, Little Roberts Lake had the highest diversity of fish species (7 species) of the lakes sampled in the Project area. Fish use Little Roberts Lake as a migratory corridor from the ocean to Roberts Lake and it is likely fish do not over winter in Little Roberts Lake due to the shallow water depths (mean depth of 2.0 m and max depth of 4.1 m) that likely result in the water freezing to the lake bottom.

None of the fish species that occur in the Project area are designated as endangered or threatened by COSEWIC (2004).

The shoreline or littoral zones of Doris, Tail, and Little Roberts lakes were assessed for fisheries habitat characterization by aerial survey. Doris Lake had the highest diversity of littoral substrate types based on the presence of sand, cobble, and boulder substrates that provide fair to high quality habitats (spawning, rearing, and feeding) for lake trout and coregonid species. Doris Lake has the most suitable shoreline habitat among the three surveyed lakes. The littoral zone of Tail Lake was rated as poor to fair habitat for lake trout and coregonids because of the predominance of bedrock substrates. Little Roberts Lake has the least diverse littoral habitat with silt and sand dominating the substrate; the entire shoreline was rated as fair quality fish habitat because these fine substrates provide feeding habitat. Despite the rating “fair”, Little Roberts Lake had the highest diversity of fish species of the lakes sampled in the Project area, likely due to the passage for diadromous species from Roberts Bay.

Stream habitat assessments were conducted at 17 stream sites. Streams that interconnect lakes or flow into Roberts Bay appeared to support the highest diversity of fish habitat for rearing, adult feeding, spawning, and migration. The associated lakes likely provide over wintering habitat, which lacking in streams due to shallow depths. Most of the small inflow tributaries that did not feature a lake or pond upstream were found to be either ephemeral, run-off from melt waters, or provided only marginal rearing and feeding habitat near their mouths. Most lake outflows had a wide diversity of in-stream habitats with riffles and runs dominating, with lesser quantities of rapids in half the outflows. Migration habitat was rated as good to excellent in Little Roberts and Roberts outflows. The outflow from Tail Lake provided marginal fish habitat, with virtually no migration corridor to Doris Lake. The outflows from Roberts and Little Roberts lakes also provided adult feeding, rearing, and spawning habitats to populations of Arctic char that likely over-winter in Roberts Lake. Although Doris Outflow was diverse in fish habitat and species, a 4.3 m waterfall approximately 400 m downstream of the lake prevents upstream migration isolating the fish populations in Doris Lake from diadromous migrants entering freshwater from Roberts Bay.

3.2.3 Vegetation

Vegetation in the Project area is characteristic of sub-arctic tundra vegetation. Three ecosystem units dominate the area: the ocean shoreline association; lowland ecosystems; and the rock outcrop and upland ecosystems. Several plant communities make up each of these ecosystems. Plant species identified include 19 shrubs, 92 herbs, 18 grasses, 32 sedges and rushes, 21 mosses and 8 species and/or genera of lichen. Inuit traditionally use many local plant species and understand the relationship between plants and caribou habitat requirements including the early showing of plants in snow free areas and the importance of such areas to caribou calving locations in the region. None of the local plants identified during the course of baseline studies are designated as endangered or threatened (COSEWIC, 2004).

3.2.4 Wildlife

The Project area provides habitat for a variety of mammals including: shrews, voles and lemmings, hares, ground squirrels, weasels, wolves and foxes, grizzly bears, caribou, and muskox. Many are year-round residents in the Project area while others such as caribou and musk-ox, are nomadic or migratory. Some large predators/scavengers such as grizzly bear, wolverine and wolf may have large ranges that extend across or beyond the Project area. The small mammal species present, including ground squirrels and Arctic hare, spend their entire life in a small area. Project area vole and lemming populations are cyclic affecting the abundance and productivity of both bird and mammal predators. Weasel populations will cycle in synchrony with vole and lemming populations. The dominant wildlife species in the Project area is caribou. Three herds occur in the region that could possibly interact with the Project. They include the Dolphin-Union herd, the Ahiak herd and the Bathurst herd. The Dolphin-Union herd is a herd that has special interests from a resource management and conservation perspective. The Project is generally situated on the fringes of all three herds.

The Project area also provides breeding habitat for a wide range of resident and migratory birds including songbirds, upland birds, shorebirds, waterfowl, seabirds and raptors. There is an abundance of raptors in the Project area including peregrine falcon, gyrfalcon and golden eagle. The Project area provides foraging and nesting habitat for a wide range of cliff nesting and ground nesting raptors. Some birds such as peregrine falcon have been the focus of special conservation and management efforts since the 1970s.

3.3 Land/Water Use

The Doris North Project is situated entirely on Inuit Owned Lands administered by the KIA with minerals development authority vested with Nunavut Tunngavik Inc. (NTI). MHBL has submitted Project related applications to the following authorizing agencies:

- Kitikmeot Inuit Association (KIA) - Land Use Application;
- Nunavut Water Board (NWB) Water – Water Use License Application including Supplementary Questionnaire for Mine Development;
- Indian and Northern Affairs Canada – Foreshore Land Lease Application under the Territorial Lands Act for use of the ocean floor to construct and operate the marine jetty; and
- Fisheries and Oceans Canada - Application for Authorization for Works or Undertakings Affecting Fish Habitat and for inclusion of Tail Lake on Schedule 2 of the Metal Mining Effluent Regulation (MMER).

3.4 Protected Areas

There are no protected areas in, or adjacent to the Project area. The closest designated land use restriction is the Queen Maud Gulf Bird Sanctuary located approximately 40 km east of the Hope Bay Belt.

3.5 Archaeology

West Kitikmeot has a diversity of archaeological and historic resources and such resources comprise an important aspect of Inuit culture, spirituality and perspectives with respect to relationships with the land. MHBL has completed comprehensive baseline surveys for historic and cultural resources in the Project area and have identified over 100 sites with some being in close proximity to Project features. Project features such as the road to Tail Lake from the plant site and two of the proposed quarries could affect up to four archaeological sites, none of which is considered to be of high value and thus can be mitigated through data collection.

4.0 PROJECT DESCRIPTION

4.1 Project Summary

Miramar Hope Bay Ltd is proposing to construct, operate and reclaim a small underground gold mine (the Doris North Project) on the Canadian mainland in the West Kitikmeot region of Nunavut approximately 125 km southwest of Cambridge Bay and 75 km northeast of Umingmaktok. The Project is located on Inuit Owned Land at 68 09" deg. N x 106 40" deg. W, 5 km south of the head of Roberts Bay, an extension of Melville Sound which connects with Bathurst Inlet about 80 km west of the Project.

The Project consists of construction, operations, decommissioning and post closure phases, with exploration activities being conducted throughout the development and operations periods.

Mineral exploration on the 80 km long Hope Bay greenstone belt has been ongoing since the early 1990's. MHBL has been exploring for commercial mineral deposits in the area since 2000 when it acquired the right to conduct such exploration from BHP Minerals Ltd. Since then a number of prospective gold deposits have been found, out of which three significant mineralized areas have been identified: the Boston area, the Doris North area (includes Doris North, Doris Connector and Doris Central) and the Madrid area (includes the Naartok, Suluk and Madrid mineralized resource areas).

Exploration work conducted through 2001, indicated that the Doris North deposit had readily accessible higher ore grade resources than the Boston or Madrid mineralized areas and thus offered Miramar an opportunity to reach commercial production at a low capital outlay. A feasibility study was completed on developing the Doris North resource in early 2003. This feasibility study indicated that this resource could be economically developed as a small tonnage underground mine (subject of this document). This feasibility study is currently being updated by SNC-Lavalin to reflect 2007 market conditions in preparation for an MHBL Board of Directors decision on whether to proceed to commercial production. The updated feasibility study is scheduled to be completed by mid 2007.

MHBL has continued exploration activity at other sites on the belt with primary focus on the Boston and Madrid areas. In 2005 and 2006 the Company continued drill programs designed to upgrade gold resources at the Boston and Madrid deposits to technical levels which, if results are positive, would be incorporated into feasibility studies to be started in the second half of 2007. To date, feasibility studies on the resources at these other two areas have not been completed and thus it is not known whether the resources identified in these areas can be commercially developed. However, MHBL is encouraged by its exploration activity at both the Madrid and Boston areas and feels that there is good reason to be optimistic that sufficient resources will be identified at both of these sites to allow these deposits to also be brought into commercial production in the foreseeable future.

The Doris North Project will consist of an underground mine with a single adit and ramp access. The ore will be brought to surface where it will be stockpiled and processed through a crushing and milling plant with a nominal capacity of 720 t/day (design capacity of 800 TPD and an operating factor of 90.0%). The product will be shipped off site in the form of dore bars. This Project is expected to operate for 24 months, process 460,000 tonnes of ore yielding approximately 311,000 ounces of gold. The site is remote and there are no permanent or winter roads that link it to any neighbouring communities or facilities. Currently, there is no infrastructure development on the site, with the exception of an exploration camp on the east shore of Windy Lake, located approximately 10 km west of the Project site. The primary access route to the property for fuel, equipment and supplies will be via the Arctic Ocean (sealift from Hay River). The proposed mill site is located approximately five kilometres from Roberts Bay. This area is accessible by ships and barges for a short ice-free shipping season. A jetty will be constructed in Roberts Bay as a landing facility for the sealift vessels (barge and tugs). Equipment will be offloaded and stored in a lay down area close to the shore. Annual fuel supply will be trucked from the sealift vessels to a 7.5 million litre tank farm constructed at the plant site.

A 4.8 km all-weather road will link the Roberts Bay sealift landing site with the mill and camp location (plant site), allowing year-round haulage of supplies from the sealift landing site laydown area. The mill, crushing plant, fuel storage tank farm, camp, offices, workshops, power generation plant, sewage treatment plant and all other operational mine infrastructure will be located in a central location adjacent to the underground mine adit. An all-weather airstrip, suitable for small aircraft will be constructed along the alignment of the main road between the plant site and Roberts Bay. During summer months the site will also be serviced by float planes and for that purpose a floating dock will be constructed at the north end of Doris Lake. This dock will be linked to the mill site with an all-weather road. During winter months an airstrip capable of handling larger aircraft will be constructed on the ice on Doris Lake and the site serviced from this airstrip.

Flotation tailings and treated barren bleed solution produced during the milling process will be deposited in Tail Lake about five kilometres from the proposed mill location. Tailings deposition will be sub-aqueous, requiring the construction of two water retaining structures: the North and South Dams. The tailings will be contained in Tail Lake by constructing a low permeability frozen core dam across the outlet of Tail Lake to the north and by a similar second dam constructed across a topographic low point at the south end of the lake. An all-weather service road will be constructed along the east side of Tail Lake all the way to its southern end. The tailings pipeline will follow the roadway, and emergency tailings dump ponds will be constructed at strategic locations. Barren bleed solution from the cyanide leach circuit within the mill will be treated in a water treatment plant within the mill to destroy residual cyanide and precipitate heavy metals and then combined with flotation circuit tailings before being discharged into Tail Lake. The tailings from the cyanide leach circuit will be treated in the cyanide destruction circuit, thickened and filtered with the dry solids placed underground as mine backfill. The water quality eventually discharged from Tail Lake will meet discharge standards established under the Metal Mining Effluent Regulation. A discharge strategy has been developed to release water from Tail Lake on an annual basis during open water periods. This water will be pumped to Doris Creek at a point immediately upstream of a 4.3 m high waterfall where the Tail Lake water will mix with the outflow from Tail Lake. Under the discharge strategy it is predicted that water quality within Doris Creek downstream of the waterfall will meet Federal water quality guidelines (Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life – Canadian Council of the Ministers of Environment (CCME)) for the protection of freshwater aquatic life (fish and benthic invertebrates).

MHBL is currently scheduling the initial mobilization of construction equipment to the Doris North site across the sea ice from Cambridge Bay in April 2007. A limited program of pre-development construction is scheduled to commence in the second quarter of 2007 (pending appropriate approvals from the KIA). Additional construction material and supplies will be shipped to Roberts Bay in the summer sealift in 2007 to be offloaded in August and moved to the mill site early in the winter of 2007/2008. This will include the permanent accommodation camp and fuel storage tank farm. The remaining milling equipment and operating supplies would arrive on the 2008 sealift. The mill and camp pads, remaining access roads, the airstrip and the tailings containment dams and access roads will be constructed over the 2007-2008 winter (early 2008)

Mine development will start in the 3rd quarter of 2007 with the collaring of the portal. Production mining (ore) would commence in the 3rd quarter 2008 and continue through the end of 2010. Milling will start approximately one month after production mining starts (4th quarter 2008) and continue through to the end of 2010.

The decommissioning phase of the Project will commence after all ore has been depleted, and will consist of reclamation and decommissioning activities related to all of the facilities constituting the Project.

Proposed Development

- A 24-month operating life based on currently known ore reserves;
- An underground mine producing approximately 460,000 tonnes of ore and 195,000 tonnes of waste rock;
- Non-Acid generating rock extracted from four quarry sites located in close proximity to the proposed infrastructure components will be used in construction of surface infrastructure (building pads, laydown areas and roads);
- An ore processing plant on site at a nominal rate of 720 tonnes per day (262,800 tonnes per annum) to produce ~311,000 ounces of gold over two years;
- Ore treatment by gravity separation, followed by froth flotation, cyanide leach of the flotation concentrate and recovery of the dissolved gold using activated carbon in a Carbon-in-Leach circuit;
- Gold bullion smelting at an on-site facility producing a gold dore; and
- The cyanide leach circuit thickener underflow slurry will be pumped to the cyanide destruct circuit where the remaining cyanide will be destroyed in a cyanide destruction circuit (water treatment plant). The treated slurry will then be sent to a thickener with the excess water (thickener overflow) recycled back to the cyanide destruction circuit. The thickener underflow slurry will then be filtered through a pressure filter to produce a “dry” filter cake to be placed underground as backfill. The target moisture content in this filter cake is 8.5% moisture by weight. The filtrate from the filter will also be recycled back to the cyanide destruction circuit;

- Approximately one third of the recycled residue thickener overflow and filtrate from the pressure filter will be bled to tailings (estimated to average 1.31 tonnes per hour) to remove a build up of metal contaminants. This bleed stream will be mixed with the rougher flotation tails and pumped to the tailings containment area (tailings pond). This will provide a dilution ratio of 30.3:1 (bleed solution to rougher flotation tails solution); and

- Treated greywater from the sewage treatment plant and sewage sludge will be co-disposed with Tailings into Tail Lake.

Access and Transportation

- Sealift of construction and operating supplies to an off-loading site at the south end of Roberts Bay, approximately 5 km from the Doris North Site;

- A rockfill jetty constructed in Roberts Bay for barge loading/off loading;

- A 4.8 km all-weather access road to be constructed from Roberts Bay to the Doris North Project site;

- A 914 m long airstrip to be constructed as a widened section of the all weather access road from Roberts Bay;

- Float and ski plane access on Doris Lake; and

- Ice strip for aircraft in winter on Doris Lake.

Utilities

- Power Supply - On-site installed diesel generators at the Doris North Project site (4 x 1.0 MW units);

- Freshwater Supply - Doris Lake;

- Process water - Approximately 40% of recycle water from the tailings containment area should be achievable for the first year after which recycle may increase to 100%. The deficiency in process water would come from Doris Lake; and

- 175-person accommodation camp on site.

4.2 Ore Reserves and Mine Life

The Doris North Project as proposed will be a small, short-life underground gold mine. The mine is expected to produce 460,000 tonnes of ore over a two-year mine life. This represents the known mineable reserve in the Doris Hinge ore zone. The expected diluted grade is 22.0 g/t gold with a predicted milling recovery of 94.9%. The surface expression of the ore deposit is shown in plan view in Figure 4.1.

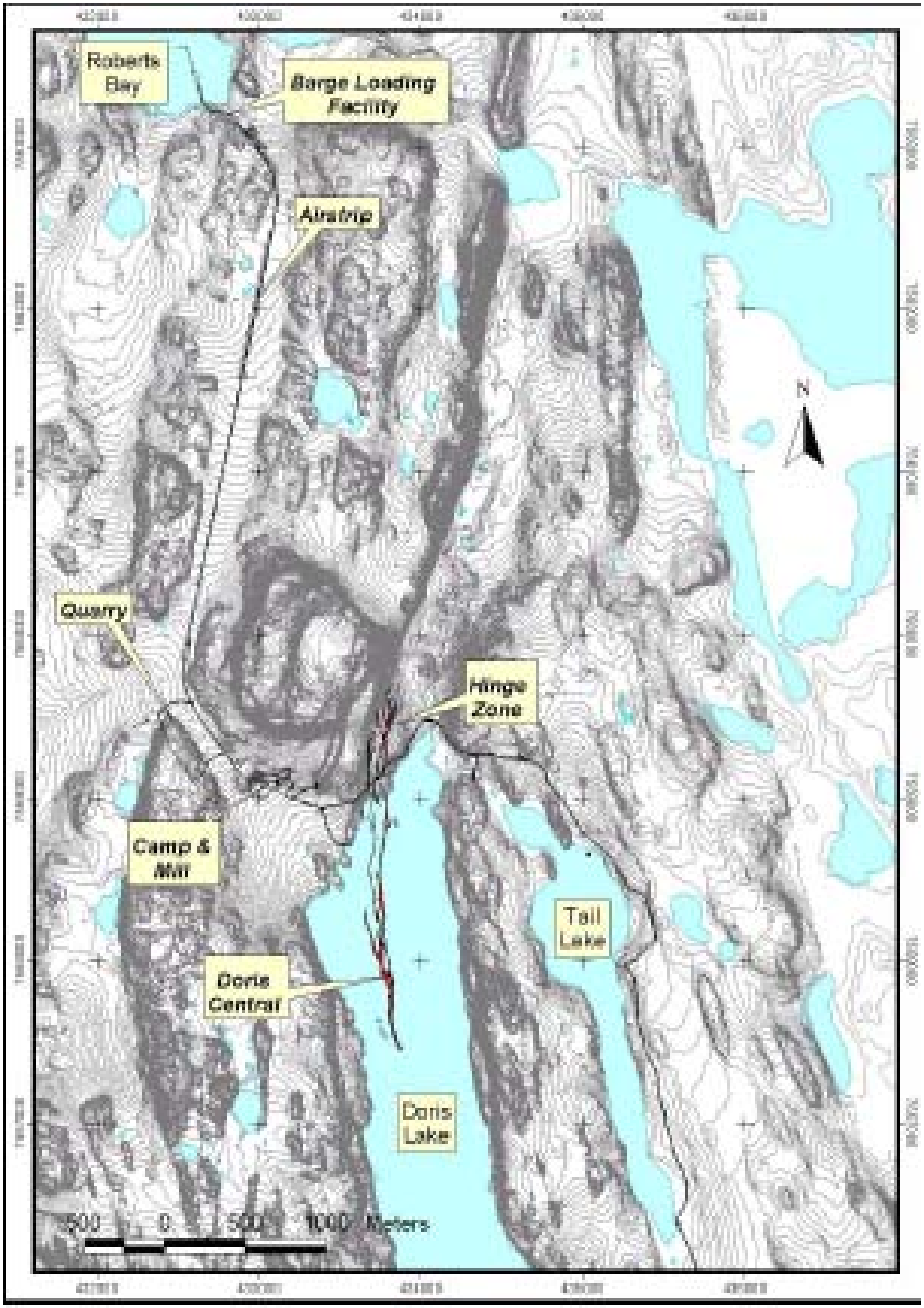


Figure 4.1: Surface Expression of Ore Zones

4.3 Underground Mine

Underground mining will be carried out by a combination of mechanized cut and fill and open stoping, assuming a minimum mining width of 2.5 m and external dilution averaging 17% at zero grade. A full spectrum of mining methods was considered. One of the most important aspects to consider was control of excavation geometry as this is a very high-grade deposit with variable and narrow geometry. Mining methods selected were, open stoping (drilling with electric hydraulic jumbo drills and jacklegs) and mechanized cut and fill. Mining methods were assigned to portions of the deposit based on shape of the mining solid and apparent vein variability defined by drilling. The selected methods are described below:

4.3.1 Open Stoping

Open stoping was chosen for all of the hinge area. It is a top-down mining method where the majority of the drilling will be done by electric-hydraulic jumbos using 4 m steel. A 3 m by 3 m pilot drift will be driven in ore, following the hanging wall near the apex of the hinge, and the ore along the sides will be slashed into the drift. Ground support, will be installed and the floor will be benched by drilling and blasting to recover all the ore.

The design allowed for a maximum of 20% in-stope-ramp grade on the hanging wall and footwall. Where the hinge plunged more steeply than could be followed with an in-stope-ramp at 20% grade, waste mined to maintain the 20% was included in the mining solid as internal dilution.

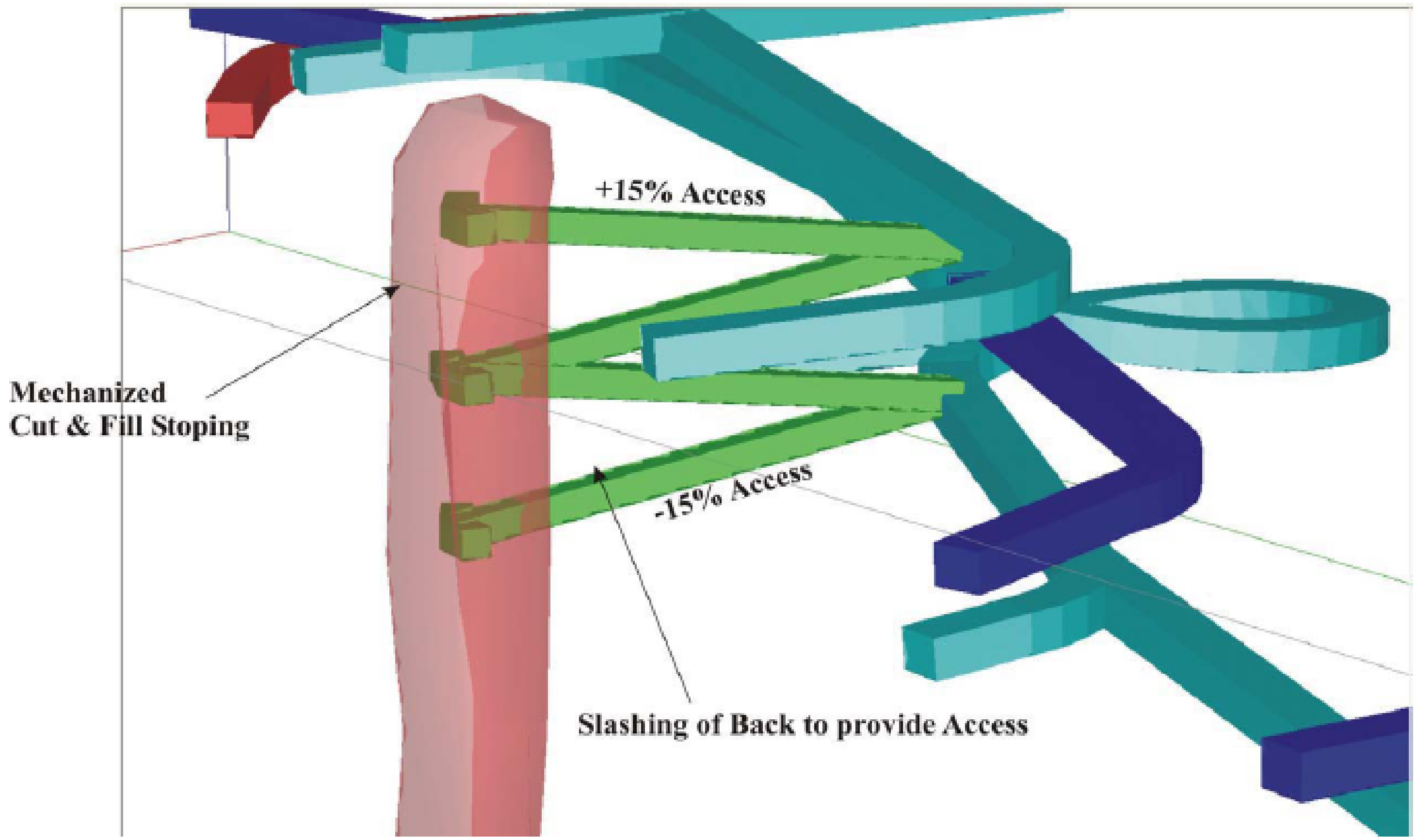
4.3.2 Mechanized Cut and Fill

Mechanized cut and fill using development waste for fill, was chosen for the remaining portions of the deposit. This method is highly flexible and will allow for dealing with irregularities in structure or grade. This mechanized cut and fill method is shown graphically in Figure 4.2.

A drift is driven along the ore structure at a planned width of 2.5 m. As it is an ore extraction drift, and not a travel way there is no legal minimum clearance required beyond the width of the equipment. Rock bolting is done along the ribs where necessary, and then a 3 lift is slashed down from the back, either by horizontal breasting, or by using uppers. Ground support is installed in the new back and ribs, and then the broken ore is mucked out using a scoop tram.

The initial access from the haulage system to a cut and fill stope is driven at minus 15% gradient and results in a decrease in elevation of 7.5 m. After each lift of ore is mucked out from the stope, the back of the access ramp is slashed and the broken muck is used to fill the ramp to provide level access to the stope at the elevation of the top of the next lift of fill (an increase of 3 m in elevation).

Waste rock is then placed in the stope, filling it to within 3 m of the new back, and the next lift is mined. When successive lifts have been mined to the point that the access ramp has increased in gradient to plus 15% a new access to the ore is driven at a gradient of minus 15%. In this way, the accesses to each stope will be spaced 15 m vertically apart.



MIRAMAR HOPE BAY LIMITED	Doris North Mine Closure & Reclamation Plan Nanavut, Canada			
	Cut and fill mining			
	PROJECT VM00259A	DATE Oct 2003	APPROVED LTC	FIGURE **4.2**

Figure 4.2: Cut and Fill Mining

Underground mining for the Doris Hinge ore zone will commence with construction of a 4 m high by 5 m wide portal, collared at surface near the mill. The location of the ramp portal (Doris Portal) is shown in Figure 4.3. It will access the northeast trending ore zone by way of a decline ramp going down to the 2,991 m level (a vertical depth of approximately 36.5 m). The ramp will have a 10% slope and be approximately 900 m in length.

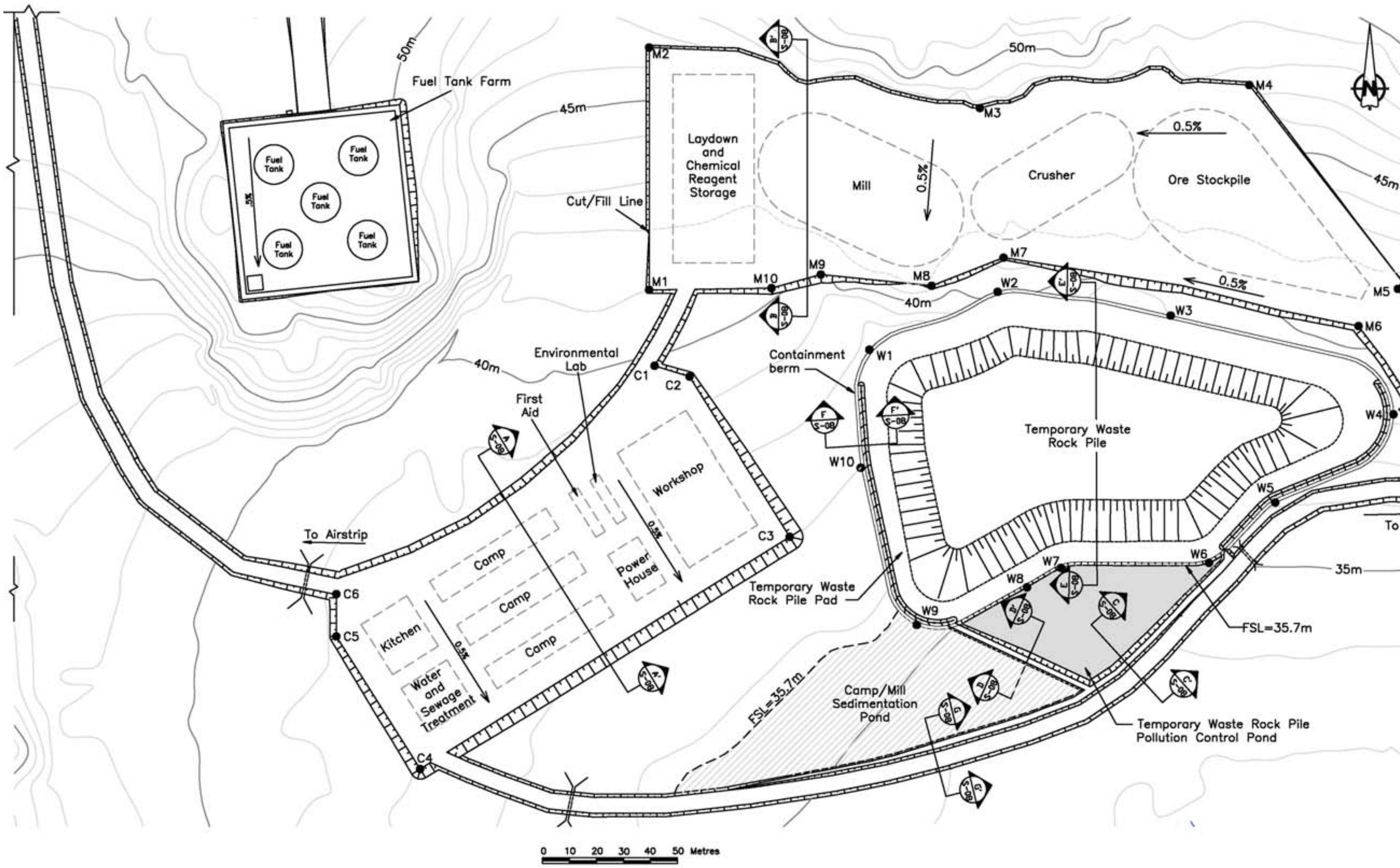


Figure 4.3: Detailed Site Infrastructure Layout at Mill/Camp Location

Initial ventilation of the ramp development will use two 45 kW (60 HP) high pressure fans with 1.2 m (48”) diameter vent tubing supplying the required 21 m^3/s (45,000 cfm) to four pieces of equipment: one 2-boom jumbo, one 3 m^3 load hull dump (low profile underground front end loader (LHD), one 30 tonne truck, and one utility vehicle.

When the main ramp reaches the orebody, approximately 500 m ramp length from surface, a temporary ventilation raise/escapeway (Vent #1) will be driven to surface. At the top of the vent raise a large diameter low pressure 45 kW (60 HP) main fan will be installed to force 47 m^3/s (100,000 cfm) up the main ramp. The auxiliary fans used for development will then be relocated to the bottom of the vent raise.

As the ramp development reaches the northern and southern extents of the mine, two additional ventilation raises/escapeway (Vent #2 and Vent #3) will be driven to surface. The temporary raise (Vent #1) will then be sealed off and the two new raises (Vent #2 and Vent #3) will each have a low pressure large diameter 45 kW (60 HP) fan mounted on top of them. The fan, which will have a total capacity of 85 m^3/s (180,000 cfm), will be adjusted to force a total of 70 m^3/s (150,000 cfm) through the ramp system and up to surface, sufficient to accommodate the mobile equipment which will be in use at that time, as required by the NWT/Nunavut Mine Health and Safety Act and Regulations. Fresh air will be drawn off the main ramp with auxiliary fans and forced into the working stopes. This configuration will remain in place until the ore body is mined out.

The 3 dimensional cross-section of the proposed Doris North underground mine is shown in Figure 4.4. (looking northwest) and in Figure 4.5 (looking southwest). It should be noted that all of the underground workings required to mine the Doris Hinge zone will be to the north of Doris Lake; none of the mine workings will extend underneath Doris Lake. Consequently no groundwater inflow from Doris Lake is expected. The mine workings for the Doris North Project are located within permafrost and are sufficiently distant from Doris Lake that groundwater inflow is not expected to be significant (i.e., based on geotechnical investigations conducted in 2002/2003, it is believed that the talik zone caused by Doris Lake is limited to the perimeter of the lake.

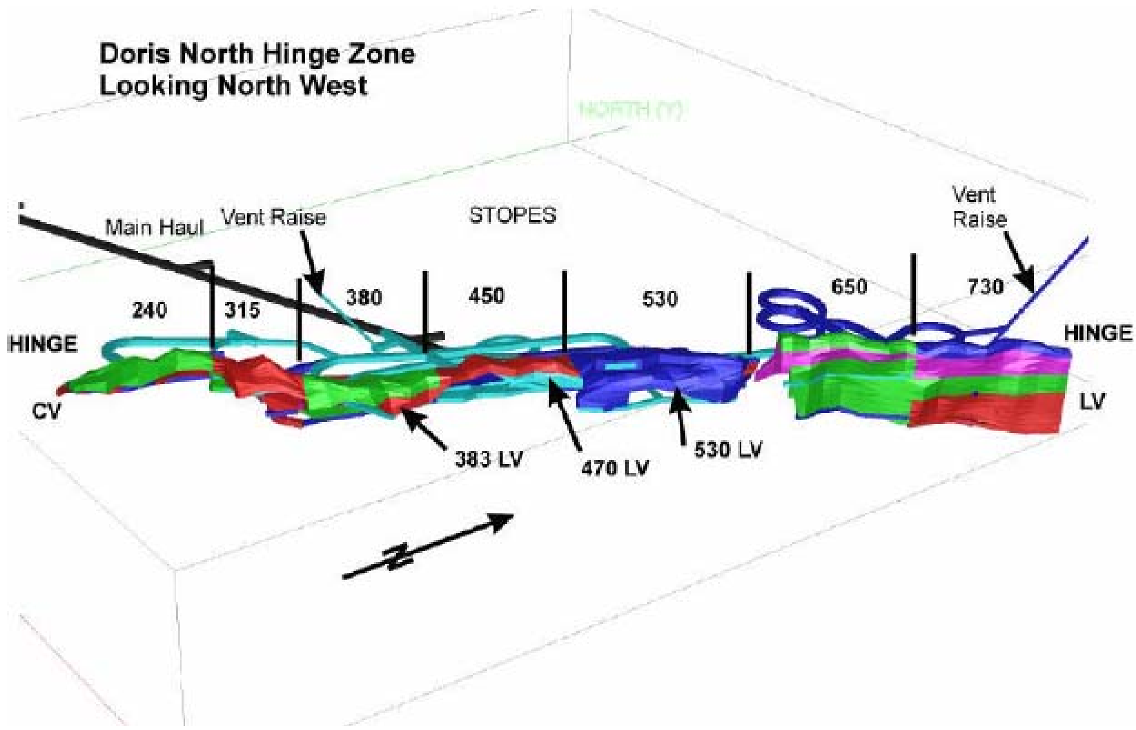


Figure 4.4: Doris North Hinge Zone Mine Design Looking North West

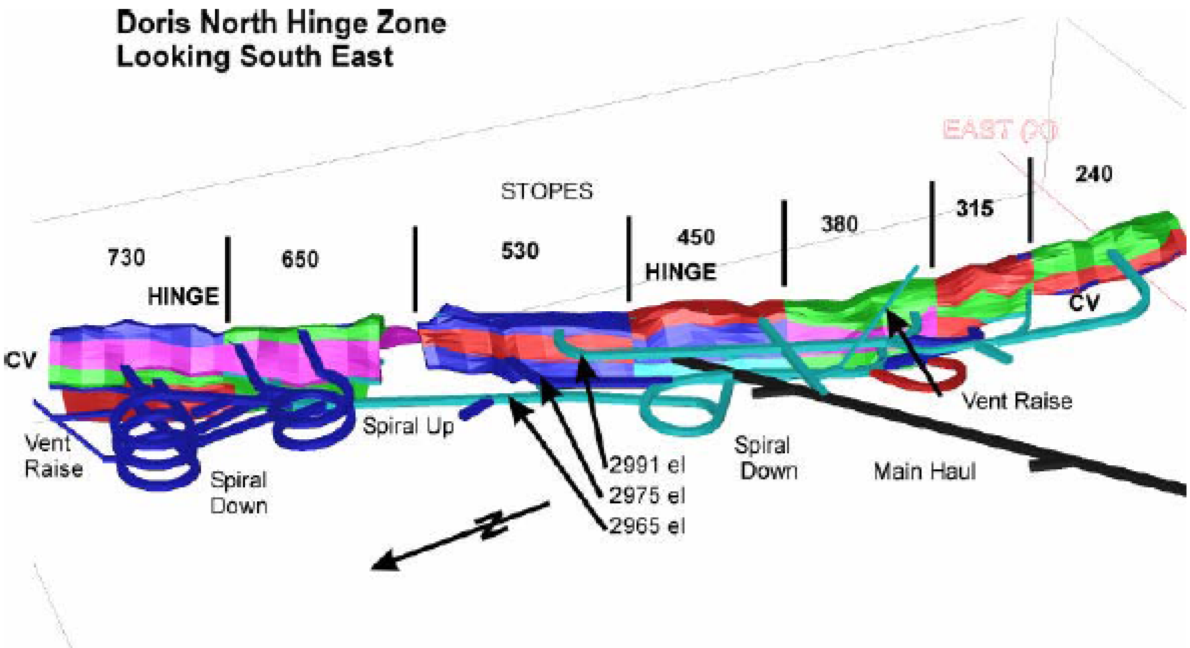


Figure 4.5: Doris North Hinge Zone Mine Design Looking South East

Water for drilling and dust suppression will be supplied from sumps and re-cycled to them. Due to the freezing conditions a brine solution will be used. The sumps will be charged by a 50 mm (2”) line from the mill. Once a sump is full the pumping will stop and the line blown clean with compressed air to eliminate freeze-up. Potable water will be supplied in bottles.

A leaky feeder system will provide communication for the entire underground mine. The system will also allow radio contact directly to the maintenance shops. A second communications line (emergency phones) will be installed directly to the underground safety station and to an appropriate location on surface such as the security desk, the first aid room, or the surface mine rescue station.

Underground trucks will haul the ore from the underground mine to a stockpile located on surface near the ore processing plant.

The major pieces of mobile equipment required for mine operations (mining and surface) will consist of:

- 2 double boom electric/hydraulic jumbo drills
- 3 single boom electric/hydraulic jumbo drills
- 3 - 3 m^3 scooptrams
- 4 - 1.5 m^3 scooptrams
- 2 - 20 tonne underground diesel haul truck
- 2 diesel powered portable air compressor units
- 1 scissors lift truck
- 4 underground equipped pick up trucks
- 1 966 Front-end loader
- 1 road grader
- 1 20-person capacity minibus.

4.4 Waste Rock Management

Under the mining plan it is expected that all development waste rock will be used internally as backfill within the mine workings. Under the mining plan it is expected that all development waste rock will be used internally as backfill within the mine workings. All of the underground waste rock brought to surface will be placed onto the temporary waste rock stockpile to be returned into the underground mine during the mine life.

There is sufficient open void space within the planned production stopes at the Doris North underground mine to receive all of the underground waste and the dewatered cyanide leach residue. The estimated void space is 148,000 m^3. The dewatered leach residue generated over the two year mine life is estimated to be 25,000 m^3 at the average concentrate weight pull of 10% (i.e., 10% of the tonnes milled reports to the dewatered cyanide leach residue, the remaining 90% being flotation tailings), leaving 123,000 m^3 of void space to accommodate the estimated 110,451 m^3 (198,812 tonnes at a broken specific gravity of 1.8 tonnes/m^3) of underground mine waste rock.

All waste rock brought to surface from the underground mine will be trucked to the bermed Temporary Waste Rock Pile pad and end dumped onto the pad. The initial pad will be constructed of a minimum 1 m thick non-acid generating rock sourced from one of the construction quarries. This bedding layer is to prevent thawing of the permafrost and provide a level base for recovery of the waste rock when it is returned underground. Kinetic testing on the waste rock suggests that the time to onset of net acid generation will be in decades due to high inherent buffering capacity. Consequently MHBL is confident that this waste rock will have been returned to the underground mine well before any net acid generation occurs.

The location of this temporary waste rock pile in relation to the mill and ore stockpile is shown on Figure 4.3. The pile will be constructed with down slope perimeter berm designed to contain and direct all runoff from the pile into a dedicated runoff collection pond (The Temporary Waste Rock Pile Pollution Control Pond). Berms will also direct clean runoff away from the waste rock pile. Periodically a dozer will be used to shape the pile to maintain stable angles, that is to reduce any overhangs or over steepened slopes and to maintain a safe truck access ramp onto the pile.

No underground waste rock is to be taken anywhere outside this Temporary Waste Rock Pile pad without authorization from the Mine General Manager who will ensure that appropriate authorization has been obtained from the Nunavut Water Board using the procedures outlined in the Waste Rock Management Plan.[6]

All precipitation runoff from within the bermed area of the Temporary Waste Rock Stockpile is to be directed to the Temporary Waste Rock Pile Pollution Control Pond. The water that accumulates within the Temporary Waste Rock Pile Pollution Control Pond is to be pumped to the tailings pump box within the mill so that it can be transferred to the tailings containment area. No water is to be discharged onto the surrounding tundra without the authorization of the Nunavut Water Board.

The Project will not involve the stripping or removal of any vegetation and/or overburden; a practice that could have serious impacts on permafrost degradation, resulting in the generation of mud and sediment that could potentially enter surface waters. It is proposed that rock fill building pads be constructed directly on top of the existing terrain. Consequently, no overburden stockpiles are proposed as part of this Project.

4.5 Process Facilities

The mill and camp complex will be located in close proximity to each other and will be constructed partly on exposed bedrock and partly on permafrost tundra. Where facilities will be on permafrost the pad thickness will be at least 2.0 m. Figure 4.3 - Detailed Site Infrastructure Layout at Mill/Camp Location show the proposed layout of the facilities in this general area.

4.5.1 Ore Stockpile

In the area between the portal and the crusher an ore stockpile pad measuring roughly 5,000 m^2 (100 m x 50 m) will be constructed (Figure 4.6). This ore stockpile of approximately 10,000 tonnes, or 15 days of mill feed will be end dumped by the underground haul trucks where ore will be drawn from the surface stockpile using a front-end loader and fed into the primary jaw crusher.

4.5.2 Surface Crushing and Ore Processing Facility (Mill)

The surface crushing plant and mill will be located immediately west of the portal, on bedrock (Figure 4.3). The bedrock is already partially exposed in this area, and thus the foundation preparation will be limited to levelling of the site using precision blasting. The areas surrounding the mill and crusher buildings that are not on exposed bedrock will be

[6] Section 6.0, Waste Rock Management Plan, Supporting Document S10d to the Revised Water License Application Support Document, April 2007.

levelled by infilling with run-of-mine quarry rock to form a final pad at least 2.0 m thick. This will serve to protect the underlying permafrost.

The ore processing equipment will be housed in a two buildings, one housing the surface crushing facilities and the other the ore processing and gold recovery circuits. The mill and crusher floors will be concrete bunded structures with selected sumps to collect any spillage or wash water. The mill will be equipped with sumps designed to hold spillage equivalent to a minimum of 110% of the volume of the largest tank or vessel within that circuit. The mill will be arranged so that spillage is segregated by circuit, i.e., spillage from the cyanide leach circuit will be kept apart from spillage from the flotation circuit so that cyanide solution does not contaminate the flotation process thereby interfering with gold recovery and potentially bypassing the cyanide detoxification circuit. The individual sumps will be equipped with pumps designed to recover spillage for return to the appropriate circuits.

Figure 4.6 shows a block diagram of the proposed ore processing flow sheet. The mill is being designed for a rated capacity of 800 tonnes per day (36.2 tonnes/hour at an operating factor of 92%), however the nominal milling rate will be 720 tonnes per day (~ 30 tonnes per hour).

Ore will be fed from the ore pad to the primary crusher by front-end loader. The product from the crushing plant will be conveyed to a crushed ore bin to be located indoors. Crushed ore will be drawn by a conveyor belt from the bin to feed the ore into the grinding circuit (ball mill). The slurry output from the grinding circuit will pass over a gravity concentrator and through a flash flotation cell to recover the “free milling” gold. It is projected that up to 30% of the gold contained in the ore will be recovered from the gravity circuit, prior to the addition of any chemicals or reagents. The underflow from the flash flotation cell will be passed through a set of cyclones with the coarse underflow particles being recycled to the ball mill for additional grinding. The overflow slurry output from the cyclones (finer sized particles) will be sent to a one-stage froth flotation process (Rougher Flotation) to recover the gold bearing sulphide minerals in the form of a flotation concentrate. The flotation circuit will reduce the mass of material going on for further processing to about 10.0% of the total weight of the ore processed (72 TPD). The remaining 90.0% (648 TPD - the Rougher flotation tails) will be discharged to the tailings containment area, with no further treatment.

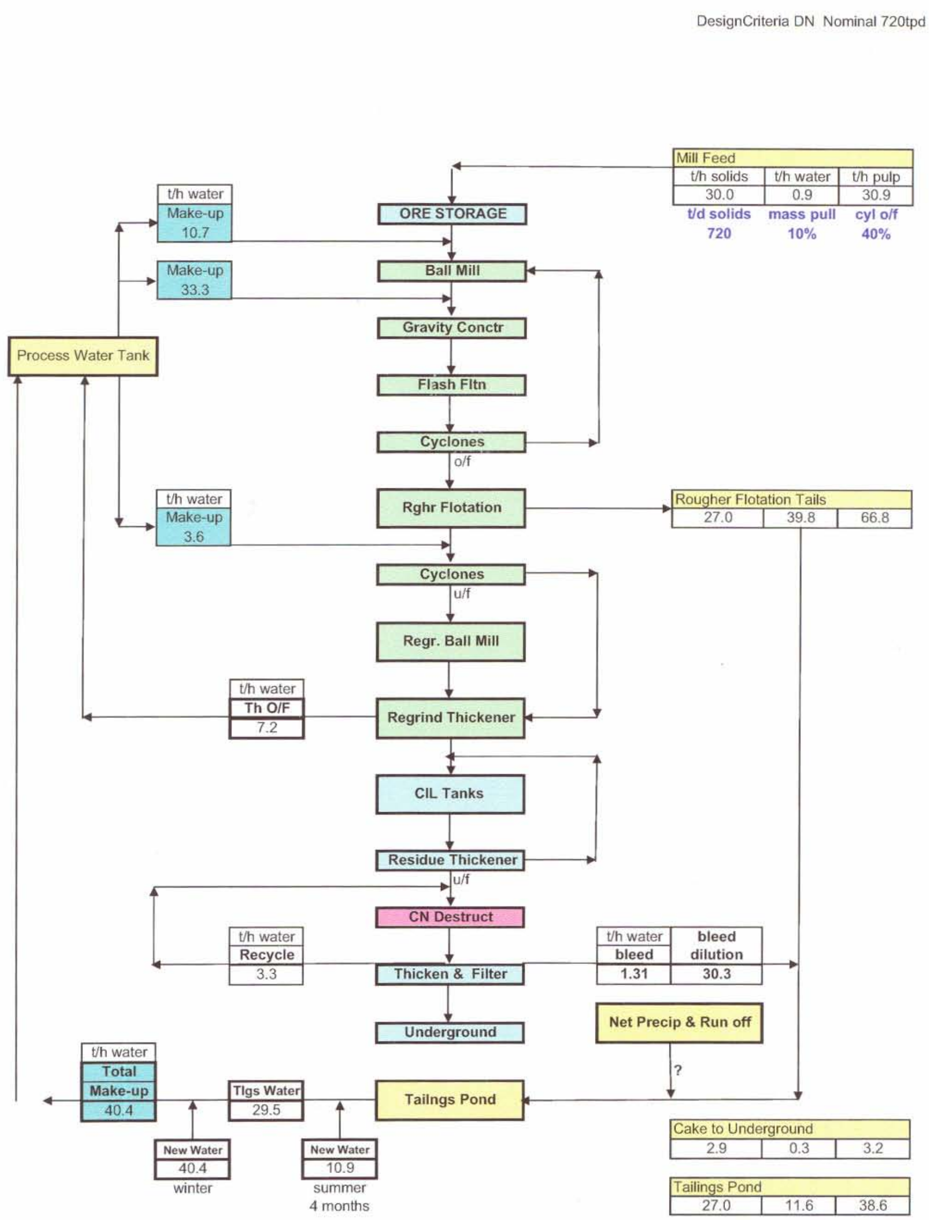


Figure 4.6: Block Diagram of Mill Process Flowsheet

The Rougher Flotation concentrate will be passed through a set of cyclones with the coarser particles contained in the underflow being sent to a regrind ball mill to further reduce the particle size prior to gold leaching. The slurry output from the regrind ball mill will be combined with the cyclone overflow (the finer particles) and sent to the Regrind Thickener to remove excess water prior to leaching. The overflow water from the Regrind Thickener will be recycled to the mill process water tank for use in the grinding circuit.

The gold contained in the flotation concentrate (Regrind Thickener underflow) will be extracted in a conventional agitated tank leach circuit (CIL – carbon in leach circuit) using a dilute sodium cyanide solution to leach out the gold. Activated carbon will be added to the leach tanks to adsorb gold leached from the concentrate. At the end of the CIL circuit the gold bearing activated carbon will be recovered from the slurry using screens. The remaining slurry (leach residue) will be fed to a Residue Thickener to remove excess water. The excess water contained in the thickener overflow will be recycled to the head end of the CIL circuit.

The Residue Thickener underflow slurry will be pumped to the cyanide destruct circuit where the remaining cyanide will be destroyed in a cyanide destruction circuit (water treatment plant). The treated slurry will then be sent to a thickener with the excess water (thickener overflow) recycled back to the cyanide destruction circuit. The thickener underflow slurry will then be filtered through a pressure filter to produce a “dry” filter cake to be placed underground as backfill. The target moisture content in this filter cake is 8.5% moisture by weight. The filtrate from the filter will also be recycled back to the cyanide destruction circuit.

Approximately one third of the recycled residue thickener overflow and filtrate from the pressure filter will be bled to tailings (estimated to average 1.31 tonnes per hour) to remove a build up of metal contaminants. This bleed stream will be mixed with the rougher flotation tails and pumped to the tailings containment area (tailings pond). This will provide a dilution ratio of 30.3:1 (bleed solution to rougher flotation tails solution).

The gold bearing activated carbon recovered from the carbon-in-leach circuit will be washed in a pressure stripping circuit to extract the recovered gold from the carbon. This gold will then be recovered from the wash water using electrowinning to plate the gold onto wire wool cathodes. The “stripped” carbon will be thermally reactivated as required and recycled back to the carbon-in-leach circuit. The gold bearing wire wool cathodes will be periodically washed with a high pressure hose to remove the gold as a sludge, which will be filtered, dried in an oven, mixed with fluxes (such as silica sand, borax and sodium nitrate) and smelted in a smelting furnace to produce gold bullion and a slag. Similarly, the gravity table concentrates will be mixed with fluxes and smelted on site to produce gold bullion and a slag. The slag will be recycled back to the milling process through the grinding circuit. The bullion will be cast into dore bars, which will be shipped off site to a custom refiner. Overall gold recovery in the milling process is projected to be 954.9%.

The filtered cyanide leach residue will be stored in a steel bin located within the mill with a nominal live capacity of approximately three days (~216 tonnes). The filter cake from the pressure filter will be trucked underground and used to backfill mined areas.

The treated barren bleed solution will be combined with the flotation tailings slurry and pumped to the Tail Lake tailings containment area. The quality of the combined effluent discharged into the tailings containment area is estimated to be 0.29 mg/L Total CN (0.04 mg/L WAD CN), 32 mg/L CNO, <0.1 mg/L SCN, 1.0 mg/L Total Ammonia, 0.039 mg/L Total Cu, <0.05 mg/L Total Pb, 0.03 mg/L Total Nickel and 0.09 mg/L Total Zn.

4.6 Surface Infrastructure

This section is intended to provide the reader with a summary description of each of the components that make up the Doris North Project. This is not intended to provide design details for these facilities. The reader is referred to the following sources for the design information:

- Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S1 to the Revised Water License Application Support Document, April 2007);

- Design of the Surface Infrastructure Components Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S2 to the Revised Water License Application Support Document, April 2007);

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S4 to the Revised Water License Application Support Document, April 2007); and

- Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S3 to the Revised Water License Application Support Document, April 2007).

4.6.1 Service Complex (Workshop)

A machine and maintenance shop and storeroom will be erected on site, in the vicinity of the camp and mill complex. The shop will be supplied with all tools and equipment required for service and maintenance of the underground mining equipment fleet. The shop will be linked to the mill and camp via Arctic Corridors, minimizing exposure of the workforce to the elements. The workshop floor will be a concrete bunded structure with selected sumps to collect any spillage or wash water. These sumps will be emptied into the tailings feed line and pumped to Tail Lake.

4.6.2 Mill Reagent Storage Area

Mill reagents will be shipped and stored in 6.1 m x 2.4 m sea-can containers. A storage area will be provided immediately adjacent the mill for storing containers single stacked, 2m apart. The mill reagent storage area has been sized based on the number of containers required to supply the mill for one year.

4.6.3 Mill and Camp Lay-down Area

An additional lay-down area for equipment and supplies will be constructed adjacent to the camp on the down slope side.

4.6.4 Camp & First Aid Station

A conventional 175-person capacity camp will be constructed at the Doris North Project site, consisting of a combination of modular skid mounted units linked together via Arctic Corridors.

The kitchen and recreation facilities will be located in five additional modular skid mounted units joined to the rest of the camp via Arctic Corridor. The first aid station will be located in a separate modular unit connected to the rest of the facilities by an Arctic Corridor.

The camp will be located west of the mill complex with access to the camp, mill complex and shop for workers provided via Arctic Corridors. Where bedrock is not present, the modular camp units will be placed on 2.0 m thick rock-fill pads to protect the underlying permafrost.

4.6.5 Office/Dry Complex

The office, and dry complex and environmental laboratory facilities will consist of two combined modular units, the environmental lab will be one unit, and the dry complex will be four combined units, ultimately joined to the dorms via an Arctic Corridor.

4.6.6 Boat & Float Plane Dock

A boat and floatplane dock[7] will be constructed in the small bay on Doris Lake immediately southeast of the mill. The dock portion will be a pre-fabricated modular unit, designed and manufactured by a specialist contractor. The modular unit can be dragged on shore during freeze-up.

The dock has been designed to allow offloading of supplies from a Twin Otter plane using a Bobcat forklift. The plane requires 7.5 m of berthing face against the dock, and a minimum

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[7] Complete dock design details are provided on Drawing S-09, Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Supporting Document S4 to the Revised Water License Application Support Document, April 2007.

water depth of 1.5 m when fully laden. Based on the most recent Doris Lake bathymetry[8], the dock will have to be 25 m long to ensure compliance with the design plane berthing requirements. To ensure sufficient buoyancy of the dock, as well as a safe working platform, the minimum width will be 4 m. Dock buoyancy will be provided via sealed HDPE pontoons. The dock will be held in place via six permanently installed bollards. These bollards will be imbedded in bedrock. Three sets of concrete filled bollards 2 bollards per set) will be constructed along the dock to secure the dock in place. The bollards will be set into the lake bottom at a depth of approximately 5 metres below the lake bottom and grouted in place using cement grout. Mooring cleats will be imbedded in the platform to provide contact points for securing float planes and watercraft.

4.6.7 Explosive Storage Facilities

MHBL will need to provide permanent and temporary storage for the following annual amounts of explosives and detonators on site:

- 38,000 kg of explosives;
- 39,000 detonators; and
- Peak annual supply of bulk ammonium of 700,000 kg.

An on-site AN/FO mixing plant will produce a maximum amount 10,000 kg at any one time. For design purposes the total amount of mixed product was assumed to be 20,000 kg which includes the weight of mixed explosives and half the weight of ammonium nitrate in the mixing plant building.

Regulations governing the storage and mixing of explosives require that powder and detonators are stored in independent magazines and that all bulk ammonium nitrate storage, explosives and detonator magazine and the mixing plant be separated by a minimum distances based on the amounts that are being stored (NRCan 1995).

In addition these regulations require the explosives storage and mixing facilities to be separated by minimum distances from permanently occupied buildings and roadways. These facilities (proposed permanent and temporary (construction) facilities) have been sited on spur roads off of the main road from Roberts Bay to ensure that these minimum setback distances are met.

The actual explosives and detonator magazines will be Type 4 prefabricated magazines, contained within sea cans. The mixing plant will also be a pre-manufactured facility contained within a sea can.

The permanent explosives magazines and storage areas will be placed on 2 m thick rock fill pads while the temporary explosives magazines and storage areas will be founded on ice pads and accessed by an ice road.

[8] See Appendix A, Design of the Surface Infrastructure Components, Supporting Document S2 to the Revised Water License Application Support Document, April 2007.

4.6.8 Power Generation Facilities

Electrical power for the Project will be generated on-site by means of diesel electric generator units with a capacity of 4.0 MW (4 x 1.0 MW diesel electric generators). The units will be installed in a permanent steel structure (powerhouse). This building will be constructed immediately adjacent to the mill and crusher building.

4.6.9 Fuel Handling and Storage Facilities

Every year 7.5 million litres of fuel will be shipped to Roberts Bay via sea-lift and pumped to a fuel truck at a contained fuel transfer station. The fuel transfer station will be located across the all weather access road from the Roberts Bay lay-down area, a minimum 100 m inshore from Robert's Bay. From the fuel transfer station, fuel would be hauled by standard fuel trucks via the all-weather access road to a permanent tank farm at the mill. The fuel transfer station will be constructed on a HDPE lined pad with lined containment berms. The containment berms will allow for the station to retain over 110% of the capacity of the largest fuel truck at 40,000 L. Ramp access for the fuel trucks will be located at opposite ends of station, allowing for safe drive through access. The access ramps will be 6 m wide and graded at a 5H:1V slope. The fuel transfer station pad will be a minimum of 2.0 m thick to preserve the permafrost and be graded to a collection sump.

Annually 7.5 million litres of fuel will be trucked from the fuel transfer station at Roberts Bay to a permanent tank farm at the mill site location. The tank farm has been designed in accordance with the principles outlined in two working documents: Environment Canada's 'Proposed Federal Petroleum Products and Allied Petroleum Products Storage Tank Systems Regulations' (Environment Canada 2003) and the Canadian Council of Ministers of the Environment's (CCME's) Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products' (CCME 2003).

The 7.5 million litre capacity fuel tank farm (five 1.5 million litre steel tanks, measuring 14.8 m diameter and 9.8 m high) will be constructed on a level precision blasted surface, on a partially exposed bedrock section at the mill site. Founding the tank farm on bedrock eliminates the risk of foundation settlement which may lead to pipe rupture and fuel spills.

The tanks will be erected in an engineered containment area consisting of a HDPE lined pad, having sufficient capacity to retain 100% of the volume of the largest single fuel tank (1,500 m^3) plus 10% of cumulative volume of all additional tanks (600 m^3). The base of the containment area will be graded to a corner sump location that will be used to pump out storm water and snowmelt (after being passed through an oil water filter separator) directly onto the tundra.

To ensure capture of any fuel spills during transfer from tanker trucks to the storage tanks, a secondary fuel transfer station will be located inside the secondary containment berm.

Ramp access for the fuel truck to the fuelling station will be located at one corner of the secondary containment berm.

The HDPE liner will cover the entire inside area of the tank farm, including the inside slopes of the containment berms and the base of the sump.

The tank farm requires a small building to house a generator and provide general storage. For these purposes a 6.1 m x 2.4 m x 2.4 m metal sea container (seacan) will be located immediately adjacent to the tank farm at one corner of the secondary containment berm.

4.6.10 Quarries

"Clean" (non acid generating and non-metal leaching) rock will be obtained from three quarry sites located close to the major infrastructure components. The location of the proposed quarries is shown on Figure 1.2:

- Quarry at the south end of Roberts Bay adjacent to the proposed sealift offloading jetty site (Q1);
- Quarry at the Doris North Project site west of the proposed camp (Q2);
- Quarry on the east side of Tail Lake close to the proposed tailings dam site (Q3); and
- Quarry at the mill site (levelling of a rock outcrop to found the mill building foundations (Q4).

4.6.11 Airstrips

The permanent all-weather airstrip must meet the minimum requirements of two design aircraft selected by MHBL; Dornier-228 and the De Havilland Twin Otter. A winter airstrip on Doris Lake will be sized to accommodate up to a Lockheed C-130/ L-100 Hercules. Both airstrips are to be equipped with lights for night use and with the instrumentation necessary to support IFR (Instrument Flight Rules) operations.

4.6.11.1 All-Weather Airstrip

The all-weather airstrip will be constructed by widening 914 m of the all weather road between the barge landing site and the mill to 23 m (Figure 1.2). This will ensure year round air access for small aircraft. A 40 m x 17 m apron for vehicle parking and an emergency power generator, fuel storage and emergency shelter will be constructed at the southern end of the runway.

4.6.11.2 Winter Airstrip

Every year, once sufficient ice has developed on Doris Lake, a 1,524 m x 45 m airstrip will be constructed. The winter airstrip will also be instrumented and illuminated for IFR night operations, similar to lighting and instrumentation proposed for the permanent all-weather airstrip.

4.6.12 All Weather Roads

The proposed Project all-weather roads will be constructed of quarried rock with a minimum fill thickness of 1.0 m required to cover micro-relief and protect permafrost. Wherever possible, roadways will be constructed in the winter to ensure the integrity of the permafrost. Some settlement of roads is expected and will be addressed through an annual maintenance program. Fill will be crushed to the required size fraction for construction on site.

The road surfaces will be 6 m and 5.0 m wide respectively for the main and secondary roads. Side slopes will be at angle of repose (40^o, or 1.2H:1V). Roadway drainage will be via 0.5% surface grading in both directions from the centreline of the roadway for all roads. The pad will consist of a 0.2 m thick surfacing grade layer overlying a 0.3 m thick select grade layer. Both of these will overlie a 0.5 m thick sub grade layer.

4.6.12.1 Main Road from Beach to Mill/Camp Site

The 4.8 km all weather road between Roberts Bay and the mill area will follow the natural topography, which is well suited towards road construction. There are no natural obstacles, and the grades are low, suggesting few construction difficulties. Between Roberts Bay and where the road will turn east towards the mill, the road will be constructed towards the windward side of the valley to avoid snowdrifts that occur in the lee side of the western outcrops. Between the turn in the road and the mill the road will follow along the northeastern edge of the valley before turning east into the mill location. There are a number of areas where culverts will have to be installed to allow seasonal runoff to continue flowing along its original routes, but there are no significant stream crossings along this stretch of road. The soil conditions consist of open tundra underlain by thick marine silts and clays with abundant ground ice overlying bedrock. Areas where the surface is marked by large ice-wedge polygons indicate that abundant ground ice encountered during drilling operations is widespread.

At two locations along the route the 6 m wide road will be widened to 10 m for a distance of 30 m to form passing turnouts. These turnouts provide space for passing and turnaround of vehicles traveling along the road.

4.6.12.2 Tailings Service Road

Tailings will be deposited into Tail Lake, necessitating a 5.9 km, 5 m wide all-weather service road. A 150 mm diameter insulated HDPE tailings feed line and a 100 mm diameter, insulated and heat traced return water pipeline will be placed on the shoulder of the road, taking up at least 1.5 m of the roadway space. The pipelines will be placed on the outside edge of the roadway, i.e. closest to the lake shorelines. This will minimize the number of pipe crossings required. Eight passing zones measuring 10 m wide and 30 m long will be constructed along this stretch of road to ensure safe passing of traffic.

The road will start at the mill and pass the portal on the south before following a north-easterly direction towards the northern end of Doris Lake. At this location a bridge will be constructed to cross the Doris Lake outlet. The road will then turn southeast and will approximately follow the east shore of Tail Lake, always above the projected full supply elevation in Tail Lake of 33.5 m. There will be a 10 m x 10 m turning platform adjacent to the South Dam where the road ends.

This roadway has been designed to have a minimum longitudinal grade of 1% at any point, as well as minimizing the number of low-points. Since the tailings and return water pipeline follow the roadway grade, these aspects will enable the lines to be drained by gravity flow in the event of a stoppage of either pipeline. Contents of the tailings line will be collected at six emergency dump catch basins located at low points along the roadway.

4.6.12.3 Explosives Magazine Service Road

A permanent explosives storage and mixing facility will be constructed 800 m northwest of the
camp, and accessed by a spur road off the main all-weather road coming from the barge landing site. The detonator magazine will be located to ensure that it is tucked in behind a rock outcrop effectively shielding it from view to the mill and camp site. The powder magazine will be located on the same road. Both of these facilities will be joined to the bulk ammonium nitrate storage area and explosives mixing plant. These roadways will all be 6.0 m wide to and from the main road. Sufficient turn-around room will be provided in the magazine areas to allow for safe vehicle turn around.

4.6.12.4 Dock Service Road

The link between the boat and float plane dock will be a 300 m long, 6 m wide all-weather road. The road will join up with the airport access and tailings service road immediately south of the portal. This roadway will also provide the bedding platform for the two four inch diameter water pipelines from Doris Lake (fresh, and fire/mill water supply). These pipelines will be heat traced and insulated and will take up at least 1.5 m of the width of the road. At the road junction a series of culverts will be installed to allow crossing of the two fresh water pipelines, the return water pipeline and the tailings pipeline.

4.6.12.5 Non-Hazardous Landfill Access Road

The permanent non-hazardous solid waste disposal site will be located in the rock quarry immediately west of the camp site (Quarry 2). A 150 m long stretch of all-weather road will link the disposal facility with the main access road to the camp. This roadway will be 6 m wide to ensure access by large equipment.

4.6.12.6 Caribou Crossings

MHBL will install graded caribou crossings at appropriate locations along all of the proposed all-weather roads. These crossings will typically consist of a gently sloped section with fine grained crushed rock covering to allow caribou to cross the roads with low risk of injury. The caribou crossings will entail flattening of the roadway shoulder to 5H:1V for a 10 m wide section on either side of the road. This flattened section will be clad in transition zone and surfacing grade material to ensure a suitable surface for caribou to travel on. Roadway signposts will be installed to warn traffic of the locations of these crossings.

MHBL will work with the Kitikmeot Inuit Association (KIA), community elders and representatives of the local hunters and trappers associations as appropriate to determine the number and location of these caribou crossings prior to the start of construction. MHBL will work with the KIA to arrange appropriate consultation and site visits with elders from local communities and representatives of the local hunters and trappers associations before the start of the 2008 construction season to look at the proposed road alignments and presence of any indications on the ground of caribou travel routes. In consultation with the KIA, MHBL will use information obtained from these site visits together with Inuit Qaujimajatuqangit obtained from these consultations to determine where and how many caribou crossings should be installed. The final design (width, grade, capping material, etc.) of the crossings will be determined in a similar manner.

4.6.12.7 Bridge Crossing over Doris Lake Outflow

The stream crossing at the Doris Lake outflow is substantial, requiring a bridge deck with a span of 32 m to minimize impact on the stream banks. Based on site specific surveys the stream bank-full width (i.e., the ordinary high water mark) of Doris Creek at this location is approximately 15 m. The bridge abutments are designed to lie outside of this bank-full width. The bridge will be a modular 7.32 m wide prefabricated steel deck bridge with a loading capacity of up to 75 tonnes. The bridge will provide 4.1 m of clearance above the ordinary high water mark.

There are suitable founding conditions just upstream of the small set of falls in the stream. The roadway will be widened to 10 m on either side of the stream crossing and raised to greater than 2.5 m thick for a bridge approach angle slope of less than 20H:1V (5%).

4.6.13 Jetty & Barge Landing Site

The mine site is approximately 4.5 km inland from a navigable portion of the Arctic coastline. Supplies and equipment will be brought to site via annual sealift. The tidal variation in Roberts Bay is in the order of 0.3 m.

4.6.13.1 Proposed New Barge Landing Site

The proposed new permanent sealift-landing site is located on the south-eastern shore of Roberts Bay (Figure 1.2). The bay is relatively shallow at this location, necessitating the construction of a 103 m long jetty out into the bay to reach water deep enough for tugs and barges to safely operate.

The final jetty design is a 103 m long, 6 m wide rock fill structure jetty, with a 25 m long mooring face. The final height of the jetty will provide 1.0 m of freeboard above the HHWL (Higher High Water Level, Large Tide).

The overall jetty width will be 6 m, which would allow easy and safe off loading of the 20 ft (6.1 m) long seacan containers with forklifts and trucks; NTCL provides a Komatsu 500 loader for such purposes. The jetty will end in a widened working area, with a 25 m long mooring face. Bollards and mooring chains will be anchored into the jetty to allow securing of barges to the jetty structure. Barges will be moored end-on to the jetty due to depth limitations at the south end of Roberts Bay, and off-loading will take place via the end of the barges. In rough weather conditions, the barges may be kept in place by the tugs, or off-loading may be suspended until the weather conditions improve.

4.6.14 Permanent Beach Lay-down Area

The land mass immediately inshore from the jetty site is relatively flat tundra, with rock outcrops on either side. Drilling has indicated that these soils are sandy to silty clays of low plasticity containing minor ground ice. This land is well suited for construction of a pad to be used as a lay-down area for annual temporary storage of ammonium nitrate, equipment and supplies off-loaded from the sealift vessels. This lay-down area will be a minimum of 100 m from the high-tide level, and will be connected to the jetty via an all-weather road.

The lay-down area will have a surface area of 6,000 m^2 (100 m x 60 m). The pad has been sized based on the volume of annual freight that is expected to be delivered. The pad will have an overall surface grade of 0.5% to allow drainage of surface water off the pad. This surface water will be considered uncontaminated and will be allowed to drain freely onto the tundra. The side-slopes of the pad will be at angle of repose for the quarry rock, approximately 40^o.

4.7 Tailings Containment Area

4.7.1 Deposition in Tail Lake

Flotation tailings produced during the milling process combined with the barren bleed solution and treated wastewater from the sewage treatment plant will be deposited in Tail Lake (Figure 1.2) about 5 kilometres from the proposed mill location. Tail Lake is 76.6 ha in size within a catchment area of 4.4 km^2. The normal water level in Tail Lake is 28.3 m above sea level. Tail Lake has a discontinuous outflow into Doris Lake immediately upstream of the Doris outflow creek. Ogama Lake (158 ha in size) is situated immediately south of Tail Lake and its normal water level is at 24.3 m above sea level. The height of land between the lakes is at 32 m above sea level. The normal volume of Tail Lake is approximately 2,196,040 m^3.

The following section is intended to provide the reader with a summary description of each of the components that make up the Doris North tailings containment system. This is not intended to provide design details for these facilities. The reader is referred to the following sources for the design information:

- Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S1 to the Revised Water License Application Support Document, April 2007);

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S4 to the Revised Water License Application Support Document, April 2007) – Drawings T01 thru T-14; and

- Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S3 to the Revised Water License Application Support Document, April 2007) – Section 11.

The tailings impoundment is sized to operate as a zero discharge facility during the two years of operation, if necessary; however, the proposed water management strategy is based on the annual release of supernatant from the impoundment. In addition, under the most conservative water balance assumptions, Tail Lake would take just over five years to reach the design Full Supply Level (FSL) of 33.5 m with no discharge. A permanent spillway will be constructed at this elevation, to prevent the possibility of dam overtopping.

The tailings will be pumped as a slurry with a solids content of ~36% and discharged sub-aqueously into Tail Lake. The discharge location will not be fixed, but will be moved around such that the tailings impoundment can be sequentially filled from its deepest location. This deposition methodology will enable the final closure water level to be as low as possible. Tailings will be pumped from the mill to Tail Lake via a 150 mm insulated HDPE pipeline. The pipeline route will be southwest from the mill site towards the northwest shore of Doris Lake. From there the pipeline will continue along the Doris Lake shore towards a crossing at the Doris outflow before continuing south-west towards the Tail Lake shoreline. The maximum piping distance from the mill to the southern tip of Tail Lake will be 5.5 km.

Return (Reclaim) water will be pumped from Tail Lake to the plant through a heat traced and insulated 100 mm diameter HDPE line. Both tailings and return water pipelines will follow the alignment of the tailings service road. The tailings and reclaim water pipelines will be placed on the shoulder of the road, taking up at least 1.5 m of the roadway space. The pipelines will be placed on the outside edge of the roadway, *i.e.,* closest to the Tail Lake shoreline. This will minimize the number of pipe crossings required. Operationally the pipe settling and freezing risk will be managed by constructing six emergency dump catch basins strategically along the pipeline to allow drainage of the pipeline in the event of a pump stopping. The tailings pipeline service road will be graded to provide positive drainage by gravity towards one of the six emergency dump catch basins. This is to provide controlled containment of the tailings in the event of a pipeline system failure. The emergency dump catch basins located outside the Tail Lake watershed will be sized to hold the contents of both the tailings and reclaim water pipelines. Within the Tail Lake watershed, the reclaim water line will drain by gravity onto the tundra and into Tail Lake. Consequently, the emergency dump catch basins within the Tail Lake watershed have been sized to hold only the contents of the tailings pipeline.

The emergency dump catch basins have been sized to allow two sequential fillings plus an additional 0.5 m of freeboard. Containment in each basin will be provided by HDPE lining.

The tailings impoundment is sized to operate as a zero discharge facility during the two years of operation, if necessary; however, the proposed water management strategy is based on the annual release of supernatant from the impoundment. In addition, under the most conservative water balance assumptions, Tail Lake would take just over five years to reach the design Full Supply Level (FSL) of 33.5 m with no discharge[9]. A permanent spillway will be constructed at this elevation, to prevent the possibility of dam overtopping.

The two dams will be constructed as water retaining structures. They will be frozen core dams founded on non-organic permafrost and/or bedrock. The frozen core integrity will be ensured by the installation of passive thermosyphons in the key trench, immediately underneath the frozen core. Secondary containment will also be provided by installation of a geosynthetic clay liner (GCL) upstream of the core. The core, transition (filter) and outer shell construction materials will be processed local quarry rock.

The water management strategy for the Project entails an active managed discharge from Tail Lake beginning in Year 1 of operations and continuing until it can be shown that there is no adverse impact on downstream aquatic life from an unregulated discharge from Tail Lake. At the end of Year 9 (seven years after mining ceases) water quality in Tail Lake is predicted to be within the CCME Guidelines allowing for a complete “walk-away” closure scenario.

During the mine’s operating life (two years) and for an additional three years after mining and milling ceases the volume of water to be released from Tail Lake will exceed the natural inflow into Tail Lake. By the third year following the cessation of mining and milling, the water level in Tail Lake will reach the pre-development level of 28.3 m above sea level and the amount of water that needs to be released from Tail Lake is predicted to be equal to the natural inflow. In the year prior to this point in time (i.e., during the 2nd year following the cessation of mining and milling), Prior to this time, MHBL will commission a human health and ecological risk assessment[10] to determine if the quality of the water contained in Tail Lake is suitable for release in an unregulated fashion through the former Tail Lake outflow into Doris Lake without resulting in an adverse impact to aquatic life downstream. In the event that the risks are shown to be unacceptable, MHBL will continue to actively manage the annual discharge from Tail Lake by pumping this water to the discharge point in Doris Outflow Creek upstream of the waterfall. Pumping would only cease if it can be

[9] Section 6.3 and Section 9, Design of the Tailings Containment Area, Supporting Document S1 to the Revised Water License Application Support Document, April 2007.
[10] See Section 6.19, Mine Closure and Reclamation Plan, Supporting Document S10l to the Revised Water License Application Support Document, April 2007.

demonstrated that no adverse impact on downstream aquatic life will occur with an unregulated discharge. At that time the North Dam will be breached and the outflow from Tail Lake will be restored to the pre-mine outflow channel (Tail Lake Outflow creek) into Doris Lake. Under this scenario no further management of water releases from Tail Lake will be required however monitoring will continue for a minimum of one more year to verify that water quality remains acceptable for discharge.
At that time water quality in Tail Lake is predicted to be within the CCME Guidelines allowing for a complete “walk-away” closure scenario.

Under this water management strategy, the maximum water level in Tail Lake will be 29.4 m, with a flooded footprint of 94 ha.

The timing of the annual release will be during the open water season and be controlled to ensure that water quality in the Doris Outflow stream below the 4.5 m high waterfall at the discharge point remained protective of freshwater aquatic life (i.e., water quality does not cause harm to fish, benthic invertebrates or other wildlife).

4.8 Water Source, Distribution and Management

4.8.1 Freshwater Supply

Potable water, fire suppression water and up to 50% of the mill water (recycle water will be maximized for up to six months of the year) will be supplied from Doris Lake. Two separate 100 mm diameter insulated and heat traced HDPE lines will pump water from the lake to storage tanks at the mill and camp sites.

The intent is to maximize the use of recycle water from the tailings impoundment, however, there is a possibility that the water may not be able to clarify sufficiently during the winter period when lake ice reduces the volume in Tail Lake. Taking up to 50% of the mill water from Doris Lake is thus a contingency measure.

During summer months (June through September), process water will be taken from Tail Lake by a pump to be located near the north end of the lake. Make up freshwater for use in the mill will be drawn from the freshwater holding tank only in case of a shortage from Tail Lake. It is projected that water will be released from Tail Lake in a controlled annual discharge during open water periods.

Mill process water requirements are projected to be 1,183 m^3/ day. During summer months the source of most of this make-up water will be recycled water recovered from Tail Lake returned to the mill by way of an insulated and heat-traced return line from a pump house.

Water use underground is expected to be minimal. A brine solution will be mixed in the mill and piped underground for use in drilling and dust suppression. This brine solution will be recirculated through an underground sump. Development and production drilling will use this brine solution to stop drills from freezing in the permafrost. Total requirements are estimated at approximately 0.1 m^3/h. As mining is expected to be within the permafrost zones, groundwater is anticipated to be minimal. Any water encountered will be pumped from underground and discharged into the tailings line to Tail Lake.

Potable water will be treated in a packaged plant installed in a 12.2 m x 2.4 m container and will consist of sand filtration followed by ultra violet light and/or chlorination treatment.

4.8.2 Mill/Camp Storm Water Management

Storm water includes precipitation runoff and snowmelt. MHBL will intercept, collect and manage storm water from those areas of the mine site where the risk of contamination pick up is significant, specifically from:

- The lined fuel transfer station, the fuel tank farm and the landfarm facility; and
- The non-hazardous landfill facility.

The methods to be used to manage this storm water are covered in the Water Management Plan[11] and summarized in the following sub-sections:

Camp and Mill Pad Area, Temporary Waste Rock and Ore Stockpiles

The camp and mill pads will house all the processing and accommodation facilities for the Project. From a water management aspect, the following operational procedures will apply:

- The mill, crusher and workshop will be in individually enclosed buildings and will have self contained sumps to contain any spills. Emptying of these sumps will depend on the nature of the spill, and may be returned to the mill or pumped to Tail Lake.

- The temporary waste rock pile is considered to be “dirty” water areas, and all runoff from these locations will be directed to the pollution control pond. Water in this pond will be pumped to Tail Lake.

- The remaining surface areas of the camp and mill pads are generally considered “clean” surfaces; however, all runoff and melt water from these pads will be collected in the sedimentation pond. Once suspended matter has settled, and if the water quality in the pond is deemed acceptable this water will be pumped out onto the tundra. If the water quality is not deemed to be of acceptable quality it will either be used as mill make-up water or pumped to Tail Lake.

The sedimentation pond is designed to retain all surface water runoff and melt water from the remaining areas of the mill and the entire camp pad. The hydraulic design criteria are identical to that for the pollution control pond (three paragraphs below). The sedimentation pond is not lined. An emergency overflow is provided for the pond in the form of an outflow culvert located at the pond full supply level of 35.7 m.

Water will be pumped from the sedimentation pond onto the tundra and be land applied, as long as it meets the proposed discharge standard. The water will be discharged to the area immediately to the south of the pond where it will have a ~500 m cross country flow path before reaching Doris Lake. Pumping from the sedimentation pond will only start once water in the pond has been verified as meeting the proposed discharge standards.

The ore stockpile area will be graded to drain towards the pollution control pond immediately downstream of the temporary waste rock pile.

The Temporary Waste Rock Pile Pollution Control Pond is designed to contain all surface runoff and melt water from the temporary waste rock pile. The pond is designed for full containment of the 1:100 year storm event of 24-hour duration, plus an additional freeboard of 0.3 m. Containment is provided, at least to the full supply level of 35.7 m by an HDPE liner sandwiched between two geotextiles. A protective cover layer is placed over the liner. No emergency spillway is provided, since it is intended that pumping out of this facility be initiated whenever there is at least one hour of pumping capacity in the pond. The pond pumps are designed to completely empty the pond within six hours.

The water that accumulates within the Temporary Waste Rock Pile Pollution Control Pond is to be pumped to the tailings pump box within the mill so that it can be transferred to the tailings containment area. No water is to be discharged onto the surrounding tundra without the authorization of the Nunavut Water Board.

The water flow pathways for the Camp and Mill Pad Area are shown on Figure 4.7. The blue arrows represent uncontaminated runoff directed by berms away from the pad area. This water will be directed around the pad. The green arrows represent the runoff flow from the “clean” areas of the pad which will be directed to the Sedimentation Pond. The red arrows represent the runoff flow from the “dirty” areas of the pad which will be directed to the pollution control pond for transfer to the TCA.

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[11] Section 6, Water Management Plan, Supporting Document S10j to the Revised Water License Application Support Document, April 2007.

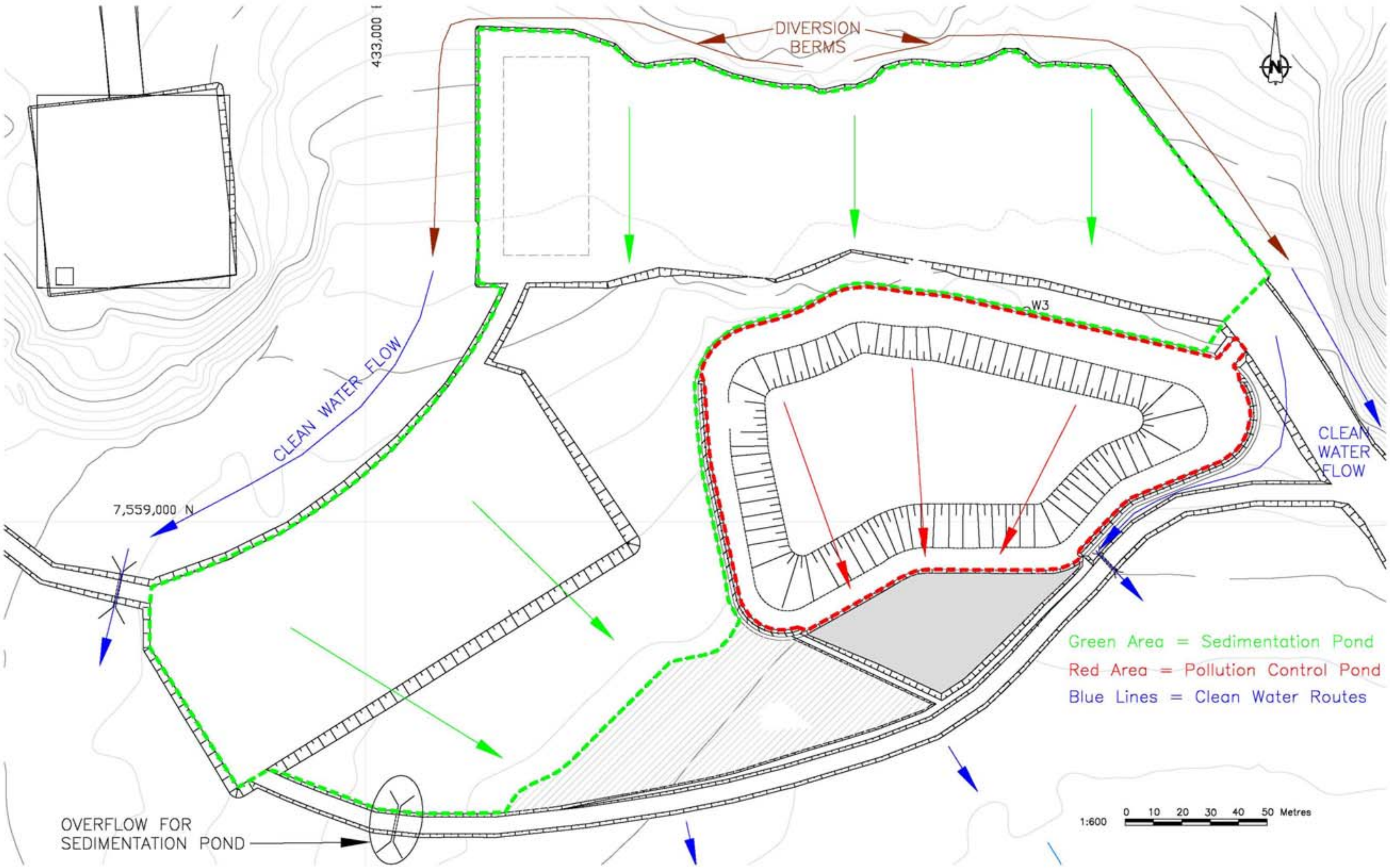

Figure 4.7: Water Flow Patterns at the Camp and Mill Pad Area (Including the Temporary Waste Rock and Ore Stockpiles)

Storm Water and Snowmelt from the Fuel Transfer Station, Fuel Tank Farm and Landfarm Facility

The precipitation runoff and snowmelt collected in the sumps at the fuel transfer station, the fuel tank farm and within the landfarm facility will be treated by passing this water through an F1 “Flow and Plug” Oil Adsorption System (Model F11-C-180-TM-Cx2 as supplied by Terry Ruddy Sales of Edmonton Alberta)[12]. This is a portable unit set up on standard pallets so that they can be moved to the fuel transfer station, the fuel tank farm and the landfarm facility as and when needed. The system consists of a self priming electric positive displacement pump, a particulate filter, a drum containing TM-100 oil adsorbing media and two activated carbon media containers connected in series. The unit operates at 5 to 7 gpm. The unit is designed so that the TM-100 oil adsorbing media will blind off when it reaches its absorbent capacity. The unit will be moved into location soon after the spring snowmelt so that the sumps in the fuel transfer station, the fuel tank farm and the landfarm can be drained of precipitation runoff and snowmelt water collected inside the lined facility sump. The unit will then be moved back into the transfer station, the fuel tank farm and the landfarm whenever the sump fills (such as in the late summer or fall when precipitation falling as rain normally increases).

No allowance has been made to remove uncontaminated snow from each of these facilities (the fuel transfer station, the fuel tank farm and the landfarm) before the spring melt. It has been assumed that all snow collected in these three lined facilities will melt and have to be treated through the oil-water adsorption system. In reality MHBL will attempt to remove uncontaminated snow from these facilities, specifically in areas of drift in the late winter ahead of the spring thaw. A combination of hand shovelling and a small bobcat front end loader will be used to clear this snow where practical. This activity will be directed by the on-site Environmental Coordinator to ensure that the liner integrity is protected.

All precipitation runoff and snowmelt from these three facilities will be treated through the Oil Adsorption System with the treated water then directed onto the nearby tundra to be land applied in a method that prevents erosion at the point of application.

Storm Water and Snowmelt Management at the Non-Hazardous Landfill Facility

Non-combustible and non-hazardous waste will be disposed of in a landfill that will be constructed in a portion of the rock quarry immediately west of the camp (Quarry 2). A surface area of at least 100 m x 100 m will be dedicated to the landfill. The landfill will be isolated from the surrounding watershed via a set of containment and barrier berms. The landfill surface will be graded towards a single sump to allow pump out of clean water directly onto the tundra, or contaminated water to a tanker and then on to Tail Lake. The landfill

[12] Appendix B, Landfarm Management Plan, Supporting Document S10h to the Revised Water License Application Support Document, April 2007.

will be fenced and access will be via a lockable vehicle gate. Geotechnical drilling[13] conducted in the winter of 2006 indicates that the rock in Quarry 2 is competent basalt and gabbro rock with little variation in rock type with depth. The tightness of the bedrock and the presence of permafrost ensures that there is no potential for leachate to drain away from the landfill site through the underlying rock. Any drainage is predicted to be on surface across the floor of the quarry.

Uncontaminated precipitation runoff will be directed away from the landfill area by small rockfill berms located along the upslope edge of the quarry excavation. Similar rockfill berms constructed along the down slope edge of the quarry excavation will retain precipitation runoff and snowmelt within the landfill footprint. The floor of the quarry is founded on bedrock and will be sloped gently to drain into an excavated sump located at the south-east corner of the landfill area.

Water will be pumped from the sump onto the tundra and be land applied, as long as the water quality is deemed to be acceptable. The water will be discharged to an area immediately to the east of quarry 2 where it will have a long cross country flow path before reaching Doris Lake. If water quality does not meet the proposed discharge standards then the water contained in the landfill pollution control sump will be pumped into a truck mounted tank and transferred to the tailings containment facility at Tail Lake. This transfer of water will continue until sampling verifies that the landfill pollution control sump water complies with the proposed discharge standards. The volume of water collected in the sump is expected to peak in the spring freshet then remain relatively dry throughout the summer months, increasing during the final 30 days leading up to winter.

4.9 Solid Waste Management

4.9.1 Domestic & Industrial Solid Waste Landfill Site

All solid non-combustible, non-hazardous waste will be disposed of in a portion of one of the rock quarries (quarry No.). An area approximately 100 m x 100 m will be dedicated to solid waste landfill operations. The final quarry configuration will consist of a flat surface, graded at in the down slope direction, adjoining a steeper angled rock surface that forms the transition to natural ground on the ridge above. Storm and melt water will be diverted away from the landfill by small berms on the upslope edges of the excavation.

Annual landfill operation will involve clearing of snow prior to spring melt, placement of waste rock over the summer period, and placement of a graded cover prior to the winter period of snow accumulation. Wastes produced during the winter months would be stored temporarily in the landfill area and relocated to its final location following snow removal.

[13] Section 4.2.1 and Appendix C, Geochemical Characterization of Quarry Materials, Supporting Document S7 to the Revised Water License Application Support Document, April 2007.

All combustible material including kitchen waste will be incinerated in an industrial incinerator to be located near the camp.

4.9.2 Waste Oil & Hazardous Waste Management

Waste oil will be consumed on site in a dedicated waste oil burner specifically designed for that purpose. Other waste products such as used glycol, vehicle batteries, waste grease, etc. will be packaged in appropriate containers and stored in a secure fashion pending shipment off-site for disposal of in an appropriate manner. These materials will be placed into sea-can containers and held (pending shipment) on the plant site rockfill pad area where any spillage can be captured in the stormwater sumps and directed to the tailings containment area.

4.9.3 Sewage Treatment Facilities

Sewage treatment will be via a modular packaged biological treatment plant that will be brought to site fully assembled within two skid mounted 12.2 m x 2.4 m containers (61 m^2). The treatment plant will have a treatment capacity of 68.6 m^3/day, which is sufficient capacity for a fully manned 175-person camp. The plant will be located downslope of the camp.

Treated effluent is collected in a discharge/recycle tank for delivery into the tailings line. Final discharge is into Tail Lake.

5.0 INTERIM RECLAMATION MEASURES

Interim reclamation planning has been developed for two scenarios: (1) temporary shutdown, and (2) indefinite shutdown. Both scenarios are based on the full intention of resuming operations once the source or reason for the shutdown has been rectified.

5.1 Temporary Shutdown

For the purposes of reclamation planning, a temporary shutdown is defined as a cessation of mining and processing operations for a finite period, generally three to twelve months, with the intention of resuming operations as soon as possible after the reason for the shutdown has been resolved. Possible causes for such a shutdown could be a major mechanical equipment failure, late delivery of critical equipment or supplies, or labour conflict.

5.1.1 Underground Mine

The extent to which the procedures listed below are implemented would depend on the anticipated length of the closure.

- All mobile equipment will be removed to surface and prepared for on-site storage. Some small service equipment will be maintained in full operating condition for use during underground inspection tours;

- Fuel, lubricants and hydraulic fluids will be removed from all underground locations, including storage areas and stored on surface;

- Explosives and accessories will be removed from the short-term underground storage magazines to the surface magazines;

- Airflow through the mine ventilation system will be reduced. The underground exhaust fans will be turned off;

- The underground electric power distribution system will be maintained;

- The full dewatering pumping capability will be maintained;

- The operation of the primary fans, dewatering pumps and drainage sumps will be monitored; and

- The underground facilities will be inspected weekly to check for rock falls, and overall integrity.

5.1.2 Process Facilities

Any remaining ore stockpiled on surface will be processed before operations are halted. The plant will then be shut down in a planned and orderly sequence to prevent damage to equipment, piping and instrumentation. The following preparatory measures will be taken:

- The plant will be purged of all gold bearing materials;
- All gold dorė will be removed from the site;
- All solids will be purged from the flotation circuit, the thickener, stock tanks and leach tanks;
- All slurry lines will be flushed of solids and drained; and
- All reagent storage and mixing tanks will be run empty or drained.

Procedures during the shutdown will be as follows:

- Power supply to the building will be maintained; and
- All major equipment will be run periodically to ensure lubrication and integrity of the rotating parts or the equipment decommissioned by lifting it off its bearings or packing moving components in grease. Minimal heating to the process building will be maintained to prevent equipment freezing.

5.1.3 Surface Infrastructure

During temporary shutdown, the site infrastructure will be placed into a care-and-maintenance mode to minimize operating costs and ensure environmental stability while maintaining conditions that will permit the safe mechanical resumption of operations at reasonable cost and schedule. Procedures during shutdown will be as follows:

- Minimal heating to the critical facilities will be maintained;
- All non-critical equipment requiring power and/or heating will be shut down;
- All necessary support facilities and services for care-and-maintenance personnel will remain in operation. This will include the freshwater intake, potable water treatment plant, sewage treatment plant, power plant, diesel fuel storage and distribution, and some areas of the camp (one dormitory trailer section, kitchen, eating area) and the service shop. Some equipment within these facilities may be adjusted or modified to operate at lower capacity and consume less power. All major equipment will be run periodically to maintain operability;

- Where possible other sleeping quarters, common areas and offices in the camp and office area, except those required by care-and-maintenance personnel, will be closed off so that heating and ventilation can be reduced;

- Any hazardous materials stored within site facilities will be collected and stored in a controlled secure area;

- Most surface mobile equipment will be relocated to a secured, common parking area and inspected for any potential oil or other fluid leaks. Emergency response vehicles will be kept indoors and available for use as required; and

- The power plant will be configured to operate at maximum efficiency under the reduced loading condition.

5.1.4 Ore and Waste Rock Piles

Procedures during temporary shutdown will be as follows:

- Ore stockpile will be run down and emptied prior to the shutdown if possible;

- Any stockpile of potentially acid generating waste rock will be placed underground prior to the shutdown if possible;

- If emptying the ore and potentially acid generating stockpile areas cannot be accomplished prior to the shutdown, then the material will be left in place and monitored for poor quality drainage; and

- Runoff from the ore and stockpile areas will be monitored for water quality throughout the shutdown period. Unacceptable water quality, if encountered will be transferred to the tailings containment area.

5.1.5 Tailings Containment Area

Prior to a temporary shutdown the mill tailings discharge pipelines will be flushed and then drained to ensure that they remain available for resumption of operations. The reclaim pumping system in Tail Lake will be similarly drained.

The water level and water quality within Tail Lake will be monitored with continued operation of the annual pumped supernatant release assuming discharge criteria is being met. The dams and thermosyphons will be monitored and maintained throughout the temporary shutdown period.

5.1.6 Water Management

Procedures during temporary shutdown will be as follows:

- Collection sumps and ditches around the site will be maintained to manage runoff.

5.2 Indefinite Shutdown

For the purposes of reclamation planning, an indefinite shutdown is defined as a cessation of mining and processing operations for an indefinite period with the intention of resuming operations in the future. In this scenario, the site must be placed into a mode of minimal operating expense while maintaining safety and environmental stability. Possible causes for such a shutdown could be depletion of developed mineable resources, prolonged adverse economic conditions or extended labour disputes.

5.2.1 Underground Mine

Procedures during indefinite shutdown will be as follows:

- Mobile and some semi-mobile and some fixed equipment will be removed from underground and stored on surface. This will include all mobile equipment; electric motors; secondary ventilation fans; portable dewatering pumps; and electrical substations. All other non-degradable and non-hazardous materials will be left underground;

- All fuel, lubricants, hydraulic fluids, hazardous materials and degradable material will be removed from the underground storage areas to surface, where they will be placed in appropriate containers and stored in a secure area; and

- The adit portal and the surface collars of the three raises will be barricaded with secured steel structures, and warning signs will be posted.

5.2.2 Process Facilities

The same measures taken for temporary shutdown of the plant (Section 5.1.2) will be taken for indefinite closure, with the following additional activities:

- Equipment and gearboxes will be drained of lubricants, which will be stored in sealed drums in a secure area;

- All tanks will be drained;

- All water, glycol and slurry lines will be flushed and drained. Glycol will be stored in sealed drums in a secure area;

- Sensitive electronic devices such as instrumentation control cards, PLCs and control system computers will either be removed from the site or stored in a heated, access-controlled location on site;

- Heavy rotating equipment such as the ball mills will be lifted off bearings and safely supported; and

- The entire process plant will be locked and all heating and power supply turned off. Minimal site staff will be required during this period.

5.2.3 Surface Infrastructure

As in the case of a temporary shutdown, the site infrastructure will be placed into a care-and-maintenance mode of operation. The same measures taken for temporary shutdown (Section 5.1.3) will be taken for indefinite closure.

5.2.4 Waste Rock Piles

In the event of an indefinite shutdown the following actions will be taken to secure the chemical stability of any ore or potentially acid generating rock stored on surface and to minimize the requirement for a continued site presence:

- Ore stockpile will be run down and emptied prior to the shutdown; and

- Any stockpile of potentially acid generating waste rock will be placed underground prior to the shutdown.

5.2.5 Tailings Containment Area

Prior to an indefinite shutdown the mill tailings discharge pipelines will be flushed and then drained to ensure that they remain available for resumption of operations. The reclaim pumping system in Tail Lake will be similarly drained.

The water level and water quality within Tail Lake will be monitored with continued operation of the annual release assuming discharge criteria is being met. The dams and thermosyphons will be monitored and maintained throughout the shutdown period.

5.2.6 Water Management

Prior to an indefinite shutdown the emergency tailings catch basins will be pumped out and the remaining solids moved to the tailings containment area. The mill sumps will be washed out and pumped dry with the washings going to the tailings containment area.

Collection sumps and ditches around the site will be maintained to manage runoff from the general site.

6.0 FINAL RECLAMATION MEASURES

With the completion of mining and ore processing (projected to be at the end of 2010), the mill and all processing circuits will be washed to recover the remaining gold and to remove any material containing cyanide and other milling reagents. All wash down water will be directed through the cyanide detoxification circuit prior to being discharged to Tail Lake.

The site will then be secured and held on a “care and maintenance” basis lasting for approximately five months (January to June) to await outdoor working temperatures more suitable for site disassembly. Over the next two summers (2011 and 2012), all buildings will be dismantled and the roads, building pads and other infrastructure remediated. Salvageable equipment and building material will be transported to the lay down area at Roberts Bay and shipped from site the year following closure (2011). Non-salvageable equipment and material will be cleaned of potentially hazardous material and then disposed of in the on-site landfill disposal area in Quarry 2. Given the remote location of the Doris North Project, it has been assumed that most equipment, buildings and materials will have no economic salvage value and will thus be demolished and disposed of on-site. Estimates of reclamation liability were made on this basis.

Part of the camp and other support facilities such as the sewage and potable water treatment plants and the shop will remain in place during most of the Closure Phase; a short period of approximately two years to provide support to the crews conducting the physical reclamation of the Doris North site. These facilities will be decommissioned and removed during the second year of reclamation (2012). The annual release of supernatant from Tail Lake will have to be actively managed for a period of seven years following the cessation of milling (through 2017. In the fall of 2017, the North Dam will be breached so that water can naturally flow from Tail Lake through the former Tail Lake discharge channel beginning with the spring freshet in 2020. At that time water quality in Tail Lake is predicted to be suitable for uncontrolled release.

In the five year period (2013 through 2017) a two person team will be mobilized to site each summer to manage the pumped release of water from Tail Lake during the open water season. This crew will be housed in a two man exploration camp (tents) re-opened each year for this purpose.

The reclamation plan assumes the worst case scenario, specifically that at the end of the Doris North reserve there is no ongoing exploration or mining activity on the remainder of the Hope Bay Belt. In the more optimistic scenario, MHBL will continue to develop additional reserves on the Belt which would continue the life of the Doris North site. MHBL has indicated that where possible from a practical and economic standpoint, the Doris North camp would continue to be used as the centre for processing other reserves found on the belt. In this case, the reclamation plan will be adjusted as needed to accommodate the extended facility life. MHBL will remove all of the Doris North buildings and facilities once all further activity on the Hope Bay Belt was completed.

The following sections provide a summary of reclamation activity proposed for each of the Project components. A detailed schedule of reclamation activities along with a cost estimate is presented in Section 9.

6.1 General

6.1.1 Inert Solid Materials

Prior to final closure and reclamation activities, it will be necessary to obtain appropriate authorization for a non-hazardous demolition waste disposal site (a demolition landfill) through the regulatory agencies dealing with land leases and water use (KIA, NWB, DIAND). This site will be used for the disposal of all non-hazardous debris generated by the demolition of all non-salvageable equipment, buildings and other materials from the Doris North Project site. MHBL anticipates that this demolition landfill will be located with Quarry 2 as an extension of the operational phase landfill site. The demolition debris will be placed in compacted layers and then buried under a minimum final waste rock cover of 1 m to ensure that large voids within the demolition debris are filled and that buried material will not protrude from the closed out landfill cap as a result of future frost heaving.

Materials destined for burial in the demolition landfill will be dismantled as safely and efficiently as possible and stacked in a stockpile within the plant site area. The materials will then be cut by flame, hydraulic shears or saw, into manageable sizes for safe transport and placement in the demolition landfill.

6.1.2 Hazardous and Salvageable Materials

All potentially hazardous materials will be removed from equipment prior to disposal. This will typically involve draining and removal of all remaining fuels, hydraulic fluid, engine oil, antifreeze, batteries and other lubricating fluids (transmission fluid, grease, etc.). Hazardous materials will be transferred into and stored in sealed containers and drums, and loaded into shipping containers pending removal from site on the next sealift. These materials will be packaged and shipped off site for disposal at an appropriate licensed disposal site. The only potential exception to off-site disposal will be the use of recovered fuel in other mobile equipment used in carrying out reclamation related activities and the use of waste oil in one of the existing waste oil burner units to generate heat during the post-closure care and maintenance and reclamation periods.

Given the remote location of the Doris North site, the salvage value of most pieces of equipment and buildings materials is likely to be insufficient to cover the cost of removal and transport. Consequently for the purposes of this Plan it has been assumed that no salvage credits will be obtained and that all equipment and building materials will be disposed of on site in an appropriate solid waste disposal facility.

Some of the larger pieces of milling and mining equipment may have economic salvage value. This Plan includes an allowance for one shipment south during the post-closure period to facilitate the removal of hazardous materials for off-site disposal. Removal of the higher value pieces of mining and milling equipment from site will be done at the same time, dependent on longer term plans for mineral activities on the Hope Bay Belt.

6.1.3 Underground Mine

Once mining has ceased all potentially hazardous materials will be removed from the underground mine and brought to surface for disposal. These will include all hydrocarbon products such as fuel, hydraulic fluid and other lubricants; explosives; vehicle batteries, glycol, transformer fluids, antifreeze, other chemicals, etc.

Underground mobile equipment will be brought to surface and cleaned of any potentially hazardous materials such as fuel, hydraulic fluids, glycol, batteries, etc. These materials will be stored in appropriate containers and prepared for off-site shipment or on-site destruction (e.g., burning of waste oil). The projected fleet of underground equipment consists of 7 scooptrams, 2 haul trucks, 5 jumbo drill units, 1 blasthole drill unit, 1 scissors lift truck, 1 service/fuel truck, 2 portable air compressors and 4 pickup trucks. Some of this equipment will be used in completing the reclamation activity. Once the equipment is no longer required, the units will be decommissioned as indicated above and then disposed of in the surface solid waste disposal facility site.

All explosives supplies and accessories will be moved off-site or destroyed on-site (typically by controlled burning or detonation) in an appropriate manner. Regulatory agencies will be consulted on the disposal method selected by MHBL in consort with its explosive supplier as the mine enters the closure phase.

Items that will be left underground will typically be non-degradable, constructed of steel or concrete, or associated with utility lines, as follows:

- Floors and walls of material storage areas and refuge stations;
- Concrete foundations;
- Power and communication cables;
- Water (brine) and air pipelines and associated supports;
- Ventilation ducting and supports;
- Ore pass and dump grizzlies, chute work and associated support steel;
- Rock support structures such as rockbolts, screening, etc.;
- Bulkheads; and
- Vent and egress raise ladders.

The three 2.4 m by 2.4 m ventilation raises will be either capped with a reinforced concrete cap or backfilled. The Plan assumes that these vertical mine openings will be closed off and permanently sealed by the placement of a concrete cap. The fans, fan housings and associated ducting will be removed from the surface over top of these three ventilation raises and disposed of in the on-site solid waste disposal facility. The collars for the raises will be capped with a reinforced concrete cap founded on solid rock. The concrete caps will be designed and constructed for a uniformly distributed load of 12 kPa and a concentrated load ranging from 24 to 54 kN as suggested in the Mine Site Reclamation Guidelines for the NWT. Provision for the venting of gas accumulation under the concrete cap will be provided as part of the cap design.

Following installation of the concrete caps, low-profile warning signs will be installed at each location.

The concrete raise caps will be designed and constructed in accordance with the regulations established in Ontario for that purpose (with the exception that the uniform and point load specifications contained in the Mine Site Reclamation Guidelines for the NWT will be substituted). Schedule 1, Part 1 of Ontario Regulation 240/00 under the Ontario Mining Act provides a standard for the installation of a reinforced concrete cap to seal mine openings, specifically:

Concrete Caps:

1) *Before installation of a concrete cap to stop shafts, raises and stopes,*
   a) *A qualified professional engineer shall examine the competency of the rock at the supports and no construction shall be undertaken unless the engineer approves the rock as competent;*
   b) *All loose rock shall be removed from the rock anchorages leaving only competent rock;*
   c) *All concrete work shall meet or exceed the minimum standards set out in the CAN/CSA-A23.1-M90 or latest revision;*
   d) *The formwork for the concrete, shoring and temporary support shall be designed by a qualified professional engineer.*

2) *The concrete cap may be left exposed to the elements or may be buried.*

3) *Where the cap is to be left exposed, consideration shall be given to providing a slope to the surface of the cap to prevent the collection of water on the surface.*

4) *All reinforced concrete caps shall meet or exceed the following specifications:*
   The reinforced concrete cap shall be designed for the following minimum design live loads:

   - *1.4 metres cover of saturated soil uniformly distributed with a unit weight of 19 kN/cubic metre, and*
   - the greater effect of either,
     - *an 18 kPa uniformly distributed load, or*
     - *an 81 kN concentrated load applied over an area 300 mm by 300 mm anywhere on the cap, and*
   - *the weight of the cap as the dead load.*

5) *The 28-day concrete strength shall be a minimum of 30 Mpa.*

6) *The reinforcing bars yield strength shall be a minimum of 400 Mpa.*

7) *The concrete cap minimum thickness shall be,*
   - *450 mm as per MNDM Drawing No. 94103-M1: "Monolithic Concrete Cap Typical Plan and Section" and Drawing No. 94103-M2: "Typical Monolithic Concrete Cap Reinforcement Schedule", or*
   - *300 mm if an alternate design with all calculations is provided.*

8) *All supports shall be founded on sound rock having a minimum bearing capacity of 600 Kpa.*

9) *All concrete design shall be as per CAN3-A23.3-M84 or it most recent revision.*

10) *The reinforced concrete cap shall be vented with a stainless steel pipe that is at least 75 mm in diameter and extends above the cap or soil cover to permit airflow.*

11) *The reinforced concrete cap shall be securely attached to the bedrock or to the concrete collar if one exists.*

12) *Appropriate reinforcing steel bars and concrete shall be used in areas where corrosive conditions may exist.*

Reinforced Concrete

1) *The concrete design shall meet the following specifications:*
   - *The minimum 28-day concrete strength shall not be less than 30 MPa.*
   - *The maximum slump shall not be greater than 75 mm +/- 25 mm.*
   - *The maximum aggregate size shall not be greater than 20 mm.*
   - *The air entrainment content shall be 6 percent +/- 1 percent.*
   - *The maximum water/cement ratio by weight shall not be greater than 0.50.*
   - *The aggregates used in the concrete mix shall be non-alkali-silica reactive type.*

2) The concrete cover shall be as follows:
   - *75 mm thick on the top of reinforcing bars.*
   - *50 mm thick on the bottom of reinforcing bars.*
   - *40 mm thick on the stirrups.*

3) *The concrete shall be cured as per CSA-A23.1-M90 or its latest revision. Curing compounds shall be clear liquid conforming to Canadian General Standards Board (CGSB) Standard 90-GP-1a, Type 1 or latest revision and applied as directed by the manufacturer.*

Inspection and Testing

1. *Before the placement of concrete, a qualified professional engineer shall inspect and approve any reinforcing steel bars that have been installed.*
2. *The concrete shall be tested for air content and slump in the field.*
3. *A minimum of one set of four cylinders shall be cast and tested for compressive strength.*
4. *The cylinders shall be cured under the same field conditions as the shaft cap and seat support (if applicable).*
5. *The testing shall be done in accordance with CAN/CSA-A23.2-M90 or its latest revision*.

A qualified professional engineer shall certify all test results obtained and the certified results submitted to the Director no later than 30 days after testing.

The portal access to the underground will be permanently closed by the placement of a 15 m thick rockfill plug and then sealed with a welded steel cover to make the underground workings inaccessible to people or wildlife in compliance with mine safety requirements. The Plan assumes that 300 m^3 of broken rock will be placed by scooptram inside the adit to form the plug followed by the construction of a welded steel barricade.

The ground in the mine will remain in a frozen condition thus there will be no anticipated movement of groundwater into or out of the mine, thus no water treatment of minewater will be required. The frozen ground combined with the lack of groundwater movement will retard any sulphide mineral oxidation and prevent the transport of any contaminants away from the mine workings.

The mine will not be force flooded during any project phase. In the unlikely event that future global warming results in a loss of permafrost in this region, then it is expected that the underground workings will ultimately flood to a level most likely equalizing with the lake level in Doris Lake.

6.1.4 Process Facilities

At the cessation of underground mining all remaining ore-grade material on surface will be processed through the crushing plant and mill to extract the contained gold. The ore stockpile laydown area will be scraped clean using a front-end loader with the material being processed through the mill.

Once all the ore has been processed through the crushing plant and mill, the various circuits will be cleaned using high-pressure water hoses starting at the front of the process and working through the various unit processes thereby maximizing the recovery of any residual gold left in the circuit. The final washings will be passed through the circuit ultimately ending up in the tailings containment area. Once the milling circuit has been cleaned out the building structures themselves will be washed thoroughly on the inside using high-pressure water hoses.

All potentially hazardous materials such as hydrocarbons, chemicals and reagents will be removed from the plant prior to this final washing. Reagent tanks will be drained and cleaned awaiting demolition. The milling equipment will be drained of any potentially hazardous materials such as lubricating oil, glycol, etc.

For the purposes of this closure plan it has been assumed that at the end of the economic life of the Doris North Project all of the crushing and milling equipment will have no off-site salvage value. Consequently the equipment will be dismantled and disposed of through burial in the proposed on-site solid demolition landfill.

Similarly the mill building used to house the crushing plant and the milling equipment is assumed to have no-off site salvage value. The building will be dismantled and/or demolished with the debris being disposed of through burial in the proposed on-site demolition landfill.

Concrete foundations, pedestals and floor slabs within the mill building will be broken up and the rubble transported to the demolition landfill.

6.1.5 Surface Infrastructure

This section provides the reader with a summary description of how each component of the surface infrastructure at Doris North will be reclaimed. This is not intended to provide design details for these facilities. The reader is referred to the following sources for the design information:

- Design of the Surface Infrastructure Components Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S2 to the Revised Water License Application Support Document, April 2007);

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S4 to the Revised Water License Application Support Document, April 2007); and

- Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting Engineers and Scientists, dated March 2007. (Supporting Document S3 to the Revised Water License Application Support Document, April 2007).

6.1.5.1 General

Specific materials will be dealt with as follows:

- Where they exist concrete foundations will be broken down to nominal ground level and the concrete rubble buried in the on-site demolition landfill;
- Any buried piping will be removed to just below grade and the ends capped. Any buried fuel and glycol lines will be flushed with water, removed and buried in the on-site demolition landfill facility (it should be noted that the current Doris North Project development plan does not include planned use of any buried piping for any purpose and consequently this condition is included in case any pipelines are buried during the mine life); and
- Buried electrical cables will be cut approximately 1 m below grade at surface terminations and left intact. (it should be noted that the current Doris North Project development plan does not include planned use of any buried cabling for any purpose and consequently this condition is included in case any cables are buried during the mine life). All above ground cable will be removed and buried in the on-site solid waste disposal facility.

The potential for soil/rockfill contamination at facility sites will be assessed. This will include fuel storage pads, fuel tank areas, process plant, power plant, accommodations complex, service shop, waste management facilities and storage facilities. oils in these areas will be sampled through a program of shallow test pitting during decommissioning and analyzed for contaminants such as hydrocarbons and metals. A soil remediation plan will be developed to address such contamination assuming that some contamination is discovered. Best available practice and research studies for contaminant remediation in arctic soil will be assessed and used in the design and development of the soil remediation plan. Typically remediation plans will involve either:

- o The in-situ treatment of some soils, such as lightly hydrocarbon contaminated soils;
- o The excavation and treatment of some soils using conventional land farming techniques using biologically enhanced treatment techniques, such as more heavily hydrocarbon contaminated soils;
- o The excavation and placement of some soils into the underground mine, such as those soils identified as being contaminated with metals to levels above accepted remediation criteria; and
- o The excavation and placement of some soils in drums and sent offsite to a licenced disposal facility.

Risk Assessment techniques will be applied in determining which soils are to be remediated and to what degree. Regulatory agencies and representatives of the land owner will be involved in this process.

The Environmental Protection Service of the Nunavut Department of Sustainable Development has published an "Environmental Guideline for Soil Remediation" that provides guidance as to acceptable levels for the remediation of hydrocarbon contaminated soils in Nunavut. These guidelines are derived from the CCME 1991 Interim Criteria and the CCME 1997 Recommended Soil Quality Guidelines.

MHBL[14] will use the industrial remediation guideline as set out in Table 6-1 to determine when soil has been remediated to an acceptable level.

Table 6.1: Nunavut Environmental Guidelines for Soil Remediation

Remediation Guidelines for Soil				
	Agricultural	Residential/ Parkland	Commercial	Industrial
Benzene	0.05	0.5	5	5
Toluene	0.1	0.8	0.8	0.8
Ethylbenzene	0.1	1.2	20	20
Xylene	0.1	1	17	20
Total Petroleum Hydrocarbons (TPH)*	-	500**	2500**	2500**
Lead	70	140	260	400
Polychlorinated biphenyl	0.5***	5***	50***	50***

Note: All values are in µg/g or parts per million (ppm). These are the more commonly required parameters. The type of contamination at the site may require analysis for additional CCME parameters.

Government guidelines such as the CCME's Canada-wide soil quality guidelines for the protection of environmental and human healthwill be consulted on an individual chemical basis for other parameters.

It should be noted that remediation of hydrocarbon contaminated soils by landfarming techniques has been successfully achieved in Arctic regions with similar climate conditions to those experienced at Doris North (see literature in Appendix C). The performance of remediation tends to be slower in the Arctic than in more temperate climates but the

[14] See discussion of applicable remediation criteria in Section 2, Landfarm Management Plan, Supporting Document S10h to the Revised Water License Application Support Document, April 2007.

procedure still works. Landfarming is not successful for all forms of hydrocarbon contamination. It typically is more successful for the lighter hydrocarbons than for heavier oils.

6.1.5.2 Buildings and Equipment

All surface mobile equipment is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all potentially hazardous materials such as batteries, hydrocarbons, glycol, fuel, etc. and then be disposed of through burial in the proposed on-site demolition landfill site. The projected surface fleet will consist of the following equipment: 4 haul trucks, 3 front end loaders, 2 dozers, 1 excavator, 1 road grader, 4 fuel trucks, 1 Plow truck, 5 pickup trucks, 1 mini-bus, 1 vacuum truck and 3 portable lighting plants.

All stationary equipment (generators, etc) is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all potentially hazardous materials such as process residues, chemicals, hydrocarbons, glycol, etc. and then be dismantled and disposed of through burial in the proposed on-site demolition landfill.

All buildings are assumed to have no-off site salvage value. Consequently all of the buildings will be checked to identify and create a listing of all potentially hazardous materials that need to be removed. The buildings will then be cleaned to remove all potentially hazardous materials such as chemicals, reagents, hydrocarbons and then dismantled and/or demolished with the debris being disposed of through burial in the proposed on-site demolition landfill. The following buildings are to be removed and disposed of:

a. Mill and Crushing Plant – 2,500 m^2 footprint (6,000 m^2 equivalent on multi floors used to cost demolition);
b. Service Workshop – steel frame, steel clad building 1,500 m^2;
c. Camp – 53 skid mounted trailer units, 61 m^2/unit;
d. Office/Dry – 6 skid mounted trailer units, 61 m^2/unit;
e. Sewage treatment plant – 2 skid mounted trailer units, 61 m^2/unit;
f. Power Plant – steel frame, steel clad building, 384 m^2;
g. Arctic Corridors – 1,500 m^2;
h. Mill reagent storage – 20 shipping containers, 30.5 m^2/unit;
i. Explosives magazines and mixing plant - 20 shipping containers, 30.5 m^2/unit; and
j. Tail Lake pump house – 100 m^2.

These buildings will all be single story buildings with the exception of the mill and crusher building which have elevated working floors throughout most of the plant. An allowance has been included for clean up and removal of miscellaneous bone yard materials from around the buildings for disposal in the demolition landfill.

Where concrete slabs are present, the slabs will be broken and removed with the concrete rubble placed in the demolition landfill.

6.1.5.3 Roads and Airstrip

All site roads not required for post-closure maintenance and monitoring will be decommissioned and reclaimed at the end of the closure and reclamation period. The rest will be reclaimed at the conclusion of the post-closure monitoring program. Most access in the post-closure period will be by aircraft (floatplane), with minimal travel across the site roads.

The airstrip will be reclaimed near the end of the reclamation program. Lighting, navigation equipment and culverts will be removed to eliminate potential hazards to wildlife. Reclamation will involve scarifying and loosening the top surface to facilitate natural revegetation. Where erosion or sedimentation is a concern, the surface will be recontoured. Culverts and other stream-crossing structures will be removed to permit natural drainage to become re-established.

All site roads will be reclaimed using the following typical process:

- All road side safety berms will be removed by dozing them off the road;

- All road signs will be removed;

- The road surfaces will be graded to provide positive drainage of precipitation and snowmelt away from the road surface onto the surrounding countryside and to prevent water ponding on the road surfaces;

- The road surfaces will be scarified to a depth of 4 to 6 inches using a grader mounted scarifying unit or other similar device to loosen up the surface to promote natural re-vegetation over the long-term. There will be a total of 7.68 ha of road and airstrip surface to be graded and scarified. MHBL will assess revegetation techniques that have been proven successful at other northern sites and where practical surfaces will be seeded to accelerate the natural invasion of native vegetation. An allowance for this revegetation has been included in the reclamation cost estimate;

- The Doris Outflow bridge crossing will be removed and the bridge disposed of in the on-site solid waste disposal site. The bridge footings will be removed and the fill on the stream banks graded and armoured at the road crossing to prevent precipitation runoff eroding away the exposed bank;

- All culverts will be removed. The culverts will be disposed of in the on-site solid waste disposal site. The excavation sides will then be pulled back and armoured if necessary with coarse rock to allow free passage of precipitation and snowmelt runoff and to prevent erosion of the former road materials into these drainage paths. There will be 15 culvert crossings to be removed and regraded by this technique.; and
- Following demolition of the buildings and final debris removal, the plant site and camp area, the beach laydown, the mill tank farm area and the explosives magazine storage area will be given a final grading and scarification to loosen up the top layer of the rockfill to enhance the natural in-growth of vegetation over time and to ensure the drainage of precipitation and snowmelt from these pads onto the surrounding countryside. As indicated for the roads and airstrip, MHBL will assess revegetation techniques that have been proven successful at other northern sites and where practical surfaces will be seeded to accelerate the natural invasion of native vegetation. An allowance for this revegetation has been included in the reclamation cost estimate;

6.1.5.4 Jetty

The jetty will remain in operation for two years of active decommissioning after mining ceases. For information purposes reclamation of the jetty structure would be completed as follows[15]

- All mooring bollards and anchor points will be removed from the rockfill jetty at Roberts Bay. The rockfill jetty will then be partially removed using the following procedure:
    - A backhoe will be used to excavate the surface of the rockfill jetty so that there is a minimum of 1 metre of water cover over the remaining rockfill to ensure no obstruction to small boats approaching the shoreline at this point;
    - The excavated rock fill will be placed into the water alongside the foot of the jetty on both sides to provide a coarse rock substrate along both sides of the removed jetty; and
    - At the shore end the rockfill will be removed and graded to ensure that no part of the jetty extends above the low water line.

It is expected that over time ice and wave action will obliterate any remaining sign of the rockfill jetty (estimate that this will occur with five years post closure). It is estimated that 2,080 cubic metres of rockfill will have to be excavated at a unit cost of $10.00 per cubic

[15] See Drawing J-01, Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Supporting Document S4 to the Revised Water License Application Support Document, April 2007.

metre to decommission the jetty as proposed. Total allowance for jetty removal is estimated at $26,000.

Complete removal of the jetty is not possible without removal of a substantial volume of natural marine sediments. After reclamation there will be no above water evidence of the jetty.

Condition number 21 of the NIRB Project Certificate states:

> *MHBL shall consult with local Elders, KIA and NTI to determine* ***if*** *the jetty should be dismantled. The Final Closure and Reclamation Plan, if it proceeds, must explain the consultation process used for the jetty and provide a summary of the issues identified during consultation.*

In October of 2006, MHBL contacted the KIA to seek assistance in meeting this condition. KIA 9funded by MHBL) arranged a series of meetings (October 12 thru the 16th) with representatives of the Community Beneficiary Committees from Kugluktuk, Bathurst Inlet, Umingmaktok and Cambridge Bay to address this issue on the jetty. MHBL provided design information to the KIA to be presented to the meeting participants so that they could have an understanding of the issue. The initial intent was to hold several smaller meeting in the communities however due to weather problems the meeting was held in Cambridge Bay and a charter flight arranged to bring the participants from the communities to Cambridge Bay.

The KIA reported to MHBL that the Community Beneficiary Committee members in attendance indicated a preference for the partial removal of the jetty at Roberts Bay as reflected in the proposed reclamation measure presented above.

6.1.5.5 Boat and Plane Dock

The boat and plane dock on Doris Lake will be removed. The wood pontoon structures will be removed and disposed of in the site landfill. The mooring bollards will be cut flush at the bottom of the lake and removed. A 0.1 metre of clean rockfill will be paced over the bollards left imbedded in the bottom of the lake. The rock fill approach ramp and laydown area will be reclaimed in the same manner as the site roads. Prior to final grading all anchor points, attached cables, wood cribbing, *etc.* will be removed.

6.1.5.6 Quarries

Reclamation of the four proposed rock quarries will involve the removal of all mobile and stationary equipment followed by slope stabilization and contouring as required. On-site stockpiles of rock will be depleted during the last years of operation. Remaining material will be spread and contoured to blend with the surrounding landscape.

Quarries 1 and 3 (Roberts Bay and Tail Lake areas respectively) will only be active during the construction period. Quarry 4 is the levelling of a rock outcrop to allow for construction of the mill building on bedrock. Quarry 1 and 3 will be closed out by stabilizing the final quarry walls by reducing them to a stable angle of repose. While it is planned that this activity will take place during construction as part of the planned quarry development plan, an allowance has been included in this reclamation cost estimate to ensure that slopes are adequately stable at final mine closure. Any remaining rockfill materials will be spread across the floor of the quarry. An for revegetation has been included to cover stabilization and seeding of any disturbed ground that is not rock outcrop. Revegetation of the quarries will be limited given the lack of available soils and the remaining rock surfaces.

Quarry 2 is proposed to become the on-site solid waste disposal site and will end up receiving demolition debris from the removal of the mine's buildings at final reclamation. This quarry will be closed out near the end of the reclamation period.

Upon closure, the non-hazardous solid waste disposal site will receive a final cover of non-PAG rock (minimum of 1 metre), over the compressed demolition debris to create a mounded cover. The surface will be re-graded to blend in with the surrounding terrain. An allowance of 10,000 m^3 of rock fill has been allowed for this activity. The unit rate used for the loading, hauling and placement of the rock fill cover assumes that the rock fill material will be non-acid generating waste rock from one of the surface quarries stockpiled in Quarry 2 through the mine's operating life. The estimate assumes an average cover thickness of 1 m in depth over a surface area of 10,000 m^2. The final cover will then be graded to shed precipitation and snowmelt from the solid waste disposal site.

Surface drainage will be directed away from the site. While it is expected that permafrost will form within the capped landfill within a short term, the closure or long term stability of the landfill does not depend upon or require the presence of permafrost within the landfill. Precipitation runoff will be directed away from the landfill by upslope berms. The landfill will not contain hazardous waste materials. The volume of seepage from the dump will be small and is not expected to be of poor quality.

A small landfarm facility[16] will be constructed inside the footprint of Quarry 2 to allow for the on-site remediation of hydrocarbon contaminated soils produced as a result of unplanned accidents on site. This landfarm will be bermed and have an underlying impervious HDPE liner. Accumulated water and snowmelt will be passed through a filter system to remove hydrocarbons and then land applied onto the nearby tundra for adsorption into the surface layer of the tundra[17]. Any contaminated soil that cannot be successfully remediated will be placed underground in an appropriate area for permanent isolation from the surface environment where it will become encapsulated within the frozen ground upon final mine closure.

Upon closure, hydrocarbon contaminated soils within the landfarm will be tested. Soils that do not meet the GN CCME remediation industrial standards for use will be removed and placed in the underground mine where they will be permanently stored within the permafrost. Soils that have been remediated to meet the GN remediation CCME standards

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[16] See additional information on the proposed design for the landfarm facility in Section 4.16, Design of the Infrastructure Components, Supporting Document S2 and Drawings S-13 and S-14, Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Supporting Document S4 to the Revised Water License Application Support Document, April 2007.

[17] See additional information on the operational management of the landfarm facility in Landfarm Management Plan, Supporting Document S10h to the Revised Water License Application Support Document, April 2007.

will also be removed and used to establish as a vegetative medium over reclaimed areas at the plant site. The underlying HDPE liner will then be brushed clean, removed, cut into pieces and disposed of within the site landfill. The underlying rockfill base and berms will be tested for hydrocarbon contamination and if within the GN remediation standard removed and used to help close out the landfill site. Rockfill that does not meet the remediation standard will be placed in the underground mine within the permafrost to isolate the material from surface and groundwater

6.1.5.7 Mill Site Fuel Storage Tanks

There will be five 1.5 million-litre capacity diesel fuel storage tanks at the mill site fuel storage tank farm area to be cleaned, decontaminated and dismantled. In addition, an allowance has been included for the decommissioning, cleaning and dismantling of five smaller fuel tanks (skid mounted Envirotanks). It is assumed that the tanks will be essentially drained of useable fuel by the end of the mine life. An allowance for the disposal of 20,000 litres of residual fuel has been incorporated into the “chemicals” component of the reclamation cost estimate.

During the reclamation period, fuel requirements will initially be met from the remaining inventory in the main tank farm storage tanks; these tanks will then be drained, cleaned out and dismantled. The storage tanks will be steam cleaned and the residual oil recovered through an oil-water separator unit either brought to site for that purpose or constructed out of one of the Envirotank units already on-site. The wash water will be recycled until all the tanks are cleaned. The tanks will then be dismantled with the non-salvageable material to be buried within the on-site demolition landfill. The containment berm and liner materials will be removed and the area regraded. Liner materials will be cut into smaller strips and buried in the demolition landfill. The containment area will then be dozed level and regraded to ensure that precipitation and snowmelt runoff do not pond in this area and that the area drains effectively onto the surrounding landscape with minimal to no erosion.

Fuel will be then drawn from the Envirotanks for the balance of the reclamation program. The Envirotanks will then be cleaned out in a similar manner, the tanks cut up and the debris disposed of in the demolition landfill.

6.1.5.8 Power Plant

The main power plant will remain in use during the reclamation period as long as the power demand is great enough for efficient operation of one or more of the main generators. This period of extended use will end when the power plant must be decommissioned to maintain the overall reclamation program schedule. At this time, the power plant will be shut down, decommissioned and dismantled using the general measures described earlier in Section 6.1.4.2. Surface power distribution lines and poles will be removed and disposed of.

6.1.5.9 Site Support Facilities

Potable water treatment, sewage treatment and communications systems will be maintained to support construction personnel throughout the reclamation program. These systems will then be decommissioned, dismantled and disposed of.

6.1.5.10 Solid Waste Management Facilities

Once no longer required for ongoing use during the reclamation period, the incinerators, waste-handling equipment and associated structures will be dismantled and all debris buried within the demolition landfill.

The potential for contamination of the ground in the immediate area of the incinerator and waste handling facilities will be assessed. Any required remediation will be carried out, and a cover of clean non-potentially acid generating (non-PAG) rock will then be placed over the site. The area will be regraded to blend with the surrounding topography.

6.1.6 Mine Waste Rock Piles

Under the mining plan it is expected that all development waste rock will be used internally as backfill within the mine workings[18]. All of the underground waste rock brought to surface will be placed onto the temporary waste rock stockpile to be returned into the underground mine during the mine life. A schedule of mine waste rock and ore production over the mine life (8 months of development and 24 months of production) is presented in Table 6-2. The table shows on a month by month basis the predicted tonnage of underground waste rock generated, the amount of waste rock moved from the mine to the temporary stockpile, the amount of waste rock returned into the underground mine as fill and the net stockpile balance. This production schedule shows the stockpile growing in size to reach a maximum of 137,041 tonnes in month 13 (5 months after mill production starts), then dropping to a zero balance by the end of the projected mine life.

The pile is projected to be fully gone by the end of August 2010 with the mill ceasing production four months later. There is sufficient open void space within the planned production stopes at the Doris North underground mine to receive all of the underground waste and the dewatered cyanide leach residue. The estimated void space is 148,000 m^3. The dewatered leach residue generated over the two year mine life is estimated to be 25,000 m^3 at the average concentrate weight pull of 10% (i.e., 10% of the tonnes milled reports to the dewatered cyanide leach residue, the remaining 90% being flotation tailings), leaving 123,000 m^3 of void space to accommodate the estimated 110,451 m^3 (198,812 tonnes at a broken specific gravity of 1.8 tonnes/m^3) of underground mine waste rock.

[18] See the Waste Rock Management Plan, Supporting Document S10d to the Revised Water License Application Support Document, April 2007.

Table 6.2: Doris North – Backfill and Waste Rock Stockpile Schedule (Oct 2006)

Month*	Tonnage Mined		Ore Tonnage Source			Fill Requirement**		Stockpile	Ending
	Ore	Waste	Dev	C&F	Open	C&F Stope	Open	Movement	Stockpile
1	0	6,387	0	0	0	0	0	6,387	6,387
2	0	12,230	0	0	0	0	0	12,230	18,617
3	0	12,638	0	0	0	0	0	12,638	31,255
4	0	13,804	0	0	0	0	0	13,804	45,059
5	0	12,136	0	0	0	0	0	12,136	57,195
6	1,738	11,817	1,738	0	0	0	0	11,817	69,012
7	5,839	16,036	5,839	0	0	0	0	16,036	85,048
8	11,430	17,440	7,182	4,248	0	1,159	0	16,281	101,329
9	12,958	16,214	5,907	2,747	4,304	6,724	0	9,489	110,818
10	19,520	14,580	3,688	5,724	10,107	6,619	0	7,961	118,779
11	21,742	13,738	5,407	5,613	10,722	7,754	0	5,984	124,763
12	18,328	12,994	3,734	4,909	9,685	6,201	0	6,793	131,556
13	21,789	12,363	5,165	5,902	10,722	6,878	0	5,485	137,041
14	19,567	10,970	3,998	11,024	4,545	6,424	21,779	-17,233	119,808
15	21,557	10,681	5,559	7,068	8,930	10,793	0	-112	119,696
16	21,767	663	4,591	0	17,176	7,377	0	-6,715	112,981
17	24,700	0	6,403	467	17,831	3,706	0	-3,706	109,275
18	21,795	0	1,759	2,206	17,831	3,372	0	-3,372	105,904
19	22,887	0	0	6,846	16,041	5,739	0	-5,739	100,165
20	17,653	0	0	6,935	10,718	5,736	0	-5,736	94,428
21	20,506	0	0	10,134	10,372	4,623	0	-4,623	89,805
22	18,487	0	0	8,756	9,731	6,756	0	-6,756	83,050
23	18,654	0	0	1,975	16,679	5,837	0	-5,837	77,212
24	17,086	0	0	4,153	12,932	1,316	0	-1,316	75,896
25	22,002	0	0	11,517	10,485	2,769	0	-2,769	73,127
26	15,498	0	0	15,498	0	7,678	0	-7,678	65,449
27	16,088	0	0	16,088	0	10,332	0	-10,332	55,117
28	19,303	0	0	19,303	0	10,725	0	-10,725	44,392
29	19,793	0	0	19,793	0	12,869	0	-12,869	31,523
30	17,245	0	0	17,245	0	13,195	0	-13,195	18,327
31	10,246	0	0	10,246	0	11,497	0	-11,497	6,831
32	0	0	0	0	0	6,831	0	-6,831	0
Total	**458,177**	**194,689**	**60,969**	**198,397**	**198,812**	**172,910**	**21,779**		

* Month 1 is the start of the main ramp development
** Fill placed takes into consideration swell factor from SG 2.7 to 1.8 (solid to broken rock)
C&F: Cut and Fill Stoping (mining method requiring fill)
Open: Open Stoping (mining method typically requiring no fill)

In the unlikely event that some of this stockpile still remains on surface at the time of closure, it will be addressed as follows:

- Preferred Closure Option:
  All remaining waste rock that is potentially acid generating will be reclaimed by front end loader and transported by haul truck back into the underground mine where it will be placed as backfill. It should be noted that under the current mine plan all potentially acid generating rock is likely to have been placed back underground as backfill well before the end of the mine life.

- Alternative Closure Option:
  All remaining waste rock that is potentially acid generating will be reclaimed by front end loader and transported by haul truck to the Tail Lake tailings containment area and then placed under water in the lake. The waste rock will have to be pushed or placed into deep water using a backhoe to ensure that there is an adequate water cover to prevent future oxidation.

No cost allowance has been included in the reclamation cost estimate for the relocation of any waste rock as it has been assumed that all of this rock will be returned underground during the mine operating life.

The KIA has indicated to MHBL that they will require a separate bond for the possible reclamation of this stockpile. In response MHBL have proposed the following:

- MHBL will place an amount of money into a security trust fund pledged to the KIA (suggested at $15 per tonne) for every tonne of waste rock placed on the temporary waste rock stockpile. The $15 per tonne cost reflects the estimated cost of having this rock picked up and hauled back underground;

- KIA will credit an amount of money back to MHBL (suggested at $20 per tonne) from this same security trust fund for every tonne of waste rock moved from the temporary waste rock stockpile back into the underground mine;

- MHBL will calculate the amount of rock moved to and from the stockpile from truck counts and load factors and report the same to the KIA every month as part of the water license SNP report. MHBL will calculate the change to the security trust amount and communicate this to the KIA at the end of every calendar quarter. KIA/MHBL agree to add or deduct from the security trust fund on this basis with the adjustment made four times every year;

- Interest earned in the fund will be payable to MHBL to be reflected as a credit against future payments or held within the fund until the entire stockpile is gone;

- MHBL will pre-pay an amount of $500,000 into the security trust fund before the first tonne of waste rock is placed onto the temporary waste rock stockpile. This pre-payment would be included in the first quarterly calculation and credited against rock placed during the first three months of stockpile operation.

This proposed arrangement is intended to provide a financial incentive to MHBL for returning this stockpile underground at the earliest possible opportunity while providing security to KIA in the event that this material is left on surface.

6.1.7 Tailings Containment Area (TCA)

This section provides the reader with a summary of the reclamation measures to be taken in closing out the tailings containment area. The reader is referred to the following sources for design information on the TCA:

- Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S1 to the Revised Water License Application Support Document, April 2007)
    - All Sections.
    - Closure Methodology – Section 12

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S4 to the Revised Water License Application Support Document, April 2007.)
    - Drawing G-02 General Arrangement;
    - Drawings T-01 thru T-14 Tailings Containment System Design Drawings.

- Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S3 to the Revised Water License Application Support Document, April 2007.)
    - Section 11 Tailings Containment Area Components;
    - General specifications for clearing and stripping is contained in Section 4;
    - General specifications for excavation is contained in Section 5;
    - General specifications for drilling and blasting is contained in Section 6;
    - General specifications for fill materials is contained in Section 7;
    - General specifications for geosynthetics is contained in Section 8, and
    - General specifications for fill placement is contained in Section 9.

The reader is referred to the following documents for additional information on the water quality model developed for the tailings containment area and for further information on the water management and discharge strategy:

- Tail Lake Water Quality Model, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated October 2005. (Supporting Document A2 to the Technical Support Document to the Final Environmental Impact Statement submitted to the Nunavut Impact Review Board, October 2005)
    - All sections

- Water Quality Model Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S6 to the Revised Water License Application Support Document, April 2007)
    - All sections

The main closure components relating to the TCA include:

- Continued active water management until such time as the water quality in the TCA returns to acceptable discharge standards;
- Establish a suitable water cover over the tailings;
- Breach the North Dam to allow the TCA catchment to revert back to its pre-deposition hydrologic cycle; and
- The South Dam will remain in place.

Active water management of the TCA will continue, either through active discharge via the discharge pump system, or through natural discharge via the spillway. Once the water quality in the TCA has returned to background water quality, containment of the TCA is no longer required, and the North Dam can be breached.

Once mining and ore processing has ceased the tailings discharge and reclaim water pipelines will be flushed with process water to remove all process slurry material from the lines. The lines will then be drained and then decommissioned. The pipelines will be removed and the debris placed in the demolition landfill.

Water Cover

The final TCA closure requires a permanent water cover of at least 3 m above the highest tailings elevation in the impoundment. Research has shown that a minimum stagnant water cover of 0.3 m is sufficient to prevent oxidization of tailings. Tailings can however be re-suspended due to wave action induced by environmental factors, and therefore the rule of thumb is to design a water cover of at least 1 m thick. Based on the orientation of the TCA, the predominant wind direction, maximum wind speeds, and the particle size of the tailings, the actual minimum water cover depth for the TCA has been calculated to be at least 2 m thick. A 3 m thick water cover was subsequently selected as the design criteria, which constitutes a factor of safety of 1.5, which seems reasonable to account for uncertainty[19].

The maximum tailings surface in the TCA is expected to be below 24.3 m, which implies that the minimum final water elevation in the TCA must be at 27.3 m to ensure compliance with the design criteria. In actual fact, since the water level in the TCA will return to its pre-deposition elevation of 28.3 m once the North Dam is breached, the water cover will be at least 4 m thick offering an overall factor of safety of 2.

North Dam Breach

Prior to breaching the North Dam, any water in the TCA above elevation 28.3 m will be pumped via the discharge system into Doris Creek. Discharge of the excess water will be

[19] Complete details of the minimum water cover thickness design calculations are presented in Appendix C, Design of the Tailings Containment Area, Supporting Document S1 to the Revised Water License Application Support Document, April 2007.

done using the same basic criteria as that used during the active discharge phase. Depending on the volume of water that has to be discharged, this draw-down period could be more than one discharge season.

Once the water level in the TCA is at 28.3 m, the North Dam will be breached by cutting a slot through the North Dam, down to the original pre-construction elevation. The slot will measure about 20 m wide, with 4H:1V side slopes on either side. The cut slopes will be covered with a 2.5 m thick layer of run of quarry material to ensure physical and thermal stability. Tail Lake outflow will be re-established along the base of the slot cut, and suitable bedding material will be put in place to ensure erosional stability of the channel.

Water Management at Closure

For the full design tailings volume over two years, the tailings surface is expected to be below 24.3 m, which implies that the minimum final water elevation in Tail Lake must be at 28.3 m. In actual fact, the existing (*i.e.* pre-mining elevation of Tail Lake is 28.3 m, which implies that once the water quality in Tail Lake returns to background concentrations, the North Dam can be breached to allow Tail Lake to return to its pre-mining elevation. Under this condition, there will be a 4.0 m water cover over the tailings.

The water management strategy for the Project entails an active managed discharge from Tail Lake beginning in Year 1 of operations and continuing until it can be shown that there is no adverse impact on downstream aquatic life from an unregulated discharge from Tail Lake.

The tailings water management strategy is based on a revision of the water quality modeling presented to the NIRB as part of the October 2005 FEIS. The revised model incorporates new baseline water quality data collected in 2005 and 2006 as required under the NIRB Project Certificate condition 13, which states "*MHBL shall collect additional water quality data for the 2006 field season and incorporate it into a revised water quality model to be submitted to the NWB as part of the water license application. MHBL will meet discharge criteria on a site specific basis set by NWB where possible, for the protection of the receiving environment at the point of discharge."*

The water management strategy for the Tail Lake tailings containment system was developed by SRK Consulting (Canada) Inc. (SRK) for MHBL and is a component of the Water Quality Model[20]. The following management plan is drawn from this source.

The primary objective of the Tail Lake water management strategy is to meet CCME guidelines (Canadian Water Quality Guidelines) for parameters of concern[21] to protect freshwater aquatic life in Doris Creek, downstream of the waterfall. These guidelines were established by the Canadian Council of the Ministers of Environment and represent a

[20] Section 5.2, Water Quality Model, Supporting Document S6 to the Revised Water License Application Support Document, April 2007.

[21] MHBL expects to meet all CCME Guideline values for the parameters of concern listed in Table 4.1 at the monitoring point down stream of the waterfall within Doris Outflow creek with the possible exception of nitrite. The predicted levels of nitrite are only marginally above CCME Guideline values (see Table 4.2 in Water Quality Model Report (DS S6) and will only occur for a very short duration as nitrite will quickly convert to nitrate in the receiving waters.

vigorous determination of levels for each parameter that are protective of aquatic life within fresh waters in Canada. These are guidelines not regulated limits and incorporate a highly conservative approach in determining from scientific research world wide at what level of each parameter are harmful effects noted on aquatic life. Consequently they provide guidance as to levels of each parameter in receiving waters below which there is assurance of “low to no” risk of adverse effect on aquatic life. It should be noted that quite often natural levels of parameters within Canadian freshwaters may already exceed the CCME Guideline values. Consequently by meeting the CCME Guidelines in the receiving water, MHBL is striving to ensure that there will be no adverse effect on aquatic life downstream of its discharge point.

MHBL chose to meet these CCME Guideline values at a point immediately downstream of a 4.3 m waterfall in the Doris Outflow creek as this is the closest point at which Arctic Char can come into contact with the water released from the TCA. This waterfall acts as natural barrier to the migration of Arctic Char and other downstream fish species up into Doris Lake.

Technology does not exist that will allow MHBL to treat the water to be released from Tail Lake to these CCME Guideline values, consequently MHBL acknowledges that it cannot achieve the CCME Guidelines at the end of the discharge pipe from Tail Lake. MHBL’s discharge strategy relies on metering the amount of water released from Tail Lake so that it can mix and for most parameters be diluted with the outflow water from Doris Lake so that the combined water meets the CCME Guideline values immediately after mixing through the drop over the waterfall. The location of the discharge pipe was placed immediately upstream of this waterfall to protect all aquatic life upstream of the discharge point within Doris Lake and the upper reaches of the Doris Outflow creek. (Tail Lake naturally drains into Doris Lake near the outflow point). In other words the proposed end of pipe discharge point was selected to minimize to the greatest extent possible the amount of Doris Outflow creek that will be exposed to the end of pipe discharge before it mixes with the receiving water as it goes over the waterfall.

The Federal Government acknowledges that CCME Guidelines are to be used for guidance purposes only and are thus not incorporated into regulated discharge standards. The Federal discharge standards that apply to the Canadian mining industry are set out in Schedule 4 of the Metal Mining Regulation under the Fisheries Act. These are based on best-practical-available-technology for water treatment and not meant to be protective of aquatic life. In most regulatory jurisdictions these end of pipe discharge standards are assessed on a case by case basis to determine acceptable levels of impact once the discharge has been mixed in the receiving waters, in other words the assessment is conducted on a case by case basis and typically relies upon a natural mixing zone within the receiving waters. Under the MMER regulation, the end-of-pipe discharge from Tail Lake must meet the MMER discharge limits by law and pass the LC_{50} fish toxicity test.

However MHBL recognizes that discharge of water from Tail Lake at these limits would not result in water quality meeting CCME guidelines in the Doris Outflow creek. Consequently

MHBL devised a discharge strategy that allows for the load (kgs) of contaminants discharged from Tail Lake to be varied in proportion to the background flow and load in the Doris Outflow creek so that CCME guideline concentrations are consistently being met in Doris Outflow creek below the point of mixing. To be successful this approach departs from the traditional fixed end of pipe discharge limit normally contained in water licenses and replaces it with a fixed allowable concentration in the receiving water.

The water management strategy for the Project entails an active managed discharge from Tail Lake beginning in Year 1 of operations and continuing until it can be shown that there is no adverse impact on downstream aquatic life from an unregulated discharge from Tail Lake. At the end of Year 9 (seven years after mining ceases) water quality in Tail Lake is predicted to be within the CCME Guidelines allowing for a complete "walk-away" closure scenario.

During the mine's operating life (two years) and for an additional three years after mining and milling ceases the volume of water to be released from Tail Lake will exceed the natural inflow into Tail Lake. By the third year following the cessation of mining and milling, the water level in Tail Lake will reach the pre-development level of 28.3 m above sea level and the amount of water that needs to be released from Tail Lake is predicted to be equal to the natural inflow[22].

In the year prior to this point in time (i.e., during the 2nd year following the cessation of mining and milling), MHBL will commission a human health and ecological risk assessment to determine if the quality of the water contained in Tail Lake is suitable for release in an unregulated fashion through the former Tail Lake outflow into Doris Lake without resulting in an adverse impact to aquatic life downstream. In the event that the risks are shown to be unacceptable, MHBL will continue to actively manage the annual discharge from Tail Lake by pumping this water to the discharge point in Doris Outflow creek upstream of the waterfall. Pumping would only cease if it can be demonstrated that no adverse impact on downstream aquatic life will occur with an unregulated discharge. At that time, the North Dam will be breached and the outflow from Tail Lake will be restored to the pre-mine outflow channel (Tail Lake Outflow creek) into Doris Lake. Under this scenario no further management of water releases from Tail Lake will be required however monitoring will continue for a minimum of one more year to verify that water quality remains acceptable for discharge.

Under this water management strategy, the maximum water level in Tail Lake will be 29.4 m, with a flooded footprint of 94 ha.

Various alternate water management strategies were also assessed, all of which would result in minimal changes of water quality in the receiving environment. For example, all water could be contained in Tail Lake until the full supply level is reached. While this strategy would provide ample time to monitor the development of water quality in Tail Lake to verify the predictive modeling results, it would necessitate an extended period of site

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[22] Tail Lake will then return to a natural water body that is in hydrologic balance, i.e. the level will be sustained as it was in the pre-development phase. While the estimated annual lake evaporation exceeds the annual average precipitation the lake will remain hydrologically sustainable as it is now as lake evaporation only operates over the lake surface while precipitation acts over the whole watershed. The Tail Lake watershed has a net positive water yield. For additional information the reader is referred to the Tail Lake Water Balance – Section 6, Design of the Tailings Containment Area, Supporting Document S1 to the Revised Water License Application Document, April 2007.

management. The strategy selected by MHBL involves maximizing the annual discharge volume from Tail Lake as early as possible in the mine life while meeting the constraint of resulting in minimal change of water quality in the receiving environment. Other benefits for this strategy include the fact that the full supply level of Tail Lake will not be reached, and, as a result the effects of permafrost thaw and associated silt release will be minimized.

Closure and reclamation of the tailings containment area will consist of the following steps;

1. Tail Lake will continue to be monitored and actively managed until it can be demonstrated that water quality is adequate for unrestricted release during the following spring freshet. During this interim period water will be released from Tail Lake using the existing supernatant pumping system using the discharge criteria and release rates established in the mine's water license;

2. During the first year the tailings and reclaim water pumping systems and pipelines will be removed and the materials disposed of in the solid waste disposal facility. The tailings pipelines are projected to be 6" diameter with a 4" diameter reclaim water pipeline, both insulated HDPE. The emergency tailings pipeline catch basins will be cleaned out with tailings material hauled to Tail Lake. The catch basins (each 25.2 m by 25.2 m) will then be breached and either graded or backfilled to prevent further ponding of water and to encourage natural re-vegetation to become re-established. The HDPE liners will be removed and disposed of in the solid waste disposal facility site; and

3. By the end of the seventh year following the cessation of mining (in 2017) it is expected[23] that water quality within Tail Lake will have returned close to pre-development background quality and will be within CCME Guidelines for protection of aquatic life. At this point the discharge from Tail Lake can continue in an unrestricted manner while meeting water quality protective of aquatic life downstream. At this point the North Dam can be breached allowing the lake outflow to equilibrate with inflow.

6.1.8 Tail Lake Shoreline Erosion

Under the proposed mine development plan, the water level in Tail Lake is expected to rise from the pre-development elevation of 28.3 m to a flooded level of 29.4 m over the mine's operating life. There is concern that this rise in water level will result in the thawing of frozen marine sediments in the newly flooded shoreline and that this thawing will result in sloughing and erosion of the thawed sediments into the lake. As part of the development plan, MHBL has proposed to install rock armouring over geotextile over the area it has identified as being most susceptible to such sloughing. This rock armour would be installed at the time of dam construction prior to the start of tailings deposition.

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[23] See Section 4, Supporting Document to the Revised Water License Application Support Document, April 2007.

The total area of shoreline that will be inundated as the water level rises from 28.3 to 29.4 m is 12.9 ha. Through field investigations, MHBL has identified 40% of this 12.9 ha (30,600 square metres) as being most susceptible to such sloughing based on observed ground conditions (slope angle, etc). During dam construction, MHBL will place 25,800 square metres of geotextile and 7,600 cubic metres (15,800 dry tonnes) of quarried rock over half of this area (20% of the 12.9 ha), a 15,300 square metre area, to create a 0.5 m thick rock armour layer to prevent potential sloughing. MHBL will then monitor the area and has assumed that during the mine life a further 15,300 square metres will be armoured in a similar manner to cover the full 3.6 ha.

MHBL has included within the closure plan cost estimate a contingency allowance for the placement of additional quarried rock and geotextile to stabilize potential shoreline erosion that may occur along the edges of Tail Lake once the North Dam has been breached. This is a contingent measure in the event that receding water levels in Tail Lake following the breaching of the North Dam result in melting of frozen marine sediments and result in sloughing and erosion of the thawed shoreline into the lake after closure. The following allowance has been included for the placement of both geotextile and quarried waste rock onto the shoreline slopes to prevent such erosion:

Shoreline Erosion (Contingency)

> An allowance to armour the remaining 60% of the 12.9 ha surface area between the predevelopment lake level of 28.3 up to the planned flooded elevation of 29.4 m; 0.5 m thickness of placed quarried rock over 47,500 square metres of shoreline – 22,800 cubic metres (47,500 dry tonnes) of rock and 77,400 square metres of geotextile.

Consequently the closure cost estimate includes an allowance of $1.2 million to cover this contingency measure, i.e., placement of an additional 22,800 cubic metres of armouring rock and 77,400 square metres of geotextile.

6.1.9 Water Management

The fresh water intake pump house and piping will be removed.

No post closure water treatment from either the tailings containment area of from the mine site itself is expected to be required once reclamation has been completed.

Surface runoff drainage patterns will be restored through removal of water retaining berms such as road safety berms, containment berms from the fuel storage area and from the explosives storage area and through the removal of culverts.

7.0 ENVIRONMENTAL EFFECTS ASSESSMENT

7.1 Assumptions

This section provides an assessment of the predicted environmental conditions in the area surrounding the Project in the post-closure time period. The assessment assumes that the following physical reclamation activities have been completed:

- All major equipment and structures, and hazardous materials have been removed from the underground mine; the openings into the mine have been physically sealed;

- All hazardous materials have been removed from the surface ore processing facilities; the plant has been cleaned out; the equipment and structure have been demolished; non-salvageable material disposed of in solid waste disposal facility;

- The water in the Tail Lake tailings containment area meets suitable water quality requirements for discharge. The Tail Lake tailings containment area has been breached at the main dam site and a self-sustaining minimum 4 metres of water cover has been established; excess water can freely drain from the tailings containment area through a rock armoured spillway into the former Tail Lake outflow stream channel and thus into Doris Lake;

- There is no ongoing sloughing of shoreline in Tail Lake on the basis that all unstable shoreline has been suitably armoured;

- All remaining hazardous materials, chemicals, reagents, hydrocarbons, etc., have been removed or disposed of in a manner approved by the appropriate regulatory agencies; and the facilities used to store these materials have been decontaminated, demolished and disposed of in the site solid waste disposal facility;

- All hazardous materials have been removed from the remaining surface infrastructure (camp, power plant, maintenance shop, explosives magazine, sewage treatment plant, etc.); the facilities have been cleaned out, the equipment and structures demolished; non-salvageable material disposed of in the solid waste disposal facility;

- The site roads and the airstrip have been decommissioned; all associated buildings, light stands, signs and drainage culverts have been removed; natural drainage across the roads and airstrip has been restored, with adequate erosion protection provided; and the roads and airstrip have been graded to shed surface runoff and scarified to promote in-growth of natural vegetation; and

- All other surface infrastructure including above-ground piping and power distribution lines has been demolished and disposed of; all building pads, parking areas, laydown areas, etc., have been regraded and scarified; and all contaminated soils have been removed and treated.

7.2 Underground Mine

It is expected that the underground mine workings will remain frozen due to the presence of permafrost throughout this region. In the highly unlikely event that global warming causes a loss of this permafrost, it is likely that water will infiltrate from the nearby Doris Lake causing the mine workings to naturally flood. The rate of flooding will be determined by the amount of water that can enter the mine through the natural fractures in the rock and the relative difference in hydraulic head between Doris Lake and the mine workings. Ultimately the water level within the mine would be expected to reach equilibrium with the water level in Doris Lake.

All sources of hazardous materials (hydrocarbons, chemical, reagents) will be removed from the underground mine workings as part of the planned reclamation activity. All underground openings will have been sealed. Potentially acid generating rock either placed underground or contained in the mine walls will remain frozen reducing the relative rates of future sulphide mineral oxidation. Thus there will no groundwater flow that could mobilize or transport acidity and/or metal contaminants away from the underground mine workings.

In the unlikely event that at some future point permafrost is lost, then natural future flooding of the underground mine workings would significantly reduce any oxidation of sulphide minerals exposed in the wall rock by eliminating contact with the air (limiting the availability of oxygen to oxidize the sulphide mineralization). In this unlikely event the material would probably be flooded before thawing thus minimizing the potential for release of any surface oxidation products into the Minewater.

7.3 Process Facilities

The land surface altered by construction of the ore processing facilities will be covered with rock and graded to enhance natural drainage and prevent water from ponding. The graded rockfill pads will be visually evident until indigenous vegetation becomes re-established (expected to take several decades). No other post-closure effects are anticipated with regard to the ore processing facilities.

7.4 Surface Infrastructure

The proposed removal and reclamation of the site infrastructure facilities will eliminate any requirement for long-term maintenance, and no substantive adverse effects are expected in the post-closure period. The infrastructure in this category includes the airstrip, site roads, quarries, waste management facilities and other site support facilities.

7.5 Mine Waste and the Tail Lake Tailings Containment Area

The Doris North Project will not result in the creation of any surface overburden or waste rock piles that will remain at the end of the mine life. All potentially acid generating waste rock will be left underground or returned to the underground mine before the completion of the reclamation. No overburden will be stockpiled due to the permafrost conditions prevalent throughout the area. Rockfill pads will be constructed on top of the frozen ground to minimize degradation of the underlying permafrost.

The Tail Lake tailings containment area dams will be breached once the contained water has reached quality suitable for discharge. A spillway will be constructed through the North dam to ensure the maintenance of a self-sustaining 4 metre minimum depth water cover over the stored tailings in Tail Lake. Acid Base Accounting test work conducted on a sample of laboratory generated mill tailings indicates that the mill tailings generated by the Doris North Project are not expected to be net acid generating[24] and thus the maintenance of the water cover is not crucial from a chemical stability but is put forward as a means of controlling dust emissions and for aesthetic value. The premise that the combined mill tailings will be non-acid generating will be verified during the mine life through additional testing conducted on actual tailings material[25].

Water level modeling has been conducted to verify that the water cover can be maintained even following successive dry years.[26]

Maintenance of the physical stability of the Tail Lake tailings containment area in the post-closure period does not rely on the continued presence of permafrost nor a frozen core in the North dam or in the ground beneath the main dam. The dam will be breached once water quality has reached a suitable quality for discharge and will no longer hold back water or tailings. It is assumed that pore water within the tailings will in time be similar to the overlying lake water due to the relatively shallow depth of stored tailings and water within the lake[27]. Subsequent to deposition, the tailings will at all times be covered by a water depth in excess of 4 m. The water cover will prevent any oxygen entry to the tailings and therefore, the sulphide minerals contained in the tailings will be prevented from oxidizing. Consequently no additional solute release from the tailings will occur after the tailings have been deposited in Tail Lake. It should further be noted that since the tailings will be fully submerged and water will be decanted from the surface of the lake, no hydraulic gradients will develop that could cause the pore water to be displaced from the tailings. It is therefore expected that the tailings pore water will be 'locked' interstitially in the tailings indefinitely.

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[24] For information on the geochemical characterization of the Doris North Mill tailings see Section 3.6.3 in the Revised Water License Application Support Document, April 2007

[25] For more detail on verification monitoring proposed by MHBL see Section 3.6.3 in the Revised Water License Application Support Document, April 2007.

[26] See Appendix C, Design of the Tailings Containment Area, Supporting Document S1 to the Revised Water License Application Support Document, April 2007.

[27] See Section 3.3.8, Water Quality Model, Supporting Document S6 to the Revised Water License Application Support Document, April 2007.

A small volume of seepage may emanate from the Tail Lake tailings containment area, affecting shallow groundwater quality in the active layer in the immediate area. The effects will be localized to the Tail Lake outflow channel area and should in time be similar in quality to water draining through the spillway in the North dam[28].

The reclamation plan will encourage a natural succession of indigenous plant species within disturbed areas, but re-establishment of vegetation can be expected to take several decades. The resultant effect on terrestrial wildlife and bird habitat associated with the reclaimed Doris North site will be relatively minor in a regional context, given the vast surrounding area of land and water providing suitable alternatives for wildlife species.

7.6 Biophysical Environment

7.6.1 Air Quality

All stationary and vehicle exhaust emissions (sulphur dioxide, oxides of nitrogen, greenhouse gases) associated with the Project will cease following the closure and reclamation of the site facilities. The only emissions in the post-closure period will be those associated with periodic trips into the site for the purpose of environmental monitoring and maintenance. These will be minimal and should have no adverse effect.

Dust emissions associated with the Project will also decrease substantially after closure and reclamation. Cessation of road and air traffic, removal of all site buildings and facilities will eliminate or substantially reduce potential dust sources. Because it will take several decades for natural in-growth of indigenous vegetation after reclamation, some dusting could occur in areas of exposed rockfill on the laydown and building rockfill pads during periods of strong winds. The only other dust emissions in the post-closure period will be those associated with periodic trips into the site for environmental monitoring. These dust sources are expected to be minimal and have little to no adverse effect.

7.6.2 Noise and Light

Noise and light effects associated with the Project will cease with the completion of closure and reclamation. No operating equipment or power sources will be left on site in the post-closure period. Some minor noise will be associated with post-closure environmental monitoring trips to the site, but this is expected to be minimal and have no adverse effect.

7.6.3 Terrain

During operations, any area used for project activities that becomes unnecessary will be recontoured to suit the natural terrain. Because of the extremely harsh growing conditions and lack of soil, re-establishment of natural vegetation will take many years, probably

[28] See Section 2.3, Water Quality Model, Supporting Document S6 to the Revised Water License Application Support Document, April 2007.

decades. At closure natural re-vegetation of surfaces used for project facilities at site will be encouraged through scouring of surfaces and seeding where possible. Arctic environment re-vegetation research will be looked at through the life of the mine and at closure to ensure that best available mitigation and management re-vegetation practices are implemented during mine closure.

The rockfill pads and quarry sites will remain visible after closure. A conceptual rendering of how the site will appear once reclamation is complete is presented in Figures 1.3 thru 1.7 previously presented in Section 1.0 of this Preliminary Mine Closure and Reclamation Plan.

7.6.4 Wildlife

The potential for human-wildlife interactions will greatly diminish in the post-closure period, and the risks of contact with equipment, vehicles and aircraft will cease once closure and reclamation activities are complete. Areas used for project facilities will essentially be lost to wildlife for the duration of the mine life and for several decades after closure while natural vegetation becomes re-established. Little to no effect on wildlife abundance and use is expected in the post-closure period.

7.6.5 Water Quality and Aquatic Resources

Predictive water quality modeling[29] was conducted to predict how the Project would affect water quality in the downstream aquatic environment during the mine's operating life. Metal leaching from the tailings has been tested and the data suggests that the tailings left in Tail Lake will not significantly contribute additional metal loadings into the Doris Outflow and Little Roberts Lake watersheds in the post-closure period.

It is projected that the reclaimed Doris North Project site will not significantly add any additional contaminant loadings into the surface water bodies of the Project area (i.e., into Doris Lake, Doris Outflow, Little Roberts Lake or Roberts Bay).

Leaching of contaminants from the non-hazardous landfill is not expected to occur due to the substrates natural characteristics (bedrock floor in the quarry) and given that the landfill will not contain hazardous materials (all hazardous materials will be shipped off site for disposal). Although permafrost is expected to naturally develop in the landfill material it is not necessary for contaminant encapsulation purposes.

Sediment loading to Doris Lake from post-closure runoff is not expected to differ from existing natural concentrations. Water quality within Doris Lake will not be adversely affected by the Doris North Project in the post-closure time period. Consequently no adverse effect to the overall aquatic community in the lake is anticipated.

[29] Water Quality Model, Supporting Document S6 to the Revised Water License Application Support Document, April 2007.

In summary, the immediate area of the Project will be physically altered due to project development, and changes will remain evident in the plant site, site roads and airstrip after closure. However, the reclamation work will help blend these sites into the surrounding landforms over the long term. The re-establishment of natural vegetation will be slow. The reclaimed project will have minimal effect on the biodiversity and sustainability of the natural renewable resources of the region and have no lasting effect on traditional and non-traditional land use activities in the area.

8.0 POST - CLOSURE MONITORING AND MAINTENANCE

MHBL is committed to minimizing the residual environmental effects associated with project development. The Closure and Reclamation plan has been developed in conjunction with the mine plan so that closure considerations can be incorporated into the mine design. Surface facilities have also been designed with closure in mind to facilitate, wherever practical, reclamation requirements and the enhancement of natural recovery of areas affected by the Project.

The closure and reclamation phase of the Project will commence once the economic ore reserves within the deposit have been exhausted and mining and processing operations have ceased. Based on current planning, it is anticipated that underground mining at the Project will commence in late 2008 and continue through 2010. Mine closure and reclamation is expected to take place in 2011 and 2012. The post-closure period would commence in 2013 and continue through 2020 or until it can be demonstrated that reclamation objectives have been achieved and no further environmental degradation is occurring.

Monitoring and maintenance programs will be implemented during the closure and post-closure phases of the mine to prevent environmental degradation and measure the performance of the closure and reclamation procedures. The data collected through post-closure monitoring will allow the planned procedures and activities to be adjusted and/or modified as necessary to ensure optimal environmental protection. The monitoring and maintenance programs discussed in this section are inherently generic at this stage of planning and will be developed in more detail in consultation with communities and regulators, and as project permitting advances.

8.1 Environmental Management and Aquatic Effects Monitoring

MHBL is developing an environmental health and safety management system (EHSMS) for the Doris North Project which will be in place prior to the start of construction in early 2008[30]. An EHSMS is a defined system or process of measuring and documenting compliance with environmental and health and safety standards and for seeking continuous improvement at a facility such as the Doris North Project. An EHSMS utilizes training, environmental monitoring, audits, inspections and other tools to measure and manage actual environmental performance against established objectives.

The EHSMS sets out how the Project will be managed to minimize its impact on the biophysical and socio-economic environment, and to continually improve its environmental performance. It sets out the management plans and the emergency plans for all key areas of the environment during construction, operations and closure. A key component of the

[30] Environmental, Health and Safety Management System Outline, Supporting Document S9 to the Revised Water License Application Support Document, April 2007.

EHSMS is the Environmental Protection Plan (EPP)[31] which consists of a number of specific management plans dealing with the various components of the mine. For example, the EPP includes separate management plans for the tailings containment area, for water management on site, for the landfarm facility, for the landfill facility, for managing hazardous materials and explosives, a spill contingency and emergency response plan and plans dealing with ongoing monitoring.

Post closure monitoring for the Doris North Project will consist of a number of features, including:

- Monitoring for regulatory compliance (i.e., compliance with the Metal Mining Effluent Regulation of the Fisheries Act, with the Project's Water License and Land Use Permits and Leases, and with the applicable Nunavut legislation, regulations and guidelines for the protection of aquatic life, and environmental and human health);

- Monitoring for project-related regional environmental effects; and

- Identifying circumstances under which additional mitigation should be undertaken if impact predictions were incorrect or impacts were underestimated.

MHBL is committed to monitoring water quality in the Project area during construction, operations and closure. The Aquatic Effects Monitoring Program (AEMP)[32] includes both biological and water chemistry sampling. A detailed AEMP has been developed for the Doris North Project area and is included as a supporting document to the Final EIS and to the Revised Water License Application Support Document. This program will change over time to adapt and respond to conditions identified through sampling over the previous years. MHBL will continue this effects monitoring program into the post-closure period.

Allowance has been included in the reclamation cost estimate to continue this aquatic effects monitoring program on an annual basis from 2011 through 2016 and then every second year through 2020. Environmental monitoring and maintenance requirements are expected to decline once the Project facilities have been fully decommissioned and the mine development area has been restored to the endpoints agreed upon in the water licence.

8.1.1 Current Water Quality Monitoring

In the pre-development phase water quality monitoring has been focussed on environmental baseline sampling in the local watersheds designed to establish current water quality prior to any mine construction activity.

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[31] These plans have been developed and included as part of Supporting Documents S10 a thru m to the Revised Water License Application Support Document, April 2007.

[32] Final Report on Effluent and Aquatic Study Monitoring Design, Supporting Document S11 to the Revised Water License Application Support Document, April 2007.

8.1.2 Environmental Monitoring During Operational Period

It is anticipated that a Surveillance Network Program (SNP) will be established as part of the water license for the Project. MHBL has included a proposed SNP program in its April re-submission of the Water License Application[33]. The proposed SNP includes the suggested location, type of sample and sampling frequency for each of the proposed sampling stations. MHBL will continue monitoring under this SNP at the appropriate stations into the post closure period. Allowance has been included in the reclamation cost estimate for continuing SNP monitoring at a frequency of 4 times per year from 2011 through 2016, with the frequency decreasing to twice per year through 2018 and then once per year through 2020.

8.1.3 Environmental Monitoring during Closure and Reclamation Period

During the reclamation phase of the Doris North Project, environmental monitoring will continue to address the following areas:

Compliance Monitoring: monitoring anticipated by MHBL to demonstrate compliance with all regulatory requirements and standards during the closure and reclamation period.

Biophysical Monitoring: monitoring conducted during the decommissioning and post closure periods to ensure that the Project is not resulting in adverse impacts to water, air, and environmental health (fish, wildlife, humans).

8.1.4 Post – Closure Monitoring

Physical reclamation of the Project facilities is expected to be complete within two years of plant shutdown. Management of the annual release of supernatant from Tail Lake would continue for an additional five years during the open water season (i.e., with a crew of two people camping on site during the annual release window each summer). Other on site activity will be minimal during this time. Environmental monitoring would continue.

The level of monitoring required will be a function of environmental performance at the site. For the purpose of this Mine Closure and Reclamation Plan, it has been assumed that post-closure environmental monitoring will continue for 10 years (2011 through 2020), with lesser degrees of effort required as it can be demonstrated that reclamation actions have achieved the stated objectives of preventing any ongoing degradation of the surrounding environment.

Initially it is expected that water quality monitoring of the same operational SNP stations will continue at the same frequency during the reclamation period (2011 and 2012). It was assumed that SNP monitoring would continue at a frequency of 4 times per year from 2011

[33] See Table 7.1 in the Revised Water License Application Support Document, April 2007 and Table 5.1 in Monitoring and Follow-Up Plan, Supporting Document S10m which includes suggested analytical parameters for each SNP station.

through 2016, with the frequency decreasing to twice per year through 2018 and then once per year through 2020.

The types of environmental monitoring anticipated includes:

- Monitoring of water quality in Doris Lake, Tail Lake, Tail Lake outflow and in Doris outflow below Tail Lake;
- Monitoring of surface runoff from the reclaimed plant area, fuel tank farm, closed out landfill and from the reclaimed fuel transfer areas;
- Program of aquatic effects monitoring, including sediment, benthos and fisheries studies to assess cumulative effects of the Project on the aquatic environment; and
- Annual inspection by a qualified professional geotechnical engineer of the Tail Lake containment dam.

It is anticipated that water quality and other data will demonstrate that environmental conditions have essentially stabilized by the end of 2015 and that a reduction in frequency of environmental monitoring can be justified. The assumed changes for post closure years 6 through 10 are summarized as follows:

- Sampling of remaining applicable SNP stations, with the sampling visits scheduled during open water periods;
- Monitoring of surface runoff from reclaimed site facilities, with the sampling visit scheduled during open water periods; and
- Annual inspection by a qualified professional geotechnical engineer of the Tail Lake containment dams.

Stabilization of environmental conditions by the end of year 10 is assumed to be sufficient to justify the cessation of further monitoring requirements by the end of 2020. However, this assumption will be revisited, assessed and modified as necessary based on measured environmental performance at that time.

In addition to the water quality, environmental effects and geotechnical monitoring, MHBL has included allowance in the reclamation cost estimate for the following additional monitoring programs:

- An allowance of $50,000 per year has been included for an annual wildlife effects monitoring program to be conducted at the site every year through 2016, then dropping to every second year through 2020;

- An allowance ($25,000 in Year 2, $50,000 in Year 5 and $35,000 in Year 10) has been included for post-closure vegetation success monitoring in Years 2, 5 and 10 following the cessation of mining; and

- An allowance has been included for the KIA to conduct consultation with Inuit beneficiary committees in the nearby communities on the status of reclamation in Years 1, 5 and 10 following the cessation of mining ($15,000 for each event).

8.2 Post – Closure Maintenance

8.2.1 General

The closure design for the surface facilities incorporates features to minimize requirements for future care and maintenance. For example, all sites will be graded to prevent surface ponding, and drainage channels will be designed and constructed with wide cross-sections and appropriate erosion protection to accommodate extreme precipitation events. No buildings will be left, eliminating maintenance requirements associated with structures. All pumping systems will be removed and natural drainage established wherever practical. Other than the environmental monitoring and inspection activities covered in the previous sections, the Mine Closure and Reclamation Plan includes no planned or scheduled post-closure maintenance activities.

MHBL recognizes, however, that some unexpected post-closure issues could arise, such as the need to construct new drainage channel(s) or sediment control pond(s). Any such works would be small in size, able to be constructed in a cost-effective manner using resources brought to site by aircraft. An allowance has been included in the post-closure maintenance cost estimate for this type of unspecified maintenance activity.

The closure cost estimate for the Doris North Project includes allowance for two projected post closure types of maintenance activity:

a. An allowance for operation during open water months of the Tail Lake supernatant discharge system for a period of nine years following the cessation of mining. It is expected that unrestricted discharge of supernatant from the tailings containment area will be acceptable by the end of the ninth year following the cessation of mining. This will require a two person crew on site for seven years after all other physical reclamation work has been completed during the open water discharge time period along with the cost associated with supporting this crew while at site; and

b. An allowance for unspecified erosion and drainage repair work. It has been assumed that periodically it will be necessary for a small crew to be brought to site to repair minor erosion damage and to effect changes in the drainage works (ditches, etc.) to prevent further erosion damage. An allowance of 80 person-hours per year has been included for this type of activity along with money for travel and equipment. It is expected that this degree of effort will not be required every year, however at some point in time this type of maintenance will be required. It may occur once every five years at which time the allowance would be 400 person-hours, or every second year at which time the allowance would be 160 person-hours.

A period of 200 years has been used in costing the second type of projected post-closure maintenance activity. This in essence allows for long term care of the site.

8.2.2 Post-Closure Revegetation Considerations

The pre-development terrain is covered with characteristic sub-arctic tundra vegetation. Three ecosystem units dominate the area: the ocean shoreline association, lowland ecosystems, and the rock outcrop and upland ecosystems. The vegetation includes shrubs, herbs, grasses, sedges and rushes, mosses and various species and/or genera of lichen (MHBL, 2005).

It is unlikely that this type of vegetation can be restored in the short term using conventional revegetation techniques. There are no stockpiles or areas at the Project site where growth media can be obtained in sufficient quantity to realistically provide a suitable growth media to be placed over the building pads, roadways, etc. to allow for revegetation using conventional seeding techniques. There are no readily available sources for seed stock for the native plant species common to this area. It may be possible to plant commercially available grass mixes that use native northern plant species (use of native plants in revegetation is now required in Nunavut). One potential source is Arctic Alpine Seed Ltd. Of Whitehorse, Yukon (website: http://www.aaseed.com/). It may be possible to use grasses indigenous to the north to get a quick vegetative cover start on the rockfill pads and roadways. However, without a good organic substrate, establishing vegetation of the reclaimed site will be difficult. MHBL does not have the technology to assure successful revegetation of the site.

However, MHBL will take action during reclamation designed to encourage a natural succession of indigenous plant species within disturbed site areas. Where appropriate, regrading, contouring and scarification of surfaces will be done to loosen up the crushed rockfill on building pads, roadways and the airstrip to provide for moisture retention and to promote natural revegetation and to increase the chance of success using the seed mixes applied during reclamation. MHBL will continue to monitor revegetation work at other sites in the Northwest Territories and Nunavut with the intent of applying successful revegetation techniques as they may become available.

8.3 Estimated Post – Closure Monitoring and Maintenance Cost

For the purposes of this Closure and Reclamation Plan, an estimate of $1.1 million has been made for the total cost of environmental monitoring and continued operation of the annual release of supernatant from the tailings containment area during both closure and post-closure.

The estimate includes allowance of $0.77 million for ongoing operation of the Tail Lake discharge system in 2013 thru 2017 (672,000 + 15% contingency allowance). The operation of the system during 2011 and 2013 is covered under site management during the reclamation period. The average annual cost is $110,400 which includes a 15% contingency. Key assumptions and considerations used in the preparation of this estimate are as follows:

- A site-based person will be tasked during the two-year closure and reclamation period to continue operation of the Tail Lake supernatant release and environmental monitoring and reporting activity during the open water season;
- Environmental monitoring in the post-closure phase will be conducted by means of periodic site visits, scheduled to coincide with the summer flow period. Initially this would involve 4 trips per year through 2016, dropping to 2 thru 2018 and 1 thru 2020. Each sampling visit to site would involve preparation, travel, sampling and reporting activities and a round-trip cost for the charter of a small, fixed-wing aircraft for personnel transport to and from Cambridge Bay and commercial air carrier to Yellowknife;
- An allowance has been included for analytical costs, sampling supplies and equipment consumed in the ongoing monitoring activities. Biological effects monitoring would be undertaken during the same visit;
- An additional allowance has been included for the preparation and submission of annual reports covering the post closure monitoring program;
- The annual geotechnical inspection would be scheduled to take place at the same time to maximize efficiency of air charter costs. An allowance of $25,000 per year has been included for this inspection including reporting; and
- A contingency allowance of 15% has been included for unspecified monitoring or light maintenance activity that may be required.

Post-closure maintenance requirements were estimated at $26,000 per year, based on the following assumptions:

- Periodic erosion repair and drainage maintenance activities were based on an allowance of 80 person-hours per year at a fully loaded hourly rate of $75/hr. A further $20,000 per year was included in this allowance for travel to and from the site and for equipment and materials. This may vary between use of hand held shovels used to open up or repair a ditch to a small piece of excavating equipment flown into the site. The need will depend upon the amount of work required. It is expected that in some years no activity will be required allowing this allowance to build to cover larger pieces of work;

It has been assumed that post-closure maintenance activities will be required over an extended time period. For this cost estimate a period of 200 years was selected. A “sinking fund” would be created at the end of the two-year reclamation period to fund the ongoing expenditure of $26,000 per year on average over 200 years. A discount rate of 3% was used to calculate the size of the required fund and to reflect the real rate of growth of money over the long-term. A sinking fund of $864,000 would be set-aside at the end of 2012 to fund this ongoing expenditure for post closure maintenance. The chosen time period of 200 years essentially reflects long term care as increasing the time period in calculating the required sinking fund does not significantly alter the size of the fund once a time period of 200 years is chosen. This sinking fund is intended to be used to fund future care and maintenance of the Doris North site once reclamation has been completed.

9.0 IMPLEMENTATION SCHEDULE AND COST ESTIMATES

9.1 Introduction

In accordance with DIAND's *Mine Site Reclamation Policy for Nunavut* (Reclamation Policy), the reclamation implementation schedule and liability cost estimates described in this section were developed based on the worst case scenario of third-party management and execution of all closure and reclamation activities, for the purpose of establishing reclamation security. Reclamation liability estimates are presented both exclusive of progressive reclamation (financial assurance and security is discussed in Section 10).

9.2 Implementation Schedule

9.2.1 Schedule Summary

A summary-level implementation schedule for final reclamation is provided in Figure 9.1. The schedule is based on final reclamation commencing at the end of the planned mine life. In summary:

- Mining and milling would cease at the end of 2010 with the exhaustion of the currently known ore reserves;

- Due to weather constraints, reclamation activities will not commence until the spring of 2011 (June of 2011). In the intervening five-month period the site will be kept on a care and maintenance basis with a minimal sized crew (i.e., a 2 person care and maintenance crew on site at any given time);

- Reclamation activity will commence in June of 2011 and continue through September as shown in Figure 9.1 (decommissioning of the mine and processing plant facilities);

- The site will be placed back on a care and maintenance status from October 2011 thru May of 2012;

- Reclamation activity will re-commence in June and be completed by the end of September 2012 as shown in Figure 9.1; and

- In the case of premature mine closure, the implementation schedule would essentially remain the same, with reclamation commencing in June of the year following the cessation of operations (assuming operations ceased after May). In the event that reclamation ceased before May, then reclamation could commence in the same year.

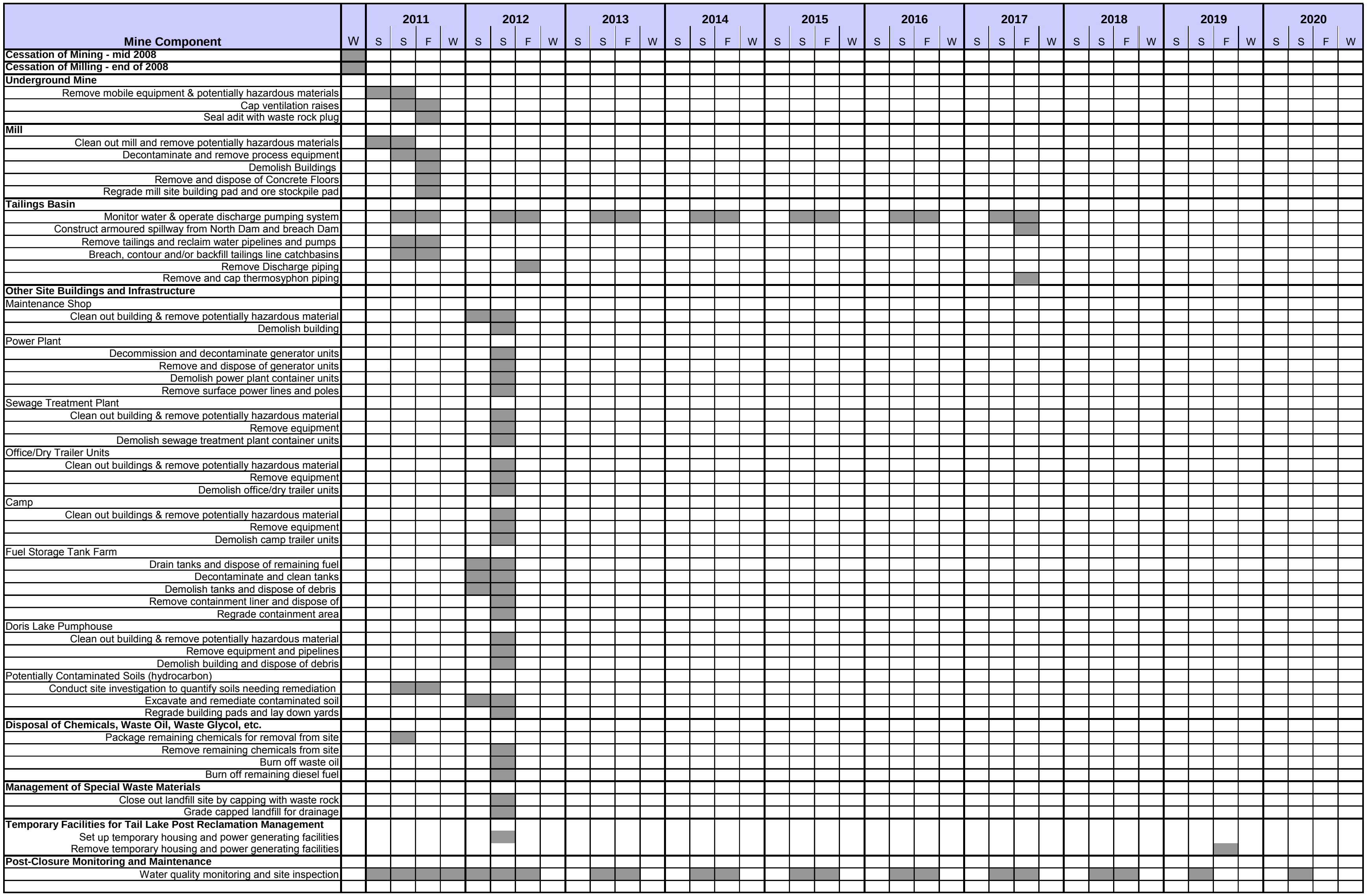

Figure 9.1: Schedule of Decommissioning & Reclamation Activity

9.2.2 Schedule Basis

The implementation schedule for final closure and reclamation assumes the following:

- Upon shutdown of site operations, a contractor will be engaged and mobilized to site via aircraft to maintain site facilities on a care and maintenance basis until reclamation activities can commence. These facilities include the camp, power plant, tailings containment area and other site support facilities. For the purposes of this estimate, a period of five months has been assumed; and

- A third-party manager and engineer will be engaged to prepare, tender and administer contracts for the site closure and reclamation activities. The engineer will also prepare detailed decommissioning, demolition and reclamation plans and specifications. This work is expected to take up to three months.

The reclamation contractor will mobilize his crews, materials and equipment to site by aircraft in the June of the year following the cessation of operations (June 2011). Most closure and reclamation activities will then be completed during 2011/2012.

9.3 Cost Estimates

9.3.1 Cost Summary

The overall cost of reclaiming the Doris North Project is estimated to be between $11.5 and $11.7 million depending on the reclamation costing model used. For the Doris North Project two models were used to estimate the overall cost of mine reclamation and post closure maintenance and monitoring:

- A cost estimate of the reclamation liability was prepared for the proposed Doris North gold mine using the Kitikmeot Inuit Association's (KIA) Reclamation Costing Model. The KIA Reclamation Costing Model was developed by Gartner Lee under contract to the KIA to provide a tool to allow the KIA to independently estimate mine reclamation liability on Inuit Owned Lands for the purpose of setting appropriate security bonding requirements. The KIA Reclamation Costing Model is intended for use by the Kitikmeot Inuit Association and mining companies that are seeking to develop projects on Inuit Owned Lands. Using the KIA model the estimated cost of mine reclamation and post closure maintenance and monitoring is $11.714 million.

- A cost estimate was prepared for the reclamation of the proposed Doris North gold mine using the RECLAIM model Version 4.0 (March 2001)[34]. The RECLAIM model was developed to estimate the cost of mine reclamation by the federal Department of Indian and Northern Affairs Canada (DIAND) for use by government agencies,

[34] RECLAIM version 5 was issued in 2006. MHBL received a copy in the first quarter of 2007. This reclamation was built prior to the release of version 5, however MHBL did not rely on the Unit Cost Table other than for costs that were subsequently increased for inflation.

mining companies, and others. Using the RECLAIM model the estimated cost of mine reclamation and post closure maintenance and monitoring is $11.535 million.

The breakdown of these two estimates is summarized by mine component in Table 9.1 (KIA Model) and Table 9.2 (RECLAIM Model). The same inputs (specific reclamation activities) were used in both models. The model outputs vary due to the way each model handles net present value of future expenditures, project management and engineering cost and contingency allowance.

Table 9.1: Summary of Estimated Reclamation Cost for the Doris North Project Using the KIA Reclamation Costing Model

Open Pit	$	-
Quarries	$	102,925.00
Underground Mine	$	234,025.00
Buildings & Equipment	$	1,519,652.43
Tailings Impoundment	$	2,270,353.89
Rock Piles	$	-
Closure Planning Studies	$	914,261.42
Chemicals & Regulated Materials	$	644,725.73
Site Access Infrastructure	$	147,988.35
General Infrastructure	$	36,085.44
Landfill	$	283,145.63
Monitoring & Maintenance	$	2,207,157.34
Management Requirements	$	3,354,054.70
Security Bond Total	$	11,714,374.92

Table 9.2: Summary of Estimated Reclamation Cost for the Doris North Project Using the INAC RECLAIM Costing Model

Capital Costs		
COMPONENT TYPE		**TOTAL COST**
UNDERGROUND MINE		$203,500
TAILINGS	Tail Lake	$2,608,493
BUILDINGS AND EQUIPMENT		$2,172,193
CHEMICALS AND SOIL MANAGEMENT		$406,500
MOBILIZATION/DEMOBILIZATION		$1,123,000
CARE AND MAINTENANCE DURING RECLAMATION		$302,000
SUBTOTAL		**$6,815,686**
PROJECT MANAGEMENT	15 % of subtotal	$1,022,353
ENGINEERING	10 % of subtotal	$681,569
CONTINGENCY	15 % of subtotal	$1,022,353
GRAND TOTAL - CAPITAL COSTS		**$9,541,960**
POST-CLOSURE MONITORING COST (NPV at 3%)		$984,231
POST-CLOSURE MONITORING CONTINGENCY 15%		$144,690
Years of post-closure monitoring	10	
POST CLOSURE MONITORING COST OVER 10 YEARS (NPV at 3%)		$1,128,921
POST CLOSURE MAINTENANCE ANNUAL AVERAGE COST		$26,000
Years of post-closure maintenance	200	
Discount Rate for Calc of NPV	3%	
POST CLOSURE MAINTENANCE SINKING FUND		$864,320
GRAND TOTAL CAPITAL AND POST-CLOSURE COSTS		**$11,535,201**

9.3.2 KIA Reclamation Costing Model Estimate

The overall cost of reclaiming the Doris North Project is estimated to be $11.714 million. The assumptions that were used to generate these cost estimate details are documented in Appendix A. The breakdown of this estimate is summarized by mine component in Appendix A - Table A1. Detailed cost breakdowns for each of the mine component areas is included in Table A2 by activity under the following mine components – Quarries; Underground Mine; Buildings & Equipment; Tailings Impoundment; Closure Planning Studies (including Project Engineering); Chemicals and Regulated Materials; Site Access Infrastructure; General Infrastructure; Landfill (Quarry 2); Post Closure Monitoring and Maintenance; and Management Requirements (including Mobilization/De-mobilization and site management during the reclamation period. These tables were generated using the KIA Reclamation costing model.

9.3.3 INAC RECLAIM Costing Model Estimate

The overall cost of reclaiming the Doris North Project is estimated to be $11.535 million. The assumptions that were used to generate these cost estimate details are documented in Appendix B. The breakdown of this estimate is summarized by mine component in Appendix B - Table B1. Detailed cost breakdowns for each of the mine component areas is included in the following Tables: Table B2 - the Underground Mine; Table B3 - the Tailings Impoundment; Table B4 – Buildings and Equipment; Table B5 – Chemicals and Soil Contamination; Table B6 – Mobilization; Table B7 – Care and Maintenance during Reclamation; Table B8 – Post Closure Monitoring; and Table B9 – Post Closure Maintenance. These tables were generated using the RECLAIM model. The unit cost table included within the RECLAIM model is attached as Table B10.

9.3.4 Cost Estimate Basis

Both of these cost estimates include all expenses anticipated from the time of mine shutdown in 2010 to completion of reclamation activities in 2012 and through post closure monitoring activities end at the end of 2020. Both cost estimates do not include any progressive reclamation credits.

Both of these estimated costs are considered to be Class I or pre-feasibility level, with an expected accuracy of +15%. All costs are presented in 2006 Canadian dollars, with no allowance for escalation.

9.3.4.1 General

In both models, for the purposes of developing the implementation schedule and cost estimates, it was assumed that the site is abandoned approximately mid-winter (end of the calendar year), following which the site would be maintained by a third-party contractor until equipment and materials needed for reclamation can be mobilized to site on the next available summer barge. Clearly, many other scenarios are possible. For example, in the event that the site is abandoned shortly after closure of the summer barging season (i.e. September), there would likely be sufficient diesel fuel in the main storage tanks (likely having been filled during the summer barge re-supply period) to supply most if not all of the closure and reclamation activity fuel requirements. However, this would also require the site to be maintained for a longer period (resulting in higher maintenance costs) before decommissioning equipment and supplies could be mobilized to site during the next available summer barge re-supply period. Conversely, if the site were abandoned late in the spring, the majority of stored diesel fuel would likely have been consumed in operations, and it would probably be necessary to purchase fuel for delivery on the next available barge re-supply, or the year after, to support the closure and reclamation program. In this scenario, however, the site maintenance period and costs would be reduced. It is expected that such variations in costs associated with alternative scenarios, such as those described above, will be accommodated within the range of accuracy of the cost estimates.

The reclamation cost estimates were based on the following general criteria, information and assumptions:

- A third-party contractor will be engaged to maintain the site on a care and maintenance basis from the date of mine shutdown by the owner to the completion of reclamation. All closure and reclamation activities, and operation of site support facilities during the care-and-maintenance and reclamation periods, will be performed by contracted labour and equipment;

- The site will be abandoned by the owner in a general state such that site facilities and mobile equipment are operational, but will require inspection, minor repairs, maintenance and an assessment of spare parts inventory needed for the care-and-maintenance period and the closure and reclamation program;

- Reclamation measures will be as described in Section 6; and

- The overall closure and reclamation schedule will be as described in Section 9.1.

9.3.4.2 Labour Costs

In both models, labour costs were estimated by applying an inclusive unit labour rate to the estimated durations for closure and reclamation activities.

Labour rates were calculated using typical wages and benefits for open shop contractors. The all-inclusive labour costs were based on working 21 ten-hour days on-site followed by a 7-day rotation off-site, which equates to working 210 hours in a four-week period. The following are included in the wage rate:

- Base labour wage rate
- Overtime premiums
- Casual overtime allowance

- Benefits and burdens
- Workers' Compensation premiums
- Travel time
- Travel costs
- Appropriate crew mixes
- Small tools and consumables
- Contractor temporary facilities and services
- Contractors' overhead and profit.

An average unit labour rate of $75/h was used for cost estimating purposes.

9.3.4.3 Engineering, Procurement and Project and Construction Management

In both models, costs were included for a third-party engineer and manager to carry out the following work:

- Project planning, including site visit, kickoff meetings and detailed planning and scheduling of decommissioning, demolition and disposal activities;

- Review of relevant drawings and information pertaining to equipment and structures to be demolished;

- Preparation of project and contract documents, including terms and conditions; drawings and specifications; safety, health and environmental management requirements; and schedules;

- Tendering, evaluation and administration of contracts;

- Procurement of equipment, materials and consumables required for the reclamation program not supplied by contractors; and

- Construction management functions, including manager, superintendents, safety supervision, accounting, contract administration, cost control, schedule management and general administration.

The above work will be initiated during the care-and-maintenance period, approximately three months prior to the first available barge re-supply period for contractor mobilization.

9.3.4.4 Temporary Construction Facilities and Services

In both models all contractor-related temporary facilities and services were included in the hourly wage rate, with the exception of camp and catering, the costs of which have been estimated separately and are covered under the Mobilization/Demobilization line item.

9.3.4.5 Salvage

In both models no salvage value has been assumed in the estimate.

9.3.4.6 Contingency

In both models a contingency of 15% was applied to all project costs to cover unforeseeable costs within the scope of the estimate.

9.3.4.7 Exclusions

The following are not included in the two estimates:

- Non-Project specific Government overhead and administration expenses during the care-and-maintenance phase, closure and reclamation phase and post-closure phase;

- Taxes and duties;

- Cost of schedule delays such as those caused by:

  - Scope changes;
  - Unidentified ground conditions;
  - Labour disputes;
  - Environmental permitting activities;

10.0 FINANCIAL SECURITY AND ASSURANCE

10.1 Introduction

DIAND's *Mine Site Reclamation Policy for Nunavut* (Reclamation Policy) sets the following guiding principles for financial security:

1. The total financial security for final reclamation required at any time during the life of the mine should be equal to the total outstanding reclamation liability for land and water combined (calculated at the beginning of the work year, to be sufficient to cover the highest liability over that time period);

2. Financial security for mine site reclamation for new mines must be readily convertible to cash. Security must meet the following basic criteria:

    - Subject to applicable legislation and due process, the form of security must provide the Crown with immediate, unconditional, unencumbered access to the full amount of the security;
    - The form of security must retain its full value throughout the life of the mine and, if applicable, beyond;
    - The form of security must remain beyond the control of the mining company, or its creditors in the event of insolvency; and

3. The Minister of Indian and Northern Affairs may consider new or innovative forms of security, such as reclamation trusts, provided they meet the above criteria.

Regulatory authority to require financial assurance for mine site reclamation is not contained in a single statute. On Crown-owned lands in Nunavut, DIAND has jurisdiction with respect to land leases and related security issues. For water licenses, the Nunavut Water Board determines the amount of security, while the Minister for DIAND has the power to determine the form of security. The Doris North Project is on Inuit owned land and thus land leases fall under the jurisdiction of the Kitikmeot Inuit Association (KIA), who are the designated Inuit organization under the NLCA for this area, and thus land lease security will fall under the jurisdiction of the KIA. DIAND will have issued a foreshore lease for the jetty in Roberts Bay.

Accordingly under the policy it is intended that DIAND take the lead in facilitating discussions between the KIA and the various regulatory bodies to promote the coordination of financial security obligations. This role includes:

- Ensuring that, at any given time during the life of the mine, the total financial security for mine site reclamation is in place, subject to the timing of any application for credit for progressive reclamation, is equal to the total outstanding reclamation liability of the mine site, and the financial security for closure-related activities, imposed by land and water jurisdictions cumulatively, does not exceed the total reclamation cost estimates for both the land-related and water-related reclamation elements at each mine;

- Ensuring that the terms, conditions and notification processes in financial security are compatible for all regulatory instruments; and

- Coordinating the regulatory determinations required for each decision maker (e.g., KIA, NWB and the DIAND Minister).

10.2 Credit for Progressive Reclamation

Ongoing reclamation throughout the life of the mine is preferable from both the environmental and financial liability perspectives. DIAND's Reclamation Policy indicates its intent that the financial security of a mining project be adjusted to reflect progressive reclamation on the following basis:

- When ongoing reclamation work reduces the outstanding environmental liability, it will result in a reduction in the level of financial security required to be maintained;

- Credit for progressive reclamation work should be made in a timely fashion in accordance with authorities set out in the applicable legislation;

- The value of reclamation work will be based on generally accepted modeling and calculated as the difference between previous outstanding liability and estimates made of the remaining liability following the reclamation work (as opposed to actual costs, if actual costs do not fully reduce outstanding liability);

- The amount of financial security on deposit will normally increase proportionately as mining proceeds. Generally this implies that as the mine site grows, water usage increases and the work to restore a site expands. Accordingly, reclamation costs are usually estimated to rise over the life of the mine. However as reclamation is performed, the environmental liability is reduced and the financial security required may decrease proportionately; and

- If, during a specific period, the value of any progressive reclamation exceeds the value of new reclamation liability created through additional mining operations, DIAND would reduce the amount of security required through the surface lease and would support an application by the mining company to the NWB to reduce the amount of the water license security accordingly.

Progressive reclamation may not reduce the financial assurance required to zero. Sometimes, a residual amount is required to meet other licensing obligations.

10.3 Post-Closure Reclamation and Final Decommissioning

DIAND's Reclamation Policy indicates that once the reclamation work required under the Mine Closure and Reclamation Plan is deemed completed, the site will be allowed to stabilize. During this time, monitoring will be conducted by the company and verified by KIA, DIAND and other agencies as appropriate, with respect to the effectiveness of the mitigative measures, the accuracy of the environmental assessment and any unforeseen environmental impacts. The duration of the required monitoring phase will be reviewed and confirmed at the time of closure and will depend on the risks associated with the potential impacts on the environment.
During this period the mining company will continue to be responsible for the site, including remediation of any additional environmental complications that develop. If warranted by site conditions, the monitoring period may be extended to ensure remedial measures are met.

The land owner and the DIAND Minister may hold back an appropriate amount of financial assurance to cover future requirements for the site. In such cases, the mining company will be responsible for the care and maintenance of the site, but will also maintain a claim to any remaining financial assurance.

When the land owner and the DIAND Minister is satisfied that the operator has met the requirements for the decommissioning under the relevant legislation and that the objectives of the Mine Closure and Reclamation Plan have been fully met, the land owner and the DIAND Minister will provide the mining company with a written acknowledgement to that effect.

10.4 Financial Security and Assurance for the Project

MHBL is committed to providing suitable financial security and assurance to cover the cost of full reclamation of the Doris North Project. MHBL expects that the estimates contained within this Mine Closure and Reclamation Plan will form the basis for future discussions between the NWB, DIAND and MHBL in establishing the appropriate level and form of financial security to be posted for the Project. MHBL acknowledges the stated principles covering financial security enunciated in the *Mine Site Reclamation Policy for Nunavut*. It is MHBL's intent to enter into discussions with the responsible authorities to reach agreement on an appropriate form and amount of security to be posted for the Project.

At this time MHBL has not developed or indicated any preference towards a specific format for the posting of security against reclamation liability. MHBL remains open to consideration of a wide range of options, including but not limited to the creation of a reclamation trust, cash, letter of credit, insurance bond or a combination of these mechanisms and others that may arise as a result of future discussions with the authorities.

MHBL is committed to a program of progressive reclamation at the Doris North Project site. Consequently, MHBL intends to manage its reclamation liability at Doris North by initiating reclamation work at an early point in the mine life where practical, thereby limiting the expansion of overall liability over time.

11.0 POST-CLOSURE ENVIRONMENT AND LAND USE USE

The key objectives of the reclamation plan are to:

- Protect public health and safety through the use of safe and responsible reclamation practices;
- Reduce or eliminate environmental effects once the mine ceases operations;
- Re-establish conditions, where practical, to pre-mining land use; and
- Reduce the need for long-term monitoring and maintenance by establishing physical and chemical stability of disturbed areas.

The following provides a brief description of the post-closure environment and land use potential.

11.1 Traditional Land Use

The Project is located within a region that was used in the past by Inuit people for hunting and fishing and as a travel route. Once the Project is reclaimed, there should be no effects on traditional land use patterns.

11.2 Non-Traditional Land Use

Potential non-traditional land uses within the area affected by the Project include extraction of subsurface minerals, domestic hunting and trapping, recreational fishing and tourism. However the area immediately surrounding the Project is currently not subject to these land uses. Few human activities are common at present because of the isolation of the area.

11.3 Aesthetic Quality

After closure, the only visible reminders of the mine’s presence will be the rockfill jetty in Roberts Bay, the quarry sites, and the rockfill building pads. All other surface infrastructure will be removed. Site roads and the outlines of laydown areas will remain readily apparent for several decades until native vegetation becomes re-established.

11.4 Biophysical Environment

Emissions of gases from the combustion of fossil fuels, dust and noise from project facilities will cease after the reclamation period. The self-sustaining permanent water cover over the Tail Lake tailings containment area will prevent significant dusting. Noise from air and road traffic will be substantially eliminated; only a few aircraft visits per year are anticipated for post-closure monitoring.

At closure, the surface disturbed by project facilities will remain visible as rock-covered, gently sloping ground that will blend with the surrounding terrain but still be distinct for several decades until native revegetation becomes re-established.

The Project area currently provides habitat for a variety of terrestrial wildlife and birds. None of these species, including caribou, is heavily dependent on resources within the Project footprint and similar habitat is prevalent throughout a wide region surrounding the Project site. The loss of habitat during Project operations and after closure (while vegetation becomes re-established) is expected to have a relatively minor impact on wildlife in a regional context.

In summary, although the Project will induce lasting physical changes to the local topography, the proposed reclamation plan will minimize these effects and assure the biodiversity and sustainability of the natural renewable resources of the region.

12.0 GLOSSARY

ARD	acid rock drainage
CCME	Canadian Council of Ministers of the Environment
˚C	degrees Celsius
DIAND	Department of Indian and Northern Affairs Canada
EA	Environmental Assessment
EMS	Environmental Management System
Ha	Hectare
ISO	International Standards Organization
Kg	Kilogram
KIA	Kitikmeot Inuit Association
Km	Kilometre
Km^2	Square kilometres
L	Litre
LSA	local study area (project footprint, surrounded by 500 m buffer)
M	Metre
m/s	metres per second
m^2	square metre
m^3	cubic metre
Masl	metres above sea level
ML	million litres
Mt	million tonnes
MTVC	Metavolcanic
NIRB	Nunavut Impact Review Board
NLCA	Nunavut Land Claims Agreement
NWB	Nunavut Water Board
PAG	potentially acid generating
Ppm	parts per million
RSA	regional study area (31 km radius from project site)
SHE	safety, health and environmental
T	tonne (1,000 kg)
t/d	tonnes per day
TDS	total dissolved solids
t/m^3	tonnes per cubic metre
TSS	total suspended solids
TSP	total suspended particulates
$\mu g/m^3$	micrograms per cubic metre

This report, “Mine Closure and Reclamation Plan, Doris North Project, Nunavut, April 2007”, has been prepared by Miramar Hope Bay Ltd.

Prepared By

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APPENDIX A

Reclamation Cost Estimate using the KIA Reclamation Costing Model

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1.0 INTRODUCTION

A cost estimate of the reclamation liability was prepared for the proposed Doris North gold mine using the Kitikmeot Inuit Association's (KIA) Reclamation Costing Model. The KIA Reclamation Costing Model was developed by Gartner Lee under contract to the KIA to provide a tool to allow the KIA to independently estimate mine reclamation liability on Inuit Owned Lands for the purpose of setting appropriate security bonding requirements. The KIA Reclamation Costing Model is intended for use by the Kitikmeot Inuit Association and mining companies that are seeking to develop projects on Inuit Owned Lands.

The model includes the major components of a typical mine. For the Doris North Project reclamation cost estimate, unit costs have been obtained from the following sources:

- Unit costs estimates were drawn from past bids submitted by Nuna Logistics and Kitnuna Corporation for specific earth works at the Doris North Project site and from unit costs quoted in other closure plans completed for work in Nunavut and the NWT (Tahera's Jericho Project and DeBeer's Snap Lake Project).

- INAC's RECLAIM model table of unit costs, although most of the unit cost items taken from this source were inflated to recognize inflation into 2006 dollars and to recognize the remote location of the Doris North Project and the inherent higher costs associated with doing work in such a remote location;

- Unit cost estimates were drawn from MHBL's past experience in doing business at the Doris North Project site (e.g.: air transport costs, barging costs) and from cost estimates provided to MHBL by prospective suppliers of goods and services to the Doris North Project; and

- Unit cost estimates for some reclamation activities were drawn from AMEC Earth and Environmental Ltd.'s experience in estimating and implementing mine closure and reclamation plans at other northern Canadian mining sites.

The base information relating to units of reclamation work and quantities used to estimate the cost of reclamation at the Doris North Project were drawn from the following sources:

- A report and the included drawings entitled "Design of the Surface Infrastructure Components, Doris North Project", dated March 2007, prepared by SRK Consulting for MHBL, (Supporting Document S2 to the Revised Water License Application Support Document, April 2007);

- The Environmental Impact Statement for the Doris North Project dated October 2005, specifically from the Project Description Chapter (Chapter 4 from the EIS Technical Support document) and associated supporting documents;

- Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S1 to the Revised Water License Application Support Document, April 2007);

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S4 to the Revised Water License Application Support Document, April 2007);

- Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007. (Supporting Document S3 to the Revised Water License Application Support Document, April 2007);

- A report entitled "Evaluation of Tailings Management Alternatives", prepared by SRK Consulting, dated August 2006;

- A report entitled: Re-Evaluation of Tailings Disposal Alternatives", prepared by SRK Consulting, dated May 2005;

- Information drawn from Bateman Minerals Limited on their work on the design of the ore processing facilities (the mill); and

- Information drawn from MHBL on their work on the design of the underground mine and related facilities.

The overall cost of reclaiming the Doris North Project is estimated to be $11.7 million. The breakdown of this estimate is summarized by mine component in Table A1. Detailed cost breakdowns for each of the mine component areas is included in Table A2 by activity under the following mine components – Quarries; Underground Mine; Buildings & Equipment; Tailings Impoundment; Closure Planning Studies (including Project Engineering); Chemicals and Regulated Materials; Site Access Infrastructure; General Infrastructure; Landfill (Quarry 2); Post Closure Monitoring and Maintenance; and Management Requirements (including Mobilization/De-mobilization and site management during the reclamation period. These tables were generated using the KIA Reclamation costing model. The assumptions that were used to generate these cost estimate details are documented in the following sections.

2.0 DISCUSSION OF COST ESTIMATE ASSUMPTIONS

2.1 General

The reclamation cost estimates were based on the following general criteria, information and assumptions:

- Mining and milling operations will cease approximately two years after start up at the end of the calendar year (For current scheduling purposes this is assumed to be at the end of 2010 on the assumption that construction will start early in 2008 with start up occurring in the second half of 2008);

- It was assumed that due to weather constraints, reclamation activities will not commence until the following summer (summer of 2011). In the intervening five-month period the site will be kept on a care and maintenance basis with a minimal sized crew (i.e., a 2 person care and maintenance crew on site at any given time);

- A third-party contractor will be engaged to maintain the site on a care and maintenance basis from the date of mine shutdown by the owner to the completion of reclamation. All closure and reclamation activities, and operation of site support facilities during the care-and-maintenance and reclamation periods, will be performed by contracted labour and equipment;

- The site will be left by the owner in a general state such that site facilities and mobile equipment are operational, but will require inspection, minor repairs, maintenance and an assessment of spare parts inventory needed for the care-and-maintenance period and the closure and reclamation program.

- Reclamation measures will be as described in Section 6 of the Mine Closure and Reclamation Plan;

- An average labour rate of $75 per hour was applied to all demolition activities. This rate is intended to reflect third party contractor rates and is inclusive of all contractor overheads including WCB, payroll burdens, administration, profit, etc. It is significantly higher than labour rates that will be incurred by the mine operator should this work be completed with the mine workforce, which is what will likely happen;

- The overall closure and reclamation schedule will be as described in Section 9.2 of the Mine Closure and Reclamation Plan. Reclamation activity will commence in the spring of 2011 and continue through until the fall. The site will once again be placed on a care and maintenance basis through the winter of 2011/2012. Reclamation will recommence in the spring of 2012 and be completed (with the exception of Tail Lake) by the fall of 2012. In other words most of the site would be reclaimed in the first two years after operations cease.

- A two person crew will remain on site during the open water seasons for an additional five years (in Year 2013, 2014, 2015, 2016, and 2017) to release supernatant from Tail Lake. The North Dam will be breached in the late summer of 2017 (nine years after the cessation of mining operations).

- Post-closure environmental monitoring and inspection of the Doris North site will continue for a period of ten years following the cessation of mining and milling (i.e., through year 2020). For the purposes of this closure cost estimate it has been assumed that a ten-year post closure monitoring period will be sufficient to verify that the reclamation objectives have been achieved and that no ongoing environmental degradation caused by the reclaimed mine site is occurring.

- A 15% contingency allowance has been added by the KIA Reclamation Costing Model to all line items. A 3% discount rate has been used to calculate net present values for future work.

3.0 OPEN PIT

The Doris North Project will not involve any open pit mining no reclamation liability cost have been incorporated under this line item.

4.0 QUARRIES

Three quarries will be developed as part of the proposed Doris North Project to provide construction rockfill materials. Quarry 1 and 3 will be closed out at the end of the construction period (end of 2008). Quarry 2 will become the site landfill during operation and will be used to permanently dispose of non-hazardous demolition waste at closure. This quarry will be closed out as part of final reclamation and the cost of reclamation for this quarry site has been included under the landfill component of this closure liability estimate.

Quarry 1 and 3 will be closed out by stabilizing the final quarry walls by reducing them to a stable angle of repose. While it is planned that this activity will take place during construction as part of the planned quarry development plan, an allowance of $97,750 (an allowance of $85,000 + 15% contingency) has been included in this reclamation cost estimate to ensure that slopes are adequately stable at final mine closure. Any remaining rockfill materials will be spread across the floor of the quarry. A $5,175 allowance ($3,500 + 15% contingency) for revegetation has been included to cover stabilization and seeding of any disturbed ground that is not rock outcrop. Revegetation of the quarries will be limited given the lack of available soils and the remaining rock surfaces.

5.0 UNDERGROUND MINE

For the purposes of this cost estimate the following assumptions related to the closure and reclamation of the Doris North underground mine facilities have been made:

1. Once mining has ceased all potentially hazardous materials will be removed from the underground mine and brought to surface for disposal. These will include all hydrocarbon products such as fuel, hydraulic fluid and other lubricants; explosives; vehicle batteries, glycol, transformer fluids, other chemicals, etc. An allowance for 4 people working 10-hour shifts for 5 days at a unit rate of $75 per hour was provided for this activity. An allowance of $5000 was included for support materials. Underground mobile equipment will be brought to surface and cleaned of any potentially hazardous materials such as fuel, hydraulic fluids, glycol, batteries, etc. and then disposed of in the surface landfill site. A cost allowance has been included in the cost estimate for both of these activities. An allowance for 2 people working 10-hour shifts for 10 days at a unit rate of $75 per hour has been provided for this activity. A further allowance of $5,000 has been included for support materials and equipment. The cost of disposal of these recovered chemicals is covered elsewhere in the cost estimate (under the "chemicals" component. The projected fleet of underground equipment consists of 7 scooptrams, 2 haul trucks, 5 jumbo drill units, 1 blasthole drill unit, 1 scissors lift truck, 1 service/fuel truck, 2 portable air compressors and 4 pickup trucks. A 15% contingency has then be added to these estimates to cover unexpected changes in volumes or unit costs;

2. The three 2.4m by 2.4m ventilation raises will be either capped with a reinforced concrete cap or backfilled. The cost estimate was based on placement of a 1 m thick concrete cap over each raise. A unit cost of $2,000 +15% contingency per cubic metre was applied for forming, reinforcing steel and concrete for this cap. The cost estimate also includes an allowance for removal of the fan housings and ductwork from the surface over top of these three ventilation raises;

3. The adit access portal will be permanently closed by the placement of a 15 m thick rockfill plug and then sealed with a welded steel cover to make the underground workings inaccessible to people or wildlife in compliance with mine safety requirements. The cost estimate allows for the placement of 300 m^3 of broken rock at $50 per m^3 to form the plug and for the construction of 4m by 5m welded steel barricade (2 people working 10 hour shifts for 10 days at a unit rate of $75/hr plus $30,000 for materials).

4. The ground in the mine will remain in a frozen condition thus there will be no anticipated movement of groundwater into or out of the mine, thus no water treatment of minewater will be required. If future global warming results in a loss of permafrost in this region, then it is expected that the underground workings will ultimately flood preventing sulphide mineral oxidation.

6.0 BUILDINGS AND EQUIPMENT

The following assumptions were made in estimating the cost related to demolition and removal of the buildings and equipment from the Doris North site:

1. All surface mobile equipment is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all

potentially hazardous materials such as batteries, hydrocarbons, glycol, fuel, etc. and then be disposed of through burial in the proposed on-site demolition debris landfill site. An allowance of 2 people working 10-hour shifts for 15 days at a unit rate of $75/hr has been applied for this activity. An allowance of $10,000 has been included for support materials and equipment. The projected surface fleet would consist of the following equipment: 4 haul trucks, 3 front end loaders, 2 dozers, 1 excavator, 1 road grader, 3 fuel trucks, 1 Plow truck, 5 pickup trucks, 1 mini-bus, and 3 portable lighting plants;

2. All stationary equipment (milling equipment, generators, etc) is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all potentially hazardous materials such as process residues, chemicals, hydrocarbons, glycol, etc and then be dismantled and disposed of through burial in the proposed on-site demolition debris landfill site. The mill is to be modular in design, prefabricated off-site and then re-assembled at site. Consequently removal of the plant equipment will be relatively straight forward involving disassembly and removal of the modules. The following time allowances have been included for cleaning, decontaminating and removal of this stationary equipment:

    a. Milling equipment – decontamination 560 person-hours
    b. Milling equipment – removal & disposal 3,600 person hours
    c. Other stationary equipment – decontamination & removal 600 person hours

A unit rate of $75/hour was applied for these activities. An allowance of $70,000 has been included for support material and equipment such as cutting torches, cranes, forklifts, hydraulic shears and other materials, etc.

3. All buildings are assumed to have no-off site salvage value. Consequently all of the buildings will be checked, then decontaminated to remove all potentially hazardous materials such as chemicals, reagents, hydrocarbons and then be dismantled and/or demolished with the debris being disposed of through burial in the proposed on-site demolition debris landfill site. The following buildings are to be removed and disposed of:

    a. Mill and Crusher Building – Steel frame structure, 2,500 m^2 footprint (allowance of 6,000 m^2 at a unit rate of $60/$m^2$ to allow for multiple floor levels within the mill and crusher building;
    b. Service Workshop – steel frame, 2,000 m^2 at a unit rate of $60/$m^2$;
    c. Camp – 38 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$;
    d. Office/Dry – 6 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$;
    e. Power Plant – Steel frame structure, 400 m^2 at a unit rate of $60/$m^2$;
    f. Arctic Corridors – 1,500 m^2 at a unit rate of $20/$m^2$;

g. Mill reagent storage – 20 shipping containers, 30.5 m^2/unit at a unit rate of \$30/m^2;
h. Explosives magazines - 20 shipping containers, 30.5 m^2/unit at a unit rate of \$30/m^2;
i. Tail Lake pump house – 100 m^2 at a unit rate of \$60/m^2.

A unit cost of $60 per square meter was selected for all building demolition based on past experience with building demolition at the Con Mine in Yellowknife and cost estimate information drawn from other northern based projects. An additional 15% has been added as a contingency to cover unexpected changes in quantities or in the unit cost. In comparison the INAC RECLAIM Model table of unit rates sets building demolition costs for steel buildings (no salvage) at between $32 and $48 per square meter. Costs are expected to be higher at Doris North due to the remote location; consequently the higher unit rate has been applied. For Seacan containers, the demolition cost was reduced to $30 +15% contingency per square meter and for the wood Arctic connecting corridors a unit demolition rate of $20 + 15% contingency was applied. With the exception of the mill these buildings will all be single story buildings.

An allowance of $15,000 + 15% contingency has been included for clean up and removal of miscellaneous bone yard materials from around the buildings for disposal in the landfill site.

4. Concrete slabs will be broken up and the rubble transported to the solid waste disposal facility. A unit cost of $6 +15% contingency per square meter has been applied in this estimate. There will be few concrete slabs to be broken within the buildings due to the use of skid-mounted trailers and modular buildings;

5. Following demolition of the buildings and final debris removal, the plant site and camp area, the beach laydown, the mill site tank farm area and the explosives magazine storage area will be given a final grading and scarification to loosen up the top layer of the rockfill to enhance the natural in-growth of vegetation over time and to ensure the drainage of precipitation and snowmelt from these pads onto the surrounding countryside. A unit cost of $4,500/ha has been applied for this light grading and scarification activity over a combined area of 4.08 ha of rockfill pad area. An additional $3,600 has been allowed for the bulldozing removal of the safety berms from the explosives magazine storage area based on 16 hours at a unit rate of $225 per hour.

6. Following re-grading of the building and laydown areas, the scarified surface will be seeded with an appropriate vegetation seed mix. A cost allowance of $0.45 per square meter ($4,500 per hectare) has been included for this seeding activity. A seed mix acceptable to the KIA will be developed for this activity during the first year of the mine life.

7.0 TAILINGS IMPOUNDMENT

For the purposes of this cost estimate the following assumptions related to the closure and reclamation of the Tail Lake tailings impoundment have been made:

1. No further chemical treatment of the water in Tail Lake will be required prior to initiating final reclamation of the Tail Lake tailings impoundment. It is assumed that water quality in Tail Lake meets discharge criteria for release as contained in the mine's water license;

2. Supernatant will be pumped from Tail Lake during open water season for seven years after the cessation of mining. At that time water inflow will have reached equilibrium with outflow and the North Dam will be deconstructed to allow unrestricted release through the former Tail Lake outflow creek. Tail Lake water quality will continue to be monitored for ten years after the cessation of milling to demonstrate that water quality is adequate for unrestricted release. An allowance of $810,000 + 15% contingency allowance has been included for the final decommissioning of the North Dam. This cost was estimated by SRK in their assessment of tailings alternatives and is based on the excavation and placement of 32,400 cubic meters of rock at a unit rate of $25 per cubic meter. This work will take place nine years after the cessation of mining; consequently a 3% discount rate was used to calculate the NPV of this expenditure. Mobilization/Demobilization ($250,000), and QA/QC engineering supervision ($96,720) for this work are included under the "Management Requirements" component of the KIA Reclamation Costing Model.

3. During the first year the tailings and reclaim water pumping systems and pipelines will be removed and the materials disposed of in the demolition debris landfill. A unit cost of $2/m has been applied for the removal and disposal of all pipelines. The tailings pipelines are projected to be 6" diameter with a 4" diameter reclaim water pipeline, both insulated HDPE. The emergency tailings pipeline catch basins will be cleaned out with tailings material hauled to Tail Lake. The catch basins (each 25.2m by 25.2m with a 1 m high berm) will then be breached and either graded or backfilled to prevent further ponding of water and to encourage natural re-vegetation to become re-established. The HDPE liners will be removed and disposed of in the landfill site. A unit cost of $7,500 per catch basin has been allowed for this activity;

4. The North dam will be breached by excavating out a section and installing rock armouring so that unrestricted release of supernatant can occur each subsequent year without impairing water quality downstream in Doris Outflow. Tail Lake will return to its pre-development water level that will ensure a minimum permanent water cover over the deposited tailings of at least 4 m. The cost of this armoured spillway is included in the estimate detailed under Item 2 above.

5. A contingent measure has been included for the placement of a geotextile and an armour rock over the remaining 60% of the 12.9 ha shoreline that will be flooded

during operation of the Tail Lake impoundment to mitigate potential erosion that may result from the thawing of the permafrost in these areas. This represents the remaining shoreline area not previously armoured during the mine life. This 12.9 ha area represents all of the potential shoreline that may be flooded between the pre-development lake level of 28.3 m to the expected operating level of 29.4 m. An allowance of $1.2 million has been included for this contingency ($570,000 for rock armouring – 22,800 cubic meters at $25.00 per cubic meter and $$619,000 for placement of geotextile – 77,400 square meters at $8.00 per square meter). The initial 20%, representing the most likely susceptible shoreline, will be armoured in a similar manner during the construction period. The second 20% will be armoured during the mine's two year operating life.

8.0 ROCK PILES

All waste rock brought to surface through the development of the underground mine will be placed into storage in a temporary waste rock pile to be constructed immediately to the north of the ore stockpile and portal access road. Under the mining plan it is expected that wherever possible development waste rock will be used internally as backfill within the mine workings. All of the underground waste rock brought to surface will be placed into the temporary waste rock stockpile to be returned into the underground mine during the mine life. The production schedule shows the stockpile growing in size to reach a maximum of 137,041 tonnes in month 13 (5 months after production starts), then dropping to a zero balance by the end of the projected mine life. Consequently there will be no rock piles to be reclaimed at the cessation of mining and thus no reclamation cost has been incorporated into this estimate against the "Rock Piles" component.

9.0 CLOSURE PLANNING STUDIES (INCLUDING DETAILED CLOSURE ENGINEERING)

This component of the reclamation cost estimate includes two categories of projected cost:

- Engineering and scientific studies required during the mine reclamation period, specifically:
    - A human health and ecological risk assessment to be conducted prior to the final breaching of the North Dam on Tail Lake to demonstrate that returning the lake to an unregulated discharge will not result in any harm to human health, to wildlife or to downstream aquatic life. An allowance of $50,000 + 15% contingency has been included in Year 6 for this study. A discount rate of 3% was used to calculate the NPV of this work.
    - A study to determine the extent of any soil contamination will be scheduled for Year 1 of the reclamation period. This will include allowance for a field program of test pitting and analysis to determine the location, nature and extent of contaminated soil/rockfill at the closed Doris North mine site and for the development of appropriate

remediation/management plans. An allowance of $45,000 + 15% contingency has been included for this work;

- Development of a hazardous materials inventory of material on site at the cessation of mining to facilitate off-site shipment and appropriate disposal in the south during the first two years of the reclamation period. An allowance of $2,500 + 15% contingency has been included in Year 1 for this work; and

- Development of a re-vegetation plan in year 1 of the reclamation period to finalize the methodology to be used to establish a vegetative cover over disturbed ground at the Doris North Project site. The study will present proposed vegetation species, seed sources, and follow up maintenance requirements.

- Detailed engineering of all closure activities, including provision of engineering support services during the reclamation period, such as surveying, quality assurance/quality control inspections for the reclamation work and contract administration support. An allowance of $450,000 + 15% has been included for Year 1, $150,000 + 15% for Year 2 and $100,000 + 15% for Year 7 when Tail Lake is to be decommissioned.

10.0 CHEMICALS AND REGULATED MATERIALS

The following assumptions were made in relation to the cost of removing, disposing and addressing the remaining chemicals, hydrocarbons and contaminated soil at the Doris North Project site:

1. All remaining inventory of laboratory chemicals will be packaged, palletized and then shipped from site for return to a supplier, for sale to an alternate user or for disposal at a licensed disposal facility. For this cost estimate it has been assumed that 2 pallets of such chemicals will have to be dealt with at mine closure. A unit rate of $2,500 per pallet was applied based on the RECLAIM model unit cost table (High end) of $2,100 plus an additional $400 due to the remoteness of this site;

2. Being a new mine it has been assumed that there will be no PCB fluids on site, no asbestos insulation materials nor lead based paints that have to be specially handled at closure;

3. Waste oil will be burned on site using a waste oil burner unit throughout the operating life of the mine. It has been assumed that 20,000 litres of waste oil will either be generated during reclamation work or remain at the time of closure. A cost allowance of $12,000 has been included for the destruction of this waste oil through burning on site. A unit rate of $0.60 per litre was applied based on the RECLAIM model unit cost table (high end) of $0.5 inflated to 2005 dollars;

4. Similarly an allowance of $12,000 has been included to burn off remaining diesel fuel. It has been assumed that diesel fuel stocks will be drawn down well before closure, however it has been assumed that 20,000 litres will need to be dealt with at closure by burning on site at a unit rate of $0.60 per litre;

5. An allowance of $150,000 has been included for the packaging and off-site disposal of any remaining reagents or chemicals left at the time of mine closure. These chemicals will be returned to the supplier, sold to another user or disposed of through a licensed disposal facility. The cost of sea-lift removal from the site is covered elsewhere under the “Management Requirements” cost component;

6. An allowance of $10,000 has been included for the on-site disposal of any remaining explosives. These will be destroyed through burning under controlled conditions following consultation with the appropriate regulatory agencies;

7. An allowance has been included for the land farming or underground disposal of 500 m^3 of Type 1 contaminated soil (light fuel) and 500 m^3 of Type 2 contaminated soil (heavy fuel and oil). The unit rates applied were $120/$m^3$ obtained from the RECLAIM model unit cost table at $110 inflated for 2006 dollars. It has been assumed that there will be no Type 3 contaminated soil (metal) on site at the time of closure. An allowance of $45,000 has been included for conducting a site investigation at closure to determine the extent and amount of any contaminated soil (rockfill) requiring remediation or alternate removal.

7. There will be five 1.5 million-litre capacity diesel fuel storage tanks at the Mill Site near the power house to be cleaned, decontaminated and dismantled. In addition there will be approximately 5 smaller fuel tanks across the site to be cleaned, decontaminated and dismantled. It is assumed that the tanks will be essentially drained of useable fuel by the end of the mine life. An allowance for the disposal of 20,000 litres of residual fuel has been incorporated into the “chemicals” component of the reclamation cost estimate. An allowance of $18,000 per large tank (200 person-hours at a unit rate of $75/hr plus $3,000 per tank in services and supplies) and $2,500 per small tank (20 person hours per tank at a unit rate of $75/hr plus $1,000 in services and materials) has been included for cleaning and decontamination. This would involve pumping out all remaining fuel, pressure washing down the insides of the tanks using an oil water separator unit constructed out of one of the Envirotanks to recycle the wash water. The tanks would then be cut up and disposed of in the on-site demolition landfill. An allowance of $24,500 per large tank (300 person-hours per tank at a unit rate of $75/hr plus $2,000 in material per tank) and $2,500 per small tank (20 person hours per tank at a unit rate of $75/hr plus $1,000 in materials and services) has been included for this activity. An allowance $6,000 (80 person hours at a unit rate of $75/hr) has been included for the removal and disposal of all fuel distribution piping and associated equipment at these fuel tank locations. An allowance of $6,000 has been included for the decontamination and demolition of the fuel transfer facility at Roberts Bay. The HDPE liner at the Mill Site fuel tank farm containment area will then be cut up, removed and disposed of in the on-site landfill. A lump sum of $6,000 (80

person-hours) has been included for this activity. The containment area will then be dozed level and regraded to ensure that precipitation and snowmelt runoff do not pond in this area and that the area drains effectively onto the surrounding landscape with minimal to no erosion. A lump sum allowance of $3,000 (40 person hours) has been included for this activity.

8. The landfarm will be decommissioned when the mine is closed, or some time period after closure, depending on requirements for its use on closure. Remediated soils that test clean (based on CCME industrial guidelines) will be used for reclamation. Soils that are contaminated and the underlying fine crushed rock from the landfarm will be placed underground at the time of landfarm decommissioning and be encapsulated by permafrost. The HDPE geomembrane will be cleaned, cut up and disposed of in the non-hazardous landfill. Bedding rockfill (below the geomembrane) will be tested for presence of petroleum hydrocarbons, and if clean, used for reclamation of the adjacent landfill but, if not, placed underground as well. The site will be levelled consistent with other reclamation activities at the mine. An allowance of $37,500 has been included for this activity ($12,500 to remove any remaining contaminated material to the underground mine; $5,000 for removal of the liner; and $20,000 for removal of the underlying rockfill bedding and berms.

A 15% contingency allowance has been added to each of the above cost items to allow for unexpected changes in volumes and/or unit costs.

11.0 SITE ACCESS INFRASTRUCTURE

All site roads and the airstrip will be reclaimed using the following process:

- All road side safety berms will be removed by dozing them off the road;
- All road signs will be removed;
- The road surfaces will be graded to provide positive drainage of precipitation and snowmelt away from the road surface onto the surrounding countryside and to prevent water ponding on the road surfaces;
- The road surfaces will be scarified to a depth of 4 to 6 inches using a grader mounted scarifying unit or other similar device to loosen up the surface to promote natural re-vegetation over the long-term. There will be a total of 7.68 ha of road and airstrip surface to be graded and scarified at a unit rate of $4,500 per ha (based on RECLAIM model unit rate table – high end);
- The scarified road and airstrip surfaces will then be seeded to establish a vegetative cover. An allowance of $0.45 per square meter

has been included for this activity for a total estimated cost of $38,586 (includes a 15% contingency allowance);

- The Doris Creek bridge crossing will be removed and the bridge disposed of in the on-site demolition debris landfill. The bridge footings will be removed and the stream banks graded and armoured at the road crossing to prevent precipitation runoff eroding away the exposed banks at the stream crossing. An allowance of $10,000 has been included to cover removal of the Doris Lake outflow bridge crossing; and

- All culverts will be removed by excavating them out of the road. The culverts will be disposed of in the on-site demolition debris landfill. The excavation sides will then be pulled back and armoured if necessary with coarse rock to allow free passage of precipitation and snowmelt runoff and to prevent erosion of the former road materials into these drainage paths. An allowance of $1,200 per culvert has been included for this activity. There will be 15 culvert crossings to be removed and regraded by this technique.

- All mooring bollards will be removed from the rockfill jetty at Roberts Bay. The rockfill jetty will then be partially removed using the following procedure:

    - A backhoe will be used to excavate the surface of the rockfill jetty so that there is a minimum of 1 meter of water cover over the remaining rockfill to ensure no obstruction to small boats approaching the shoreline at this point.
    - The excavated rock fill will be placed into the water alongside the foot of the jetty on both sides to provide a coarse rock substrate along both sides of the removed jetty.
    - At the shore end the rockfill will be removed and graded to ensure that no part of the jetty extends above the low water line.

It is expected that over time ice and wave action will obliterate any remaining sign of the rockfill jetty (estimate that this will occur with five years post closure). It is estimated that 2,080 cubic meters of rockfill will have to be excavated at a unit cost of $10.00 per cubic meter to decommission the jetty as proposed. Total allowance for jetty removal is estimated at $26, 000.

- The float plane dock in Doris Lake will be decommissioned in a similar manner to the Roberts Bay jetty. An allowance of $3,900 (includes contingency allowance) has been included in the estimate.

12.0 GENERAL INFRASTRUCTURE

General site infrastructure will be reclaimed as follows:

- Communications equipment will be removed from site. Antennas and satellite dishes will be dismantled and the non-hazardous debris disposed of within the site landfill. Allowance of $5,000 for this work;

- Surface power distribution lines and poles will be removed and disposed of. A total of 5 km of power lines will be removed at a unit cost of $2,500/km;

- The site sewage treatment plant – 2 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$ will be cleaned and dismantled with the demolition debris disposed of within the site landfill;

- An allowance of $8,373 (includes 15% contingency) has been included in the reclamation cost estimate for final removal of the temporary accommodation facility, including power generator and fuel system used to house the last demolition employees after the main accommodation camp has been removed.

13.0 LANDFILL

The landfill site used for the disposal of the demolition debris will be closed out by placing rockfill over the compressed debris to create a mounded rockfill cover. An allowance of 10,000 m^3 of rockfill has been allowed for this activity. The unit rate used for the loading, hauling and placement of the rockfill cover is $25/$m^3$ which assumes that the rockfill material will be non-acid generating waste rock from Quarry 2 previously stockpiled in the landfill quarry (quarry #2) through the mine's operating life. The estimate assumes an average cover thickness of 1 m in depth over a surface area of 10,000 m^2. The final cover will then be graded to shed precipitation and snowmelt from the landfill area. A grading cost of $3,600 was applied based on 16 hours of equipment time at a unit rate of $225/hr.

14.0 POST CLOSURE MONITORING AND MAINTENANCE

It will be necessary to monitor the environmental performance of the reclamation work for an extended period before it can be determined that the reclamation objectives have been achieved, specifically that the reclaimed site is not adversely affecting the surrounding environment nor contributing to ongoing environmental degradation. The following assumptions have been made in estimating the cost of this post closure environmental monitoring and maintenance activity:

1. Environmental monitoring will continue for a 10 year period following the cessation of mining (8 years after reclamation has been completed) to provide sufficient time and data collection to enable a conclusion to be made on the effectiveness of the reclamation activities;

2. Post Closure environmental monitoring will consist of four trips to site every year for the first five years for the purpose of collecting and having analyzed a set of water samples; to facilitate a physical inspection of the site to assess erosion, revegetation and to assess seepage from the landfill, drainage from Tail Lake and runoff from the roads and building pads; and to carry out minor maintenance activities such as repairing erosion, creating minor drainage pathways and cleaning of any debris from the Tail Lake outflow. The frequency would then drop to twice per year for the next 2 years and then to once per year for the next three years. It has been assumed for the purpose of this estimate that a total of 10 water samples per trip will be collected. An estimate of $10,400 per trip has been included to pay for the cost of the air charter from Cambridge Bay, sampling labour, analytical costs, air transportation to and from Cambridge Bay by commercial carrier from Yellowknife to Cambridge Bay;

3. An allowance for one geotechnical inspection of the site every year thru 2016 to inspect and report on the performance and continued stability of the Tail Lake impoundment structures and other earthworks. The frequency would drop to every second year through 2020. An estimate of $25,000 per year has been included to pay for the services of a qualified geotechnical engineer, travel expenses and report preparation. It is assumed that this inspection will take place at the same time as the annual water sampling site visit;

4. An allowance of $50,000 per year has been included for an annual environmental effects monitoring program to be conducted at the site every year through 2016, then dropping to every second year through 2020;

5. An allowance of $50,000 per year has been included for an annual wildlife effects monitoring program to be conducted at the site every year through 2016, then dropping to every second year through 2020;

6. An allowance ($25,000 in Year 2, $50,000 in Year 5 and $35,000 in Year 10 + 15% for each event) has been included for post-closure vegetation success monitoring in Years 2, 5 and 10 following the cessation of mining;

7. An allowance has been included for the KIA to conduct consultation with Inuit beneficiary committees in the nearby communities on the status of reclamation in Years 1, 5 and 10 following the cessation of mining ($15,000 + 15% contingency for each event); and

8. A 15% contingency allowance has been applied to the annual post closure monitoring and maintenance cost estimate to cover uncertainties in these estimates. A 3% discount rate was used to calculate the NPV of the post closure monitoring cost over the 10 year period. The NPV of this post closure monitoring is estimated at $1.4 million.

It has been assumed that no significant environmental nor maintenance issues will arise in the post-closure period. This is based on the relative simplicity of the site following implementation of the closure plan and the low risk associated with the post closure facilities, i.e., no waste rock dumps, removal of all buildings and equipment, a breached tailings dam, etc. However it has been assumed that some ongoing periodic maintenance will be required at the site, either annually, bi-annually or as needed. The typical post closure maintenance activities assumed are as follows:

1. Periodic erosion repair of removed culverts, stream crossings, breached emergency dump ponds, etc. For the purpose of closure cost estimating an allowance of 80 person-hours per year has been included for this type of activity along with money for travel and equipment. It is expected that this degree of effort will not be required every year, however at some point in time this type of maintenance will be required. It may occur once every five years at which time the allowance would be 400 person-hours, or every second year at which time the allowance would be 160 person-hours;

It has been assumed that post closure maintenance will be required over a 40 year period at an average annual cost of $26,000 +15% contingency allowance. A discount rate of 3% was used to calculate the NPV of these costs over the 40 year post closure period. The NPV of this maintenance activity was estimated at $652,936.

15.0 MANAGEMENT REQUIREMENTS

The following assumptions have been made in estimating the cost of managing the reclamation program and for fixed costs such as mobilization/demobilization, catering and transportation for the crews associated with reclamation of the Doris North Project site:

1. It has been assumed that all equipment and buildings will have no economic salvage value and will be disposed of on-site through the demolition debris landfill site;

2. It has been assumed that the mine's fleet of surface and underground mobile equipment will be on-site and available for use (with maintenance) for carrying out the reclamation activity. In this regard it has been assumed that minimal heavy equipment will have to be mobilized to site to carry out the reclamation activity;

3. It has been assumed that the workforce required to complete reclamation will be transported to site by charter aircraft from either Yellowknife or Cambridge Bay. It has been assumed that over the two 4 month long (June, July, August, September) reclamation activity periods (one in 2011 and the other in 2012) that a total of 32 charter flights will be used to change out crews (16 per year, 4 per month) at a unit rate of $5,000 per flight;

4. It has been assumed over the 8 month long reclamation period (excluding care and maintenance), i.e. 4 months in 2011 and 2012 each, there will be on average

15 people on site requiring accommodation and food. This translates into 3,600 person-days at a camp cost of $55 per person-day. Consequently an allowance of $198,000 has been included for camp costs during this time period;

5. It has been assumed that over the reclamation period it may be necessary to move larger pieces of equipment to and from the site for specialty purposes. An allowance of $100,000 has been included for charter flights using a large cargo aircraft such as a Hercules aircraft. A further allowance of $400,000 has been included for two sea-lift visits to the Doris North site to bring in equipment and to remove hazardous materials and other salvageable equipment;

6. An allowance of $200,000 has been included for maintenance of insurance on the site over the two year closure period;

7. An allowance of $65,000 has been included for incidental operating supplies (other than those included in specific activity estimates) during this 2-year period. Nominally these costs have been allocated as $50,000 for fuel and lubricants, $10,000 for minor tools and repair parts and $5,000 for tires.

8. A further allowance of $250,000 has been included for mobilization/demobilization of the contractor in Year 7 who will decommission the North Dam on Tail Lake

It has been assumed that the site will be carried on a care and maintenance basis for 13 months over the two-year reclamation period, broken down as follows:

- January thru May of 2011 (5 months); and
- October of 2008 through May of 2012 (8 months).

During this time the Doris North Project site will be maintained by a two person crew (i.e., two people on site at all time) who will look after site security and to ensure that no environmental damage occurs as a result of the mine's facilities. For the purposes of this reclamation cost estimate, the following assumptions related to care and maintenance have been applied:

- An allowance has been included for 26 person months of caretaker labour at a monthly rate of $4,500;

- An allowance of $5,000 per month in food and supplies has been assumed over this 13 month period;

- An allowance for 24 charter flights from Cambridge Bay has been included at a unit cost of $2,500 per flight over this 13-month period for crew rotation and re-supply.

9. An allowance of $1.2 million has been included for the management of the Doris North Project during the reclamation period. This allowance is to include project

management, supervision and administration during the reclamation period and is broken down as follows:

- Year 1 - $500,000
- Year 2 - $300,000
- Year 3 - $50,000
- Year 4 - $50,000
- Year 5 - $50,000
- Year 6 - $50,000
- Year 7 - $146,720
- Year 8 - $10,000
- Year 9 - $10,000
- Year 10 - $10,000
- Year 11 - $10,000

Years 3 thru 7 include $50,000 per year for off site management of the site while active management over the Tail Lake water release continues. Year 7 also includes project management while the North Dam and the Tail Lake tailings impoundment site is decommissioned. Years 8 thru 11 include $10,000 per year for off site management oversight while post closure monitoring continues.

16.0 CONTINGENCY ALLOWANCE

The KIA Reclamation Costing Model adds a specified contingency to all line activity items within the reclamation costing spreadsheet. For the Doris North estimate a contingency allowance of 15% has been specified. It is intended to cover uncertainties and inaccuracies contained in the cost estimates completed for the specified reclamation components.

Table A 1: Reclamation Cost Summary

Open Pit	**$**	**-**
Quarries	**$**	**102,925.00**
Underground Mine	**$**	**234,025.00**
Buildings & Equipment	**$**	**1,519,652.43**
Tailings Impoundment	**$**	**2,270,353.89**
Rock Piles	**$**	**-**
Closure Planning Studies	**$**	**914,261.42**
Chemicals & Regulated Materials	**$**	**644,725.73**
Site Access Infrastructure	**$**	**147,988.35**
General Infrastructure	**$**	**36,085.44**
Landfill	**$**	**283,145.63**
Monitoring & Maintenance	**$**	**2,207,157.34**
Management Requirements	**$**	**3,354,054.70**
Security Bond Total	**$**	**11,714,374.92**

Table A 2: Reclamation Cost Estimate by Activity

Underground Mine	Remove Regulated Materials	$	23,000.00
	Remove Mine Materials	$	23,000.00
	seal adit	$	69,000.00
	seal raises (3)	$	103,500.00
	remove ventilation equipent	$	15,525.00
Buildings & Equipment	Tear Down Accommodation Buildings	$	155,283.50
	Tear Down Processing Buildings	$	414,000.00
	Break and remove Concrete Slabs/Pedestals	$	85,300.97
	Decontamination	$	56,350.00
	Remove Stationary Equipment	$	442,750.00
	Remove Mobile Equipment	$	37,375.00
	Re-Vegetation	$	18,238.11
	incinerator units (2)	$	2,233.01
	remove boneyard waste	$	17,250.00
	Tear down complex/office/dry/power/pumphouse	$	191,994.17
	tear down arctic corridors	$	33,495.15
	Contour Pads	$	24,518.45
	tear down magazine/reagent storage (40 sea cans)	$	40,864.08
Tailings Impoundment	Remove Mine Equipment (pipelines/pumps)	$	31,395.00
	Breach Dams	$	735,334.70
	Water Treatment	$	389,543.91
	shoreline protection	$	1,079,580.28
	tailngs catch ponds (4)	$	34,500.00
Closure Planning Studies	Ecological Risk Assessment	$	49,600.01
	Contaminated Soil Study (ESA)	$	51,750.00
	Hazardous Materials Inventory	$	2,875.00
	Re-vegetation Plan	$	28,750.00
	Detailed closure engineering (Miramar 10% plus dam)	$	781,286.42
Chemicals & Regulated Materials	Dispose/Secure Laboratory Chemicals (2 pallets)	$	5,750.00
	Dispose/Secure Process Chemicals/Glycols/batteries	$	172,500.00
	Dispose/Secure Used Oils and Others	$	13,398.06
	Dispose/Remediate Contaminated Soils	$	133,980.58
	Clean and Empty Fuel Systems (5 large + 5 small tanks)	$	127,839.81
	Dispose Fuel Systems	$	137,888.35
	Dispose Explosives	$	11,500.00
	Close out Landfarm Facility in Quarry 2	$	41,868.93
Site Access Infrastructure	Scarify Airstrip/Roads and Remove culverts (15)	$	58,683.50
	Re-Vegetate Airstrip/Roads	$	38,586.41
	Deconstruct Docks/Jetties and Remove Pilings/Fill	$	26,014.56
	remove Doris Creek bridge	$	20,796.12
	deconstruct float plane dock	$	3,907.77
General Infrastructure	Remove Communications Gear	$	5,582.52
	Remove Electrical Systems (5 km powerline)	$	13,956.31
	Remove Septic & Water Systems	$	8,172.82
	Remove Temporary Decommissioning Camp	$	5,582.52
	Remove Temporary Decommissioning Fuel Supply	$	2,791.26
Landfill	Soil/Rock Cover	$	283,145.63
Monitoring & Maintenance	Post Closure Water Quality Monitoring Labour	$	78,556.73
	PC Water Quality Monitoring Supplies and Equipment	$	5,383.29
	Transportation to and from Site for Post Closure WQ Monitor	$	184,165.29
	Post Closure Water Quality Analytical Costs	$	53,832.93
	Transportation of Water Quality Samples to Lab	$	7,083.28
	Area Aquatic Effects Monitoring Program	$	411,654.89
	Area Wildlife Monitoring Programs	$	411,654.89
	Post Closure Geotechnical Inspections	$	205,827.44
	Annual Reporting of Environmental Monitoring Results	$	40,416.10
	Post Closure General Maintenance (incl dams & spillways)	$	652,936.51
	Post Closure Vegetation Success Monitoring	$	109,848.90
	Post Closure Consultation with Inuit Beneficiaries by KIA	$	45,797.09
Management Requirements	Mobilize/Demob Contractor Equipment	$	807,402.94
	Project Management (Miramar 15%)	$	1,294,566.05
	Site Caretaker Required	$	205,548.54
	Bulk Supplies Required	$	73,661.41
	Transportation	$	419,575.99
	Catering	$	326,649.29
	Site Liability Insurance	$	226,650.49

APPENDIX B

Reclamation Cost Estimate using the INAC RECLAIM Reclamation Costing Model

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LIST OF TABLES

1.0 INTRODUCTION

A cost estimate was prepared for the reclamation of the proposed Doris North Project using the RECLAIM model Version 4.0 (March 2001)[1]. The RECLAIM model was developed to estimate the cost of mine reclamation by the federal Department of Indian and Northern Affairs Canada (DIAND) for use by government agencies, mining companies, and others.

The model includes the major components of a typical mine. An important feature of the model is a table of unit costs of common reclamation activities, which can be updated or customized to be site specific. The tabulated unit costs contained within the RECLAIM model are based on experience from reclamation work at northern mines.

For the Doris North Project reclamation cost estimate, unit costs have been obtained from the following sources:

- The RECLAIM model table of unit costs, although most of the unit cost items taken from this source were inflated to recognize inflation into 2006 dollars and to recognize the remote location of the Doris North Project and the inherent higher costs associated with doing work in such a remote location;

- Unit costs estimates were drawn from past bids submitted by Nuna Logistics and Kitnuna Corporation for specific earth works at the Doris North Project site and from unit costs quoted in other closure plans completed for work in Nunavut and the NWT (Tahera's Jericho Project and De Beer's Snap Lake Project).

- Unit cost estimates were drawn from MHBL's past experience in doing business at the Doris North Project site (e.g.: air transport costs, barging costs) and from cost estimates provided to MHBL by prospective suppliers of goods and services to the Doris North Project;

- Unit cost estimates for some reclamation activities were drawn from AMEC Earth and Environmental Ltd.'s experience in estimating and implementing mine closure and reclamation plans at other northern Canadian mining sites; and

The base information relating to units of reclamation work and quantities used to estimate the cost of reclamation at the Doris North Project were drawn from the following sources:

- A report entitled "Design of the Preliminary Surface Infrastructure Components, Doris North Project", dated March 2007, prepared by SRK Consulting for MHBL, (Supporting Document S2 to the Revised Water License Application Support Document, April 2007);

- The Environmental Impact Statement for the Doris North Project dated October 2005, specifically from the Project Description Chapter (Chapter 4 from the EIS Technical Support document) and associated supporting documents;

[1] RECLAIM version 5 has issued in 2006. MHBL received a copy in the first quarter of 2007. This reclamation was built prior to the release of version 5, however MHBL did not rely on the Unit Cost Table other than for costs that were subsequently increased for inflation.

- Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007 (Supporting Document S1 to the Revised Water License Application Support Document, April 2007); and

- Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007 (Supporting Document S4 to the Revised Water License Application Support Document, April 2007).

Technical Specifications for Tailings Containment Area and Surface Infrastructure Components, Doris North Project, Hope Bay, Nunavut, Canada, prepared for MHBL by SRK Consulting (Canada) Inc., dated March 2007(Supporting Document S3 to the Revised Water License Application Support Document, April 2007);

- A report entitled "Evaluation of Tailings Management Alternatives Assessment", prepared by SRK Consulting, dated August 2006;

- A report entitled: Re-Evaluation of Tailings Disposal Alternatives", prepared by SRK Consulting, dated May 2005;

- Information drawn from Bateman Minerals Limited on their work on the design of the ore processing facilities (the mill); and

- Information drawn from MHBL on their work on the design of the underground mine and related facilities.

The overall cost of reclaiming the Doris North Project is estimated to be $11.5 million. The breakdown of this estimate is summarized by mine component in Table B1. Detailed cost breakdowns for each of the mine component areas is included in the following Tables: Table B2 - the Underground Mine; Table B3 - the Tailings Impoundment; Table B4 – Buildings and Equipment; Table B5 – Chemicals and Soil Contamination; Table B6 – Mobilization; Table B7 – Care and Maintenance during Reclamation; Table B8 – Post Closure Monitoring; and Table B9 – Post Closure Maintenance. These tables were generated using the RECLAIM model. The unit cost table included within the RECLAIM model is attached as Table B10. The assumptions that were used to generate these cost estimate details are documented in the following sections.

2.0 DISCUSSION OF COST ESTIMATE ASSUMPTIONS

2.1 General

The reclamation cost estimates were based on the following general criteria, information and assumptions:

- Mining and milling operations will cease approximately two years after start up at the end of the calendar year (For current scheduling purposes this is assumed to be at the end of 2010 on the assumption that construction will start early in 2008 with start up occurring in the second half of 2008);

- It was assumed that due to weather constraints, reclamation activities will not commence until the following summer (summer of 2011). In the intervening five-month period the site will be kept on a care and maintenance basis with a minimal sized crew (i.e., a 2 person care and maintenance crew on site at any given time);

- A third-party contractor will be engaged to maintain the site on a care and maintenance basis from the date of mine shutdown by the owner to the completion of reclamation. All closure and reclamation activities, and operation of site support facilities during the care-and-maintenance and reclamation periods, will be performed by contracted labour and equipment;

- The site will be left by the owner in a general state such that site facilities and mobile equipment are operational, but will require inspection, minor repairs, maintenance and an assessment of spare parts inventory needed for the care-and-maintenance period and the closure and reclamation program;

- Reclamation measures will be as described in Section 6 of the Mine Closure and Reclamation Plan;

- An average labour rate of $75 per hour was applied to all demolition activities. This rate is intended to reflect third party contractor rates and is inclusive of all contractor overheads including WCB, payroll burdens, administration, profit, etc. It is significantly higher than labour rates that will be incurred by the mine operator should this work be completed with the mine workforce, which is what will likely happen;

- The overall closure and reclamation schedule will be as described in Section 9.1 of the Mine Closure and Reclamation Plan. Reclamation activity will commence in the spring of 2011 and continue through until the fall. The site will once again be placed on a care and maintenance basis through the winter of 2011/2012. Reclamation will recommence in the spring of 2012 and be completed (with the exception of Tail Lake) by the fall of 2012;

- A two person crew will remain on site during the open water seasons for an additional five years (in Year 2013, 2014, 2015, 2016, and 2017) to release supernatant from Tail Lake. The North Dam will be breached in the late summer of 2019 (nine years after the cessation of mining operations); and

- Post-closure environmental monitoring and inspection of the Doris North site will continue for a period of ten years following the cessation of mining and milling (i.e., through year 2020). For the purposes of this closure cost estimate it has been assumed that a ten-year post closure monitoring period will be sufficient to verify that the reclamation objectives have been achieved and that no ongoing environmental degradation caused by the reclaimed mine site is occurring.

3.0 UNDERGROUND MINE

For the purposes of this cost estimate the following assumptions related to the closure and reclamation of the Doris North underground mine facilities have been made:

1. Once mining has ceased all potentially hazardous materials will be removed from the underground mine and brought to surface for disposal. These will include all hydrocarbon products such as fuel, hydraulic fluid and other lubricants; explosives; vehicle batteries, glycol, transformer fluids, other chemicals, etc. An allowance for 4 people working 10-hour shifts for 5 days at a unit rate of $75 per hour was provided for this activity. An allowance of $5000 was included for support materials. Underground mobile equipment will be brought to surface and cleaned of any potentially hazardous materials such as fuel, hydraulic fluids, glycol, batteries, etc. and then disposed of in the surface landfill site. A cost allowance has been included in the cost estimate for both of these activities. An allowance for 2 people working 10-hour shifts for 10 days at a unit rate of $75 per hour has been provided for this activity. A further allowance of $5,000 has been included for support materials and equipment. The cost of disposal of these recovered chemicals is covered elsewhere in the cost estimate (under the "chemicals" component. The projected fleet of underground equipment consists of 7 scooptrams, 2 haul trucks, 5 jumbo drill units, 1 blasthole drill unit, 1 scissors lift truck, 1 service/fuel truck, 2 portable air compressors and 4 pickup trucks;

2. The three 2.4m by 2.4m ventilation raises will be either capped with a reinforced concrete cap or backfilled. The cost estimate was based on placement of a 1 m thick concrete cap over each raise. The cost estimate also includes an allowance for removal of the fan housings and ductwork from the surface over top of these three ventilation raises;

3. The adit access portal will be permanently closed by the placement of a 15 m thick rockfill plug and then sealed with a welded steel cover to make the underground workings inaccessible to people or wildlife in compliance with mine safety requirements. The cost estimate allows for the placement of 300 m^3 of broken rock at $50 per m^3 to form the plug and for the construction of 4m by 5m welded steel barricade (2 people working 10 hour shifts for 10 days at a unit rate of $75/hr plus $30,000 for materials); and

4. The ground in the mine will remain in a frozen condition thus there will be no anticipated movement of groundwater into or out of the mine, thus no water treatment of minewater will be required. If future global warming results in a loss of permafrost in this region, then it is expected that the underground workings will ultimately flood preventing sulphide mineral oxidation.

4.0 ROCK PILES

All waste rock brought to surface through the development of the underground mine will be placed into storage in a temporary waste rock pile to be constructed immediately to the north of the ore stockpile and portal access road. Under the mining plan it is expected that wherever possible development waste rock will be used internally as backfill within the mine workings. All of the underground waste rock brought to surface will be placed into the temporary waste rock stockpile to be returned into the underground mine during the mine life. The production schedule shows the stockpile growing in size to reach a maximum of 137,041 tonnes in month 13 (5 months after production starts), then dropping to a zero balance by the end of the projected mine life. Consequently there will be no rock piles to be reclaimed at the cessation of mining and thus no reclamation cost has been incorporated into this estimate against the “Rock Piles” component.

5.0 TAIL LAKE TAILINGS CONTAINMENT AREA

For the purposes of this cost estimate the following assumptions related to the closure and reclamation of the Tail Lake tailings impoundment have been made:

1. No further chemical treatment of the water in Tail Lake will be required prior to initiating final reclamation of the Tail Lake tailings impoundment. It is assumed that water quality in Tail Lake meets discharge criteria for release as contained in the mine’s water license;

2. Supernatant will be pumped from Tail Lake during open water season for seven years after the cessation of mining. At that time water inflow will have reached equilibrium with outflow and the North Dam will be deconstructed to allow unrestricted release through the former Tail Lake outflow creek. Tail Lake water quality will continue to be monitored for ten years after the cessation of milling to demonstrate that water quality is adequate for unrestricted release;

3. During the first year the tailings and reclaim water pumping systems and pipelines will be removed and the materials disposed of in the demolition debris landfill. A unit cost of $2/m has been applied for the removal and disposal of all pipelines. The tailings pipelines are projected to be 6” diameter with a 4” diameter reclaim water pipeline, both insulated HDPE. The emergency tailings pipeline catch basins will be cleaned out with tailings material hauled to Tail Lake. The catch basins (each 25.2m by 25.2m with a 1 m high berm) will then be breached and either graded or backfilled to prevent further ponding of water and to encourage natural re-vegetation to become re-established. The HDPE liners will be removed and disposed of in the landfill site. A unit cost of $7,500 per catch basin has been allowed for this activity;

4. The North dam will be breached in 2017 (seven years after the cessation of mining) by excavating out a section and installing rock armouring so that unrestricted release of supernatant can occur each subsequent year without impairing water quality downstream in Doris Outflow. Tail Lake will return to its pre-development water level that will ensure a minimum permanent water cover over the deposited tailings of at least 4 m. An allowance of $810,000 has been included for the final decommissioning of the North Dam. This cost was estimated by SRK in their assessment of tailings alternatives and is based on the excavation and placement of 32,400 cubic meters of rock at a unit rate of $25 per cubic meter. Mobilization/Demobilization ($250,000), Engineering ($106,000) and QA/QC construction supervision ($96,720) for this work are also included. This work

will take place nine years after the cessation of mining; consequently a 3% discount rate was used to calculate the NPV of this expenditure; and

5. A contingent measure has been included for the placement of a geotextile and an armour rock over the remaining 60% of the 12.9 ha shoreline that will be flooded during operation of the Tail Lake impoundment to mitigate potential erosion that may result from the thawing of the permafrost in these areas. This represents the remaining shoreline area not previously armoured during the mine life. This 12.9 ha area represents all of the potential shoreline that may be flooded between the pre-development lake level of 28.3 m to the expected operating level of 29.4 m. An allowance of $1.2 million has been included for this contingency. If required this work will take place nine years after the cessation of mining; consequently a 3% discount rate was used to calculate the NPV of this expenditure.

6.0 BUILDINGS AND EQUIPMENT

The following assumptions were made in estimating the cost related to demolition and removal of the buildings and equipment from the Doris North site:

1. All surface mobile equipment is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all potentially hazardous materials such as batteries, hydrocarbons, glycol, fuel, etc. and then be disposed of through burial in the proposed on-site demolition debris landfill site. An allowance of 2 people working 10-hour shifts for 15 days at a unit rate of $75/hr has been applied for this activity. An allowance of $10,000 has been included for support materials and equipment. The projected surface fleet would consist of the following equipment: 4 haul trucks, 3 front end loaders, 2 dozers, 1 excavator, 1 road grader, 3 fuel trucks, 1 Plow truck, 5 pickup trucks, 1 mini-bus, and 3 portable lighting plants;

2. All stationary equipment (milling equipment, generators, etc) is assumed to have no off-site salvage value. Consequently the equipment will be cleaned, decontaminated to remove all potentially hazardous materials such as process residues, chemicals, hydrocarbons, glycol, etc and then be dismantled and disposed of through burial in the proposed on-site demolition debris landfill site. The mill is to be modular in design, prefabricated off-site and then re-assembled at site. Consequently removal of the plant equipment will be relatively straight forward involving disassembly and removal of the modules. The following time allowances have been included for cleaning, decontaminating and removal of this stationary equipment:

    a. Milling equipment – decontamination — 560 person-hours
    b. Milling equipment – removal & disposal — 3,600 person hours
    c. Other stationary equipment – decontamination & removal — 600 person hours

    A unit rate of $75/hour was applied for these activities. An allowance of $70,000 has been included for support material and equipment such as cutting torches, cranes, forklifts, hydraulic shears and other materials, etc.;

3. All buildings are assumed to have no-off site salvage value. Consequently all of the buildings will be checked, then decontaminated to remove all potentially hazardous materials such as chemicals, reagents, hydrocarbons and then be dismantled and/or demolished with the debris being disposed of through burial in the proposed on-site demolition debris landfill site. The following buildings are to be removed and disposed of:

    a. Mill and Crusher Building – Steel frame structure, 2,500 m^2 footprint (allowance of 6,000 m^2 at a unit rate of $60/$m^2$ to allow for multiple floor levels within the mill and crusher building;
    b. Service Workshop – steel frame, 2,000 m^2 at a unit rate of $60/$m^2$;
    c. Camp – 38 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$;
    d. Office/Dry – 6 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$;
    e. Sewage treatment plant – 2 skid mounted trailer units, 61 m^2/unit at a unit rate of $60/$m^2$;
    f. Power Plant – Steel frame structure, 400 m^2 at a unit rate of $60/$m^2$;
    g. Arctic Corridors – 1,500 m^2 at a unit rate of $20/$m^2$;
    h. Mill reagent storage – 20 shipping containers, 30.5 m^2/unit at a unit rate of $30/$m^2$;
    i. Explosives magazines - 20 shipping containers, 30.5 m^2/unit at a unit rate of $30/$m^2$; and
    j. Tail Lake pump house – 100 m^2 at a unit rate of $60/$m^2$.

    With the exception of the mill these buildings will all be single story buildings. An allowance of $15,000 has been included for clean up and removal of miscellaneous bone yard materials from around the buildings for disposal in the landfill site;

4. Concrete slabs will be broken up and the rubble transported to the solid waste disposal facility. There will be few concrete slabs to be broken within the buildings due to the use of skid-mounted trailers and modular buildings;

5. Following demolition of the buildings and final debris removal, the plant site and camp area, the beach laydown, the mill site tank farm area and the explosives magazine storage area will be given a final grading and scarification to loosen up the top layer of the rockfill to enhance the natural in-growth of vegetation over time and to ensure the drainage of precipitation and snowmelt from these pads onto the surrounding countryside. A unit cost of $4,500/ha has been applied for this light grading and scarification activity over a combined area of 4.08 ha of rockfill pad area. An additional $3,600 has been allowed for the bulldozing removal of the safety berms from the explosives magazine storage area based on 16 hours at a unit rate of $225 per hour;

6. Following re-grading of the building and laydown areas, the scarified surface will be seeded with an appropriate vegetation seed mix. A cost allowance of $0.45 per square meter ($4,500 per hectare) has been included for this seeding activity. A seed mix acceptable to the KIA will be developed for this activity during the first year of the mine life;

7. There will be five 1.5 million-litre capacity diesel fuel storage tanks at the Mill Site near the power house to be cleaned, decontaminated and dismantled. In addition there will be approximately 5 smaller fuel tanks across the site to be cleaned, decontaminated and dismantled. It is assumed that the tanks will be essentially drained of useable fuel by the end of the mine life. An allowance for the disposal of 20,000 litres of residual fuel has been incorporated into the "chemicals" component of the reclamation cost estimate. An allowance of $18,000 per large tank (200 person-hours at a unit rate of $75/hr plus $3,000 per tank in services and supplies) and $2,500 per small tank (20 person hours per tank at a unit rate of $75/hr plus $1,000 in services and materials) has been included for cleaning and decontamination. This would involve pumping out all remaining fuel, pressure washing down the insides of the tanks using an oil water separator unit constructed out of one of the Envirotanks to recycle the wash water. The tanks would then be cut up and disposed of in the on-site demolition landfill. An allowance of $24,500 per large tank (300 person-hours per tank at a unit rate of $75/hr plus $2,000 in material per tank) and $2,500 per small tank (20 person hours per tank at a unit rate of $75/hr plus $1,000 in materials and services) has been included for this activity. An allowance $6,000 (80 person hours at a unit rate of $75/hr) has been included for the removal and disposal of all fuel distribution piping and associated equipment at these fuel tank locations. An allowance of $6,000 has been included for the decontamination and demolition of the fuel transfer facility at Roberts Bay. The HDPE liner at the Mill Site fuel tank farm containment area will then be cut up, removed and disposed of in the on-site landfill. A lump sum of $6,000 (80 person-hours) has been included for this activity. The containment area will then be dozed level and regraded to ensure that precipitation and snowmelt runoff do not pond in this area and that the area drains effectively onto the surrounding landscape with minimal to no erosion. A lump sum allowance of $3,000 (40 person hours) has been included for this activity;

8. All site roads will reclaimed using the following process:

    - All road side safety berms will be removed by dozing them off the road;
    - All road signs will be removed;
    - The road surfaces will be graded to provide positive drainage of precipitation and snowmelt away from the road surface onto the surrounding countryside and to prevent water ponding on the road surfaces;
    - The road surfaces will be scarified to a depth of 4 to 6 inches using a grader mounted scarifying unit or other similar device to loosen up the surface to promote natural re-vegetation over the long-term. There will be a total of 7.68 ha of road and airstrip surface to be graded and scarified at a unit rate of $4,500 per ha (based on RECLAIM model unit rate table – high end);
    - The Doris Creek bridge crossing will be removed and the bridge disposed of in the on-site demolition debris landfill. The bridge footings will be removed and the stream banks graded and armoured at the road crossing to prevent precipitation runoff eroding away the exposed banks at the stream crossing.

An allowance of $10,000 has been included to cover removal of the Doris Lake outflow bridge crossing; and

- All culverts will be removed by excavating them out of the road. The culverts will be disposed of in the on-site demolition debris landfill. The excavation sides will then be pulled back and armoured if necessary with coarse rock to allow free passage of precipitation and snowmelt runoff and to prevent erosion of the former road materials into these drainage paths. An allowance of $1,200 per culvert has been included for this activity. There will be 15 culvert crossings to be removed and regraded by this technique;

9. All mooring bollards will be removed from the rockfill jetty at Roberts Bay. The rockfill jetty will then be partially removed using the following procedure:

    - A backhoe will be used to excavate the surface of the rockfill jetty so that there is a minimum of 1 meter of water cover over the remaining rockfill to ensure no obstruction to small boats approaching the shoreline at this point.
    - The excavated rock fill will be placed into the water alongside the foot of the jetty on both sides to provide a coarse rock substrate along both sides of the removed jetty.
    - At the shore end the rockfill will be removed and graded to ensure that no part of the jetty extends above the low water line.

    It is expected that over time ice and wave action will obliterate any remaining sign of the rockfill jetty (estimate that this will occur with five years post closure). It is estimated that 2,080 cubic meters of rockfill will have to be excavated at a unit cost of $10.00 per cubic meter to decommission the jetty as proposed;

10. The float plane dock in Doris Lake will be decommissioned in a similar manner to the Roberts Bay jetty. An allowance of $3,400 has been included in the estimate;

11. The landfill site used for the disposal of the demolition debris will be closed out by placing rockfill over the compressed debris to create a mounded rockfill cover. An allowance of 10,000 m^3 of rockfill has been allowed for this activity. The unit rate used for the loading, hauling and placement of the rockfill cover is $\$25/m^3$ which assumes that the rockfill material will be non-acid generating waste rock from Quarry 2 previously stockpiled in the landfill quarry (quarry #2) through the mine's operating life. The estimate assumes an average cover thickness of 1 m in depth over a surface area of 10,000 m^2. The final cover will then be graded to shed precipitation and snowmelt from the landfill area. A grading cost of $3,600 was applied based on 16 hours of equipment time at a unit rate of $225/hr;

12. The landfarm will be decommissioned when the mine is closed, or some time period after closure, depending on requirements for its use on closure. Remediated soils that test clean (based on CCME industrial guidelines) will be used for reclamation. Soils that are contaminated and the underlying fine crushed rock from the landfarm will be placed underground at the time of landfarm decommissioning and be encapsulated by

permafrost. The HDPE geomembrane will be cleaned, cut up and disposed of in the non-hazardous landfill. Bedding rockfill (below the geomembrane) will be tested for presence of petroleum hydrocarbons, and if clean, used for reclamation of the adjacent landfill but, if not, placed underground as well. The site will be levelled consistent with other reclamation activities at the mine. An allowance of $37,500 has been included for this activity ($12,500 to remove any remaining contaminated material to the underground mine; $5,000 for removal of the liner; and $20,000 for removal of the underlying rockfill bedding and berms;

13. Following demolition of the buildings and final debris removal, the plant site and camp area, the beach laydown, the mill site tank farm area and the explosives magazine storage area will be given a final grading and scarification to loosen up the top layer of the rockfill to enhance the natural in-growth of vegetation over time and to ensure the drainage of precipitation and snowmelt from these pads onto the surrounding countryside. A unit cost of $4,500/ha has been applied for this light grading and scarification activity over a combined area of 4.08 ha of rockfill pad area. An additional $3,600 has been allowed for the bulldozing removal of the safety berms from the explosives magazine storage area based on 16 hours at a unit rate of $225 per hour;

14. Three quarries will be developed as part of the proposed Doris North Project to provide construction rockfill materials. Quarry 1 and 3 will be closed out at the end of the construction period (end of 2008). Quarry 2 will become the site landfill during operation and will be used to permanently dispose of non-hazardous demolition waste at closure. This quarry will be closed out as part of final reclamation and the cost of reclamation for this quarry site has been included under the landfill component of this closure liability estimate.

    Quarry 1 and 3 will be closed out by stabilizing the final quarry walls by reducing them to a stable angle of repose. While it is planned that this activity will take place during construction as part of the planned quarry development plan, an allowance of $85,000 has been included in this reclamation cost estimate to ensure that slopes are adequately stable at final mine closure. Any remaining rockfill materials will be spread across the floor of the quarry. A $3,500 allowance for revegetation has been included to cover stabilization and seeding of any disturbed ground that is not rock outcrop. Revegetation of the quarries will be limited given the lack of available soils and the remaining rock surfaces;

15. General site infrastructure will be reclaimed as follows:

- Communications equipment will be removed from site. Antennas and satellite dishes will be dismantled and the non-hazardous debris disposed of within the site landfill. Allowance of $5,000 for this work;

- Surface power distribution lines and poles will be removed and disposed of. A total of 5 km of power lines will be removed at a unit cost of $2,500/km;

- An allowance of $7,300 has been included in the reclamation cost estimate for final removal of the temporary accommodation facility, including power generator and fuel system used to house the last demolition employees after the main accommodation camp has been removed; and

16. Surface power distribution lines and poles will be removed and disposed of. A total of 5 km of power lines will be removed at a unit cost of $2,500/km.

7.0 CHEMICALS AND SOIL CONTAMINATION

The following assumptions were made in relation to the cost of removing, disposing and addressing the remaining chemicals, hydrocarbons and contaminated soil at the Doris North Project site:

1. A hazardous materials inventory will be prepared at closure to facilitate planning for shipment off-site to appropriate disposal facilities in the south. A cost allowance of $2,500 has been included to cover preparation of this inventory;

2. All remaining inventory of laboratory chemicals will be packaged, palletized and then shipped from site for return to a supplier, for sale to an alternate user or for disposal at a licensed disposal facility. For this cost estimate it has been assumed that 2 pallets of such chemicals will have to be dealt with at mine closure. A unit rate of $2,500 per pallet was applied based on the RECLAIM model unit cost table (High end) of $2,100 plus an additional $400 due to the remoteness of this site;

3. Being a new mine it has been assumed that there will be no PCB fluids on site, no asbestos insulation materials nor lead based paints that have to be specially handled at closure;

4. Waste oil will be burned on site using a waste oil burner unit throughout the operating life of the mine. It has been assumed that 20,000 litres of waste oil will either be generated during reclamation work or remain at the time of closure. A cost allowance of $12,000 has been included for the destruction of this waste oil through burning on site. A unit rate of $0.60 per litre was applied based on the RECLAIM model unit cost table (high end) of $0.5 inflated to 2005 dollars;

5. Similarly an allowance of $12,000 has been included to burn off remaining diesel fuel. It has been assumed that diesel fuel stocks will be drawn down well before closure, however it has been assumed that 20,000 litres will need to be dealt with at closure by burning on site at a unit rate of $0.60 per litre;

6. An allowance of $150,000 has been included for the packaging and off-site disposal of any remaining reagents or chemicals left at the time of mine closure. These chemicals will be returned to the supplier, sold to another user or disposed of through a licensed disposal facility. The cost of sea-lift removal from the site is covered elsewhere under the “mobilization” cost component;

7. An allowance of $10,000 has been included for the on-site disposal of any remaining explosives. These will be destroyed through burning under controlled conditions following consultation with the appropriate regulatory agencies;

8. An allowance has been included for the land farming or underground disposal of 500 m^3 of Type 1 contaminated soil (light fuel) and 500 m^3 of Type 2 contaminated soil (heavy fuel and oil). The unit rates applied were $120/$m^3$ obtained from the RECLAIM model unit cost table at $110 inflated for 2005 dollars. It has been assumed that there will be no Type 3 contaminated soil (metal) on site at the time of closure. An allowance of $45,000 has been included for conducting a site investigation at closure to determine the extent and amount of any contaminated soil (rockfill) requiring remediation or alternate removal; and

9. A human health and ecological risk assessment will be conducted prior to the final breaching of the North Dam on Tail Lake to demonstrate that returning the lake to an unregulated discharge will not result in any harm to human health, to wildlife or to downstream aquatic life. An allowance of $50,000 contingency has been included in Year 8 for this study.

8.0 MOBILIZATION

The following assumptions have been made in estimating the cost of mobilization/demobilization associated with reclamation of the Doris North Project site:

1. It has been assumed that all equipment and buildings will have no economic salvage value and will be disposed of on-site through the demolition debris landfill site;

2. It has been assumed that the mine's fleet of surface and underground mobile equipment will be on-site and available for use (with maintenance) for carrying out the reclamation activity. In this regard it has been assumed that minimal heavy equipment will have to be mobilized to site to carry out the reclamation activity;

3. It has been assumed that the workforce required to complete reclamation will be transported to site by charter aircraft from either Yellowknife or Cambridge Bay. It has been assumed that over the two 4 month long (June, July, August, September) reclamation activity periods (one in 2011 and the other in 2012) that a total of 32 charter flights will be used to change out crews (16 per year, 4 per month) at a unit rate of $5,000 per flight;

4. It has been assumed over the 8 month long reclamation period (excluding care and maintenance), i.e. 4 months in 2011 and 2012 each, there will be on average 15 people on site requiring accommodation and food. This translates into 3,600 person-days at a camp cost of $55 per person-day. Consequently an allowance of $198,000 has been included for camp costs during this time period;

5. It has been assumed that over the reclamation period it may be necessary to move larger pieces of equipment to and from the site for specialty purposes. An allowance of

$200,000 has been included for four charter flights using a large cargo aircraft such as a Hercules aircraft. A further allowance of $300,000 has been included for two sea-lift visits to the Doris North site to bring in equipment and to remove hazardous materials and other salvageable equipment;

6. An allowance of $200,000 has been included for maintenance of insurance on the site over the two year closure period; and

7. An allowance of $65,000 has been included for incidental operating supplies (other than those included in specific activity estimates) during this 2-year period. Nominally these costs have been allocated as $50,000 for fuel and lubricants, $10,000 for minor tools and repair parts and $5,000 for tires.

9.0 CARE AND MAINTENANCE DURING RECLAMATION

It has been assumed that the site will be carried on a care and maintenance basis for 13 months over the two-year reclamation period, broken down as follows:

- January thru May of 2011 (5 months); and
- October of 2011 through May of 2012 (8 months).

During this time the Doris North Project site will be maintained by a two person crew (i.e., two people on site at all time) who will look after site security and to ensure that no environmental damage occurs as a result of the mine's facilities. For the purposes of this reclamation cost estimate, the following assumptions related to care and maintenance have been applied:

1. An allowance has been included for 26 person months of caretaker labour at a monthly rate of $4,500;

2. An allowance of $5,000 per month in food and supplies has been assumed over this 13 month period; and

3. An allowance for 24 charter flights from Cambridge Bay has been included at a unit cost of $2,500 per flight over this 13-month period for crew rotation and re-supply.

10.0 PROJECT MANAGEMENT

An allowance of $1.0 million has been included for the management of the Doris North Project during the reclamation period. This allowance is to include project management, supervision and administration over a 21 month long period. However most of the site supervision and administrative costs will be incurred over the 8 month long period during which reclamation work is actually carried out. Project management during the remaining 13 months of care and maintenance would be limited to one person. This cost was based on a 15% allowance against the estimated direct reclamation cost items as shown on Table B1. It is intended to cover labour, communications, and travel expenses incurred in managing reclamation of the Doris North Project site.

11.0 ENGINEERING

An allowance of $0.7 million has been included for engineering work required to implement the Doris North mine closure and reclamation plan. This allowance is to cover the detailed reclamation planning and design, preparation of contract tender documents, specifications and to oversee engineering aspects of the reclamation work. This cost was based on a 10% allowance against the estimated direct reclamation cost items as shown in Table B1.

12.0 CONTINGENCY ALLOWANCE

An allowance of $1.0 million has been included for contingencies. This allowance is based on 15% of the estimated direct reclamation cost items as shown in Table B1. It is intended to cover uncertainties and inaccuracies contained in the cost estimates completed for the specified reclamation components caused by the level of engineering design available at this point in the Project life.

13.0 POST-CLOSURE MONITORING AND MAINTENANCE

It will be necessary to monitor the environmental performance of the reclamation work for an extended period before it can be determined that the reclamation objectives have been achieved, specifically that the reclaimed site is not adversely affecting the surrounding environment nor contributing to ongoing environmental degradation. The following assumptions have been made in estimating the cost of this post closure environmental monitoring and maintenance activity:

1. Environmental monitoring will continue for a 10 year period following the cessation of mining (8 years after reclamation has been completed) to provide sufficient time and data collection to enable a conclusion to be made on the effectiveness of the reclamation activities;

2. Post Closure environmental monitoring will consist of four trips to site every year for the first five years for the purpose of collecting and having analyzed a set of water samples; to facilitate a physical inspection of the site to assess erosion, revegetation and to assess seepage from the landfill, drainage from Tail Lake and runoff from the roads and building pads; and to carry out minor maintenance activities such as repairing erosion, creating minor drainage pathways and cleaning of any debris from the Tail Lake outflow. The frequency would then drop to twice per year for the next 2 years and then to once per year for the next three years. It has been assumed for the purpose of this estimate that a total of 10 water samples per trip will be collected. An estimate of $10,400 per trip has been included to pay for the cost of the air charter from Cambridge Bay, sampling labour, analytical costs, air transportation to and from Cambridge Bay by commercial carrier from Yellowknife to Cambridge Bay;

3. An allowance for one geotechnical inspection of the site every year thru 2016 to inspect and report on the performance and continued stability of the Tail Lake impoundment structures and other earthworks. The frequency would drop to every second year through 2020. An estimate of $25,000 per year has been included to pay for the services of a qualified geotechnical engineer, travel expenses and report preparation. It is

assumed that this inspection will take place at the same time as the annual water sampling site visit;

4. An allowance of $50,000 per year has been included for an annual environmental effects monitoring program to be conducted at the site every year through 2016, then dropping to every second year through 2020;

5. An allowance ($25,000 in Year 2, $50,000 in Year 5 and $35,000 in Year 10) has been included for post-closure vegetation success monitoring in Years 2, 5 and 10 following the cessation of mining;

6. An allowance has been included for the KIA to conduct consultation with Inuit beneficiary committees in the nearby communities on the status of reclamation in Years 1, 5 and 10 following the cessation of mining ($15,000 for each event); and

7. A 15% contingency allowance has been applied to the annual post closure monitoring and maintenance cost estimate to cover uncertainties in these estimates;

It has been assumed that no significant environmental nor maintenance issues will arise in the post-closure period. This is based on the relative simplicity of the site following implementation of the closure plan and the low risk associated with the post closure facilities, i.e., no waste rock dumps, removal of all buildings and equipment, a breached tailings dam, etc.

Required post closure maintenance activities assumed are as follows:

1. Periodic erosion repair of removed culverts, stream crossings, breached emergency dump ponds, etc. For the purpose of closure cost estimating an allowance of 80 person-hours per year has been included for this type of activity along with money for travel and equipment. It is expected that this degree of effort will not be required every year, however at some point in time this type of maintenance will be required. It may occur once every five years at which time the allowance would be 400 person-hours, or every second year at which time the allowance would be 160 person-hours.

It has been assumed that post closure maintenance will be required over a 200 year period at an average annual cost of $26,000. A sinking fund approach was used to fund this long-term maintenance requirement. In other words a sinking fund of $0.86 million put aside at the time of completion of reclamation at a real rate of growth of money of 3% will generate an annual income of $26,000 every year to pay for this maintenance requirement. A period of 200 years was chosen as being representative of long-term care. The calculated value of the sinking fund required does not vary much once the period is set at 200 years. For example for a period of 500 years the sinking fund remains $0.86 million. In essence a 200-year period represents close to funding long term care.

TABLE B1: SUMMARY OF ESTIMATED RECLAMATION COST - DORIS NORTH PROJECT

Capital Costs		
COMPONENT TYPE		**TOTAL COST**
UNDERGROUND MINE		$203,500
TAILINGS	Tail Lake	$2,608,493
BUILDINGS AND EQUIPMENT		$2,172,193
CHEMICALS AND SOIL MANAGEMENT		$406,500
MOBILIZATION/DEMOBILIZATION		$1,123,000
CARE AND MAINTENANCE DURING RECLAMATION		$302,000
SUBTOTAL		**$6,815,686**
PROJECT MANAGEMENT	15 % of subtotal	$1,022,353
ENGINEERING	10 % of subtotal	$681,569
CONTINGENCY	15 % of subtotal	$1,022,353
GRAND TOTAL - CAPITAL COSTS		**$9,541,960**
POST-CLOSURE MONITORING COST (NPV at 3%)		$984,231
POST-CLOSURE MONITORING CONTINGENCY 15%		$144,690
Years of post-closure monitoring	10	
POST CLOSURE MONITORING COST OVER 10 YEARS (NPV at 3%)		$1,128,921
POST CLOSURE MAINTENANCE ANNUAL AVERAGE COST		$26,000
Years of post-closure maintenance	200	
Discount Rate for Calc of NPV	3%	
POST CLOSURE MAINTENANCE SINKING FUND		$864,320
GRAND TOTAL CAPITAL AND POST-CLOSURE COSTS		**$11,535,201**

1 **Table B2: Underground Mine** **UG Mine # 1**

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST
A	OBJECTIVE: CONTROL ACCESS					
	Fence	m		#N/A	0	$0
.	Signs	each		#N/A	0	$0
.	Ditch, mat'l A	m3		#N/A	0	$0
.	, mat'l B	m3		#N/A	0	$0
.	Berm	m3		#N/A	0	$0
.	Block Doris North adit - rockfill plug	m3	300		50	$15,000
	Block Doris North adit - Steel Barricade (200 hrs + $30,000)	each	1		45000	$45,000
.	Cap shaft	m3		#N/A	0	$0
.	Cap raise #1 - Ventilation Raise (Reinforced concrete cap)	m3	15	SR	2000	$30,000
.	Cap raise #2 - Ventilation Raise (Reinforced concrete cap)	m3	15	SR	2000	$30,000
.	Cap raise #3 - Ventilation Raise (Reinforced concrete cap)	m3	15	SR	2000	$30,000
.	Backfill shaft	m3		#N/A	0	$0
.	Backfill raise #1	m3		#N/A	0	$0
.	Backfill raise #2	m3		#N/A	0	$0
.	Backfill open stopes	m3		#N/A	0	$0
.	Other - Remove ventilation raise housings and fans (40 hrs ea	each	3	#N/A	4500	$13,500
B	OBJECTIVE: STABILIZE GROUND SURFACE					
.	Backfill mine	m3		#N/A	0	$0
.	Collapse crown pillar	m3		#N/A	0	$0
.	Contour, mat'l A	m3		#N/A	0	$0
.	, mat'l B	m3		#N/A	0	$0
.	Maintain dewatering (see "MONITORING/MAINTENANCE" costing component)			#N/A	0	
.	Other			#N/A	0	$0
C	OBJECTIVE: FLOOD MINE					
.	Plug adits	m3		#N/A	0	$0
.	Plug drillholes to surface	each		#N/A	0	$0
.	Grouting	m3		#N/A	0	$0
.	LIme addition, kg/m3 of water	tonne		#N/A	0	$0
.	Lime, purchase and shipping	tonne		#N/A	0	
D	OBJECTIVE: HAZARDOUS MATERIALS					
.	remove hazardous materials (200 person hours + $5,000)	each	1	LS	20000	$20,000
.	remove/decontam. Equipment (200 person hours + $5000)	each	1	LS	20000	$20,000
.	Other			#N/A	0	$0
E	SPECIALIZED ITEMS					$0
.				#N/A	0	
	Subtotal					$203,500

COMMENTS:

Labour Rate of $75.00 per hour used (includes all benefits)

1 **Table B3: Tailings Impoundment** **Impoundment #** ***1***

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST	
A	OBJECTIVE: CONTROL ACCESS						
.	No required activity					$0	
B	OBJECTIVE: STABILIZE TAIL LAKE IMPOUNDMENT (From SRK)						
.	Breach North Dam in Year 9	cu m	32400		25	$620,798	NPV to 2006$
.	Contractor Mobilization & Demobilization (year 9)					$191,604	NPV to 2006$
.	Engineering (year 9)					$81,240	NPV to 2006$
.	Construction Supervision (year 9)					$74,128	NPV to 2006$
	Contingency for Shoreline Stabilization (Year 9)						
	(allowance for armouring of remaining 60% of 12.9 ha shoreline to elec 29.4 m)						
	Stabilize Shoreline by placement of rock armouring (Contingency Measure)	cu m	22,800		25	$436,858	NPV to 2006$
	Stabilize Shoreline by placement of geotextile (Contingency Measure)	sq m	77,400		8	$474,565	NPV to 2006$
C	OBJECTIVE: FLOOD TAILINGS						
.	No required activity						
E	OBJECTIVE: MONITOR AND RELEASE SUPERNATANT						
.	Pump water during open water season for 9 years after closure						
.	Labour (2 people for 4 months for 7 years)	person-months	56		4500	$252,000	
	(Reclamation site people will be used for the first two years)						
.	Operating Supplies Including Power	Allowance	28	LS/month	5000	$140,000	
.	Camp Cost	Allowance	28	LS/month	5000	$140,000	
	Air Charters (8 trips per year)	trips	56	each	2500	$140,000	
G	OBJECTIVE: REMOVE RECLAIM WATER SYSTEM						
.	Remove Reclaim barge and pumps	LS	1	LS	1500	$1,500	
.	Pipe - remove 5,000 m of reclaim water pipeline	m	5000	PPL	2	$10,000	
.	Other			#N/A	0	$0	
H	OBJECTIVE: REMOVE TAILINGS DISCHARGE						
.	Pipe - Remove 2,500 m of Discharge pipeline	m	2500	PPL	2	$5,000	
.	Pipe - remove 5,400 m of tailings	m	5400	PPL	2	$10,800	
.	Clean out, breach and fill spill catchbasins	each	4	LS	7500	$30,000	
	Subtotal					$2,608,493	

COMMENTS:

Estimated $1.26 million closure cost for the Tail Lake facility is drawn from the SRK Report "Tailings Alternatives Assessment, Doris North Project, Hope Bay, Nunavut Canada" prepared for Miramar Hope Bay Limited dated October 2005. Costs for post closure water quality monitoring of Tail Lake are included under the "Post Closure Monitor" worksheet.

Close out of Tail Lake Tailings Containment Area	NPV at 3%	Reclamation Period		Post Closure							Sum
		2011	2012	2013	2014	2015	2016	2017	2018	2019	
Year - Post Closure		1	2	3	4	5	6	7	8	9	
Breach North Dam	$620,798	$0	$0	$0	$0	$0	$0	$0	$0	$810,000	$810,000
Contractor Mobilization & Demobilization	$191,604	$0	$0	$0	$0	$0	$0	$0	$0	$250,000	$250,000
Engineering	$81,240	$0	$0	$0	$0	$0	$0	$0	$0	$106,000	$106,000
Construction Supervision	$74,128	$0	$0	$0	$0	$0	$0	$0	$0	$96,720	$96,720
Contingency for Shoreline Stabilization	$1,724	$0	$0	$0	$0	$0	$0	$0	$0	$2,250	$2,250
(allowance for armouring of remaining 60% of 12.9 ha shoreline)	$0	$0	$0	$0	$0	$0	$0	$0	$0		$0
Stabilize Shoreline by placement of rock armouring (Cont Measure)	$436,858	$0	$0	$0	$0	$0	$0	$0	$0	$570,000	$570,000
Stabilize Shoreline by placement of geotextile (Contingency Measur	$474,565	$0	$0	$0	$0	$0	$0	$0	$0	$619,200	$619,200
Total	**$1,880,917**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,454,170**	**$2,454,170**

1 **Table B4: Building / Equipment** **Bldg / Equip #: *1***

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST
A	OBJECTIVE: DISPOSE MOBILE EQUIPMENT					
	Decontaminate and ship off-site	each		#N/A	0	$0
.	Decontaminate, dispose on-site (300 person hours + $10000)	LS	1	LS	32500	$32,500
.	Other	each		#N/A	0	$0
B	OBJECTIVE: DISPOSE STATIONARY EQUIPMENT					
.	Decontaminate and ship off-site	person-hours		#N/A		$0
.	Decontaminate, dispose on-site	person-hours	600		75	$45,000
.	Support Equipment & Material	Allowance	1	LS	20000	$20,000
C	OBJECTIVE: DISPOSE MILLING EQUIPMENT					
.	Decontaminate Milling Equipment	person-hours	560		75	$42,000
.	Remove & Dispose of Milling Equipment	person-hours	3600		75	$270,000
.	Support Equipment & Material	Allowance	1	LS	50000	$50,000
D	OBJECTIVE: DISPOSE WATER TREATMENT EQUIPMENT					
.	Decontaminate tanks & plumb.	each		#N/A	0	$0
.	Remove tanks & plumbing	each		#N/A	0	$0
.	Other			#N/A	0	$0
E	OBJECTIVE: DECONTAMINATE BUILDINGS & TANKS					
.	Maintenance plant, chemicals	LS	1	LS	5000	$5,000
.	Camp	LS	1	LS	2000	$2,000
F	OBJECTIVE: MOTHBALL BUILDINGS					
.	Building 1	m2		#N/A	0	$0
.	Building 2	m2		#N/A	0	$0
.	Building 3	m2		#N/A	0	$0
.	Building 4	m2		#N/A	0	$0
.	Building 5	m2		#N/A	0	$0
.	Other	m2		#N/A	0	$0
G	OBJECTIVE: REMOVE BUILDINGS					
.	Mill Building - steel frame	m2	6000	BRS1	60	$360,000
.	Service Complex Workshop - Steel Frame	m2	2000	BRS1	60	$120,000
.	Camp - 38 Skid Mounted Trailer Units	m2	2318	BRS1	60	$139,080
.	Office/Dry - 6 Skid Mounted Trailer Units	m2	366	BRS1	60	$21,960
.	Sewage Treatment Plant - 2 Skid Mounted Units	m2	122	BRS1	60	$7,320
.	Power House	m2	400	BRS1	60	$24,000
	Arctic Corridors	m2	1500	BRW1	20	$30,000
	Mill Reagent - 20 Storage Containers	m2	610	BRW1	30	$18,300
	Explosive Magazine - 20 Storage Containers	m2	610	BRW1	30	$18,300
	Tail Lake Pumphouse	m2	100	BRS1	60	$6,000
	Incinerator Units	LS	2	LS	1000	$2,000
.	Remove boneyard waste	LS	1	LS	15000	$15,000

1 Table B4: Building / Equipment — Bldg / Equip #: *1*

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST
H	OBJECTIVE: BREAK BASEMENT SLABS					
.	Mill Building - steel frame	m2	6000	BRC	6	$36,000
.	Powerhouse	m2	400	BRC	6	$2,400
.	Maintenance Shop	m2	2000	BRC	6	$12,000
.	Remove concrete equipment foundations in mill	Allowance	1	#N/A	50000	$50,000
	Revegetation of plant site area	Ha	3.63		4500	$16,335
I	OBJECTIVE: FUEL STORAGE TANKS					
.	Mill Site Fuel Tanks, decontaminate (5 tanks) (200 person hours/tan	each	5	each	18000	$90,000
.	Mill Site Fuel Tanks , demolish & dispose (300 person hours/tank)	each	5	each	24500	$122,500
.	Other Small Fuel Tanks, decontaminate	each	5	each	2500	$12,500
.	Other Small Fuel Tanks, demolish & dispose	each	5	each	2500	$12,500
	Remove Fuel Piping	LS	1	LS	6000	$6,000
	Remove Fuel Transfer Station & Piping at Roberts Bay	LS	1	LS	6000	$6,000
	Remove containment liner at Mill Site Fuel Tank Farm	LS	1	LS	6000	$6,000
.	Breach & Level Containment at Mill Site Fuel Tank Farm	LS	1	LS	3000	$3,000
J	OBJECTIVE: LANDFILL FOR DEMOLITION WASTE					
.	Place rockfill cover (1 m thick)	m3	10000		25	$250,000
	Grade landfill cover	hours	16		225	$3,600
.	Vegetate	ha		#N/A	0	$0
.	Landfill disposal fee	tonne		#N/A	0	$0
K	OBJECTIVE: GRADE AND CONTOUR					
.	Grade plant site & camp area	ha	2.67	SCFYH	4500	$12,000
	Grade beach laydown area	ha	0.6	SCFYH	4500	$2,700
	Grade Mill Fuel Tank Farm Area	ha	0.36	SCFYH	4500	$1,620
	Grade explosives magazine area	ha	0.45	SCFYH	4500	$2,020
	Doze off Safety Berms at explosives magazine	hours	16	hours	225	$3,600
.	Place soil cover	m3		#N/A	0	$0
.	Rip rap on ditches	m3		#N/A	0	$0
.	Vegetate	ha	4.08	#N/A	4500	$18,360
.	Other			#N/A	0	$0
L	OBJECTIVE: RECLAIM ROADS					
	Remove Doris Outflow Bridge & Armour Banks	LS	1	LS	10000	$10,000
	Remove culverts from roads & armour cuts	each	15		1200	$18,000
.	Scarify and install water breaks on roads & airstrip	ha	7.68	SCFYH	4500	$34,538
.	Vegetate	ha	7.68		4500	$34,560
M	OBJECTIVE: RECLAIM LANDFARM					
	Remove remaining soil to UG Mine	m3	1250		10	$12,500
	Remove HDPE Liner	LS	1		5000	$5,000
	Remove Base Rockfill	m3	2000		10	$20,000
N	OBJECTIVE: PARTIALLY REMOVE ROBERTS BAY JETTY					
	Remove mooring attachments from jetty and regrade approaches	LS	1		2500	$2,500
	Remove rockfill to 1 metre below water level	m3	2080		10	$20,800
O	OBJECTIVE: RECLAIM CONSTRUCTION QUARRIES					
	Stabilization of quarry walls (3 quarries)	LS	1		85000	$85,000
	Revegetation	LS	1		3500	$3,500
P	SPECIALIZED ITEMS					
	Remove Float Plane Dock from Doris Lake	LS	1		3400	$3,400

1 **Table B4: Building / Equipment** **Bldg / Equip #:** ***1***

ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST
Removal of communications equipment	LS	1		5000	$5,000
. Remove Power Lines	km	5	POWR	2500	$12,500
Removal of Final Temporary Accommodation Facility	LS	1		7300	$7,300
Subtotal					$2,172,193

COMMENTS:

Labour Rate of $75 per hour inclusive of all benefits

1 TABLE B5: Chemicals and Soil Contamination: 1

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST

Note: The procedures, equipment and packaging for clean up and removal of chemicals or contaminated soils are highly dependent on the nature of the chemicals and their existing state of containment. Government guidelines should be consulted on an individual chemical basis. Any estimate made here should be considered very rough unless specific evaluations have been conducted.

.

	ACTIVITY/MATERIAL	UNITS	QUANTITY	COST CODE	UNIT COST	COST
A	LABORATORY CHEMICALS					
.	Allowance for removal of lab chemicals	pallet	2	LCRH	2500	$5,000
B	PCB, hauling	litre		#N/A	0	$0
.	PCB, disposal	litre		#N/A	0	$0
C	FUEL					
.	Allowance for burning of remaining fuel on site	litre	20000	OBH	0.6	$12,000
.	Type 2	kg		#N/A	0	$0
.	Type 3	kg		#N/A	0	
D	WASTE OIL					
.	Oils/lubricants - burn on-site (allowance)	litre	20000	OBH	0.6	$12,000
.	Oils/lubricants - ship off-site	litre		#N/A	0	$0
.	Oils/lubricants - disposal fee	litre		#N/A	0	$0
E	PROCESS OR TREATMENT CHEMICALS					
.	Allowance for removal of remaining chemicals	LS	1	LS	150000	$150,000
.	Type 2	kg		#N/A	0	$0
.	Type 3	kg		#N/A	0	$0
.	Type 4	kg		#N/A	0	$0
F	EXPLOSIVES					
.	Allowance for removal of remaining explosives	kg	5000	ER	2	$10,000
G	CONTAMINATED SOILS					
.	Type 1, light fuel (allowance)	m3	500	CSR	120	$60,000
.	Type 2, heavy fuel and oil (allowance)	m3	500	CSR	120	$60,000
.	Type 3, metals	m3		#N/A	0	$0
H	Haz. Mat. testing & assessment					
.	Technician and analyses	each	1	#N/A	5000	$5,000
.	Drilling	each	1	#N/A	25000	$25,000
.	Audit	LS	1	#N/A	15000	$15,000
.	OTHER					
	Hazardous Material Inventory	LS	1	#N/A	2500	$2,500
.	Human Health and Ecological Risk Assessment St	LS	1	#N/A	50000	$50,000
	Subtotal					$406,500

COMMENTS:

1 **TABLE B6: Mobilization** **Mob # *1***

	ACTIVITY/MATERIAL		UNITS	QUANTITY	COST CODE	UNIT COST	COST
A	MOBILIZE HEAVY EQUIPMENT						
	Allowance to mobilize equipment to and from si		Lump Sum	2	LS	100000	$200,000
B	MOBILIZE CAMP				#N/A	0	$0
.							
C	MOBILIZE WORKERS						
.	Allowance for air charters		trips	32	#N/A	5000	$160,000
D	MOBILIZE MISC. SUPPLIES						
.	Fuel & lubricants		allowance	1	#N/A	50000	$10,000
.	Minor tools and equipment		allowance	1	#N/A	10000	$50,000
.	Truck tires		allowance	1	#N/A	5000	$5,000
E	CAMP COST TO HOUSE WORKERS		person-day	3600	#N/A	55	$198,000
.							
.	BARGING COSTS						
.	Sea-Lift Trips to site		each	2	#N/A	150000	$300,000
.							
F	BONDING	lump sum			#N/A	0	$0
.							
G	TAXES	lump sum			#N/A	0	$0
.							
H	INSURANCE	lump sum	year	2	#N/A	100000	$200,000
.							
	Subtotal						$1,123,000

COMMENTS:

1 TABLE B7: CARE AND MAINTENANCE DURING RECLAMATION Mon / Mtce # 1

	ACTIVITY/MATERIAL	UNITS	QUANTITY in 2006/2007	QUANTITY in 2007/2008	COST CODE	UNIT COST	COST
A	CARE AND MAINTENANCE OF SITE						
	Care and Maintenance Crew (crew of 2) - labour	person-months	10	16		$4,500	$117,000
	Care and Maintenance Crew (crew of 2) - supplies	per month	5	8		$5,000	$65,000
	Charter Flights	trips	24	24		$2,500	$120,000
	Subtotal						$302,000

COMMENTS:

1 **TABLE B8: POST-CLOSURE MONITORING** **Mon / Mtce # *1***

Post Closure Monitoring & Maintenance	NPV at 3%	Reclamation Period		Post Closure								Sum
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
# of Site Visits		4	4	4	4	4	2	2	1	1	1	
Monitoring Labour	$66,321	$20,000	$20,000	$8,000	$8,000	$8,000	$2,400	$2,400	$1,200	$1,200	$1,200	$72,400
Monitoring Supplies & Equipment	$4,545	$760	$760	$760	$760	$760	$380	$380	$190	$190	$190	$5,130
Transportation to and from Site	$155,479	$26,000	$26,000	$26,000	$26,000	$26,000	$13,000	$13,000	$6,500	$6,500	$6,500	$175,500
Analytical Costs	$45,448	$7,600	$7,600	$7,600	$7,600	$7,600	$3,800	$3,800	$1,900	$1,900	$1,900	$51,300
Transportation of Samples to Lab	$5,980	$1,000	$1,000	$1,000	$1,000	$1,000	$500	$500	$250	$250	$250	$6,750
Aquatic Effects Monitoring Program	$350,985	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000		$50,000		$50,000	$400,000
Annual Geotechnical Inspection	$175,492	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000		$25,000		$25,000	$200,000
Post Closure Vegetation Monitoring	$103,432		$25,000			$50,000					$35,000	$110,000
Post Closure Consultation with Inuit Beneficiary Com.	$42,429	$15,000				$15,000					$15,000	$45,000
Annual Reporting	$34,121	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$40,000
Sub-Total	**$984,231**	**$149,360**	**$159,360**	**$122,360**	**$122,360**	**$187,360**	**$99,080**	**$24,080**	**$89,040**	**$14,040**	**$139,040**	**$1,106,080**
Contingency Allowance (15%)	$144,690	$22,404	$23,904	$18,354	$18,354	$28,104	$14,862	$3,612	$13,356	$2,106	$20,856	$165,912
Total	**$1,128,921**	**$171,764**	**$183,264**	**$140,714**	**$140,714**	**$215,464**	**$113,942**	**$27,692**	**$102,396**	**$16,146**	**$159,896**	**$1,271,992**

Analytical Costs	Cost per Sample#
Assay Set Ref #1	$25
Assay Set Ref #2	$158
Assay Set Ref #3	$169
Assay Set Ref #4	$190
Assay Set Ref #5	$113
Assay Set Ref #6	$82

1 TABLE B9: POST-CLOSURE MAINTENANCE

	ACTIVITY/MATERIAL	UNITS	QUANTITY per Year	COST CODE	UNIT COST	COST
A	POST CLOSURE MAINTENANCE					
	Erosion Repair - labour	person-hours/year	80	(allowance)	$75	$6,000
	Erosion Repair - Travel & Equipment	LS	1	LS	$20,000	$20,000
	Subtotal					$26,000
	Discount rate for calculation of net present value of long term mtce cost, %		3%			
	Number of years of post-closure activity		200	years		
	Present Value of payment stream				$864,320	

COMMENTS:
Allowance for Post-Closure Maintenance to take place over a 200 year period following the cessation of reclamation (i.e., post 2011).

TABLE B10: Unit Cost Table

ITEM	Detail	COST CODE	UNITS	LOW $	HIGH $	SPECIFIED $	COMMENTS
1 **excavate Rock, Bulk**							
	drill, blast, load short haul (<500m) Dump	RB1	m3	8.5	12.75	#N/A	quarry operations for bulk fill
	RB1 + long haul, up to 1500 m	RB2	m3	9	13.25	#N/A	
	RB1 + spread and compact	RB3	m3	9	13.25	#N/A	
	RB1 + long haul + spread and compact	RB4	m3	9.5	13.75	#N/A	
	RB1 + Specified activity	RBS	m3	#N/A	#N/A	#N/A	
2 **excavate Rock, Controlled**							
	drill, blast, load short haul (<500m) Dump	RC1	m3	20	30	#N/A	spillway excavation
	RC1 + long haul, up to 1500 m	RC2	m3	9.5	13.75	#N/A	
	RC1 + spread and compact	RC3	m3	9	13.25	#N/A	
	RC1 + long haul + spread and compact	RC4	m3	10.1	14.3	#N/A	
	RC1 + Specified activity	RCS	m3	#N/A	#N/A	132	$132/M3-drift excavation
3 **excavate Soil, Bulk**							
	excavate, load short haul (<500m) dump	SB1	m3	2.91	4.4	#N/A	LOW cost: excavation of loose soil, high volume
	SB1 + long haul, up to 1500 m	SB2	m3	3.61	5.43	#N/A	LOW cost: excavation of loose soil, 1.5 km haul, high volume
	SB1 + spread and compact	SB3	m3	3.34	4.83	#N/A	
	SB1 + long haul + spread and compact	SB4	m3	4.05	8.14	#N/A	LOW cost: excavation of loose soil, 1.5 km haul, high volume, const. of simple soil cover
	SB1 + Specified activity	SBS	m3	2.1	5.8	9.95	LOW cost: rehandle waste rock dump into pit, >500,000 m3, 2 km haul SPECIFIED cost: rehandle waste rock, haul 3 km, place & compact on dam
	Soil, tailings	SBT	m3	2.75	6.5		LOW cost: doze tailings, HIGH cost: excavate & short haul
4 **excavate Soil, Controlled**							
	excavate, load short haul (<500 m), dump	SC1	m3	5.1	6.95	#N/A	
	SC1 + long haul, up to 1500 m	SC2	m3	6.32	8.76	#N/A	
	SC1 + spread and compact	SC3	m3	5.1	10.6	#N/A	HIGH cost: for simple soil covers
	SC1 + long haul + spread and compact	SC4	m3	5.73	17.3	#N/A	HIGH cost: for complex covers & dam construction, spillway repair, LOW volume
	SC1 + Specified activity	SCS	m3	#N/A	#N/A	14.3	SPECIFIED cost: backfill adit with waste rock
Geo-synthetics							
	geotextile, filter cloth	GST	M2	0.9	1.8	#N/A	FOB Edmonton, add shipping & installation
	geogrid	GSG	M2	4.3		#N/A	
	liner, HDPE	GSHDPE	M2	5.35		#N/A	
	liner, PVC	GSPVC	M2			#N/A	
	geosynthetic installation	GSI	m2	0.75	1	#N/A	
	bentonite soil ammendment	GSBA	tonne	230	260	#N/A	FOB Edmonton, add shipping & mixing

TABLE B10: Unit Cost Table

ITEM	Detail	COST CODE	UNITS	LOW $	HIGH $	SPECIFIED $	
Shaft, Raise & Portal Closures							
	Shaft & Raises	SR	m2	480	1590	#N/A	LOW cost: pre-cast concrete slabs, little site prep. HIGH cost: for hand construction, remote site
	Portals	POR	m3		185	55	HIGH cost: for excavate & backfill collapsed portal SPECIFIED cost: concrete for pressure plug
5 **Concrete work**							
	Small pour, no forms	CS	m3	270	540	#N/A	
	Large pour, no forms	CL	m3	212	318	#N/A	
	Small pour, Formed	CSF	m3	318	1590	#N/A	
	Large pour, Formed	CLF	m3	265	370	#N/A	
6 **Vegetation**							
	Hydroseed, Flat	VHF	ha	1450	4500	#N/A	
	Hydroseed, Sloped	VHS	ha	1680	5050	#N/A	
	veg. Blanket/erosion mat	VB	ha	10000	12000	#N/A	
	Tree planting	VT	ha	10000	12000	#N/A	
	Wetland species	VW	ha	50000	75000	#N/A	
7 **Pumps**							
	Small, <	PS	each	3000	6000	#N/A	
	Large, >	PL	each	5000	9000	#N/A	
8 **PiPes**							
	Small, < 6 inch diameter	PPS	m	0.5	5	#N/A	LOW cost: pipe removal, HIGH cost: supply new pipe SPECIFIED: small, heat traced & insulated pipe
	Large, > 6 inch diameter	PPL	m	1	200	#N/A	LOW cost: pipe removal, HIGH cost: supply new 16in. Pipe
							add shipping & installation
9 **pump sand BackFill**		BF	m3	5	15	#N/A	
10 **Fence**		F	m	10	150	#N/A	
11 **Signs**		S	each	10	30	#N/A	
12 **rock, Drill and Blast only**		DB	m3	10	20	#N/A	
(flatten slope, collapse drift)							

TABLE B10: Unit Cost Table

ITEM	Detail	COST CODE	UNITS	LOW $	HIGH $	SPECIFIED $	
13 **excavate Rip Rap**							
	drill, blast, load short haul (<500 m) dump and spread	RR1	m3	9.95	14.85	#N/A	
	RR1 + long haul	RR2	m3	10.1	15.4	#N/A	HIGH cost: quarry & place rip rap in channel
	excavate rock from waste dump, short haul, spread	RR3	m3	3.82	5.25	#N/A	LOW cost: removal of 18 in minus from dump, long haul and spread HIGH cost: removal of coarse rock from dump, long haul, armour spillway
	RR3 + long haul	RR4	m3	4.25	5.68	#N/A	
	specified rip rap source	RR5	m3	#N/A	#N/A	#N/A	
14 **Import LimeStone**		ILS	tonne	8	12	#N/A	
15 **Import LiMe**		ILM	tonne	150	450	#N/A	LOW cost: bulk shipping, high volume, FOB Vancouver/Edmonton HIGH cost: bags delivered to central Yukon, small volume
16 **Grouting**		G	m3	180	218	#N/A	HIGH cost: cement, FOB Yellowknife
17 **Dozing**							
	doze Rock piles	DR	m3	0.77	1.77	#N/A	LOW cost: doze crest off dump
	doze overburden/Soil piles	DS	m3	0.71	2.83	#N/A	HIGH cost: push up to 300 m
18							
						#N/A	
						#N/A	
19							
						#N/A	
						#N/A	
20							
			each	0	0	#N/A	
			each			#N/A	
21 **Buildings - Decontaminate**							
	Chemicals	BDC	m3	#N/A	#N/A	#N/A	
	Asbestos	BDA	m2	19	38	#N/A	LOW cost: removal of asbestos siding & flooring HIGH cost: removal of insulated pipes, friable asbestos
22 **Buildings - Remove**							
	areas are per floor on 3 m average height						LOW cost: removal and on-site disposal - small wooden structures
	Wood - teardown	BRW1	m2	19.5	30	#N/A	
	Wood - burn	BRW2	m2	5	10	#N/A	
	Masonry	BRM	m2	21.5	30	#N/A	
	Concrete	BRC	m	30	45	6	LOW cost: removal of building perimeter walls, HIGH cost: per m3 for bulk concrete SPECIFIED cost: $/m2 to break floor slab
	Steel - teardown	BRS1	m2	32	48	240	SPECIFIED cost: demolition shear $/hour operating
	Steel - salvage	BRS2	m2	50	75	#N/A	
23 **Power & Pipe Lines**							

TABLE B10: Unit Cost Table

ITEM	Detail	COST CODE	UNITS	LOW $	HIGH $	SPECIFIED $	
	Power lines, remove	POWR	each	1900	4200	#N/A	
						#N/A	
24	**Laboratory Chemicals**						
	Remove from site	LCR	pallet	1590	2100	#N/A	
	Dispose on site	LCD	each	#N/A	#N/A	#N/A	
25	**PCB - Remove from site**	PCBR	litre	30	35	#N/A	LOW cost: shipping, handling & disposal from Yellowknife
26	**Fuel**						
	Remove from site	FR	kg	0	0.93	#N/A	
	Burn on site	FB	kg	#N/A	#N/A	#N/A	
27	**Oil**						
	Remove from site	OR	litre	0.3	0.93	#N/A	
	Burn on site	OB	litre	0.3	0.5	#N/A	
28	**Process Chemicals**						
	Remove from site	PCR	kg	0.3	1.87	#N/A	
	Dispose on site	PCD	kg	#N/A	#N/A	#N/A	
29	**Explosives**						
	Remove from site	ER	kg	0	2	#N/A	
	Dispose on site	ED	kg	#N/A	#N/A	#N/A	
30	**Contaminated Soils**						
	Remediate on site	CSR	m3	35	110	#N/A	LOW cost: bio-remediate on-site. HIGH cost: ship off-site to landfil as haz. waste
	consolidate & cover	Use cost code items 1 - 4					
	cover in place	Use cost code items 1 - 4					
31	**Mobilize Heavy Equipment**						
	Road access	MHER	$/km	2.55	7.65	1.86	SPECIFIED cost: $/tonne/km in cargo plane
	Air access	MHEA	each	#N/A	#N/A	1250	SPECIFIED cost: helicopter cost, $/hr of operation
32	**Mobilize Camp**						
	<20 persons Road access	MC<R	each	#N/A	#N/A	#N/A	
	<20 persons Air access	MC<A	each	#N/A	#N/A	#N/A	
33	**Mobilize Workers**						
	mobilize	MM<	person	175	900	#N/A	LOW cost: road access. HIGH cost: transport by Twin Otter aircraft
	>20 persons	MM>	person	900	1200	#N/A	
34	**ACCoModation**	ACCM	month	1200	1800	#N/A	LOW cost, accom in existing camp, per man, HIGH cost: - supply new camp
35	**Mobilize Misc. Supplies**	MMS	each	#N/A	#N/A	#N/A	LOW cost: winter road - limited use, LOW snowfall
36	**Winter Road**	WR	km	1200	2400	#N/A	
37	**Visual site Inspection**	VI	each	3200	6400	10000	
38	**Survey site Inspection**	SI	each	#N/A	#N/A	#N/A	

TABLE B10: Unit Cost Table

ITEM	Detail	COST CODE	UNITS	LOW $	HIGH $	SPECIFIED $
39	**Water Sampling**	WS	each	4775	8000	#N/A
40	**site inspection RePorT**	RPT	each	#N/A	10000	#N/A
41	**Security Guard**	SG	pers/mon	5000	7000	#N/A
42	**Maintain Pumping**	MP	month	3000	#N/A	#N/A
43	**Clear SpillWay**	CSW	each	1700	4800	#N/A
44	**Build Treatment Plant**					
	Small (< 1000 m3/d)	BTPS	lump sun	1E+06	2E+06	#N/A
	Large (> 1000 m3/d)	BTPL	lump sun	2E+06	3.5E+6	#N/A
45	**Operate Treatment Plant**	OTP	m3	0.25	1.5	#N/A
46	**SCariFY road and install water breaks**	SCFY	km	3215	4500	#N/A

water treatment chemicals			
ferric sulphate	ferric	kg	0.61
ferrous sulphate	ferrous	kg	0.4
lime	lime	kg	0.27
hydrogen peroxide, 50%	hperox	kg	1.3
Sodium Metabisulfate	Nametab	kg	0.9
Caustic soda, 50%	caustic	kg	0.56
Sulfuric acid, 93%	sulfuric	kg	0.24
flocculant	flocc	kg	4.9
copper sulphate	copper	kg	
typical shipping, to Whitehorse or Yellowknife		kg	0.065

APPENDIX C

Landfarming of Hydrocarbon Contaminated Soil Experience in Arctic Climates – Selected Literature

CHAPTER 8

Bioremediation of Diesel Contaminated Soil and Tundra in an Arctic Environment

Michael R. Piotrowski, and **Robert G. Aaserude,** Woodward-Clyde Consultants, San Diego, California
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INTRODUCTION

A United States Air Force station in arctic Alaska operated from 1950 through 1982, when the majority of operations at the facility were curtailed. Several hazardous materials had been used on the station during operation, and spills and leaks of the materials had occurred. Since 1985, site investigations have been conducted to assess residual contamination in areas of the site as part of the U.S. Air Force's Installation Restoration Program (IRP).

As a result of these investigations, several areas on the site have been documented as being contaminated with hazardous substances.[1] One such area is a hillside composed of soil fill and native tundra that became contaminated with diesel fuel as a result of the rupture of a distribution pipeline in 1984. The released diesel fuel affected an area of the tundra hillside covering approximately two acres. Recovery efforts were implemented and resulted in the collection of several accumulations of diesel fuel. However, a portion of the fuel entered the tundra and killed the vegetation. As a result, the two-acre area impacted by the spill became largely denuded.

Although some natural recovery of the vegetation has been observed on the hillside since 1984, most of the two-acre region was apparently still impacted by the spilled diesel fuel in 1989. Diesel fuel contamination was also apparent in the soil fill area adjacent to the location of the pipeline rupture. Therefore, the U.S. Air Force authorized Woodward-Clyde Consultants (Woodward-Clyde) to assess the feasibilities of remedial options for treatment of the hillside and to develop a remediation plan.

During the assessment of remedial options, bioremediation was identified as a feasible approach for treatment of the diesel contaminated soil and tundra. However, there were concerns regarding the effectiveness of that treatment technology under relatively harsh arctic conditions. Furthermore, it was uncertain whether the approach could produce appreciable reductions in diesel fuel concentrations in the affected soil and tundra during the relatively short arctic summers. Finally, because the contaminated tundra is underlain by permafrost, active bioremediation (tilling) of contaminated tundra would likely produce damage to the permafrost. As such, a passive (nontilling) bioremediation approach would be required for the hillside, and there were concerns over the effectiveness of that bioremediation approach.

To address these concerns and uncertainties, Woodward-Clyde developed remediation plans for the contaminated soil and tundra,[2] and these plans were implemented onsite at pilot-scale levels in August 1989. The results of the bioremediation pilot studies that were conducted during the summers of 1989 and 1990 are reported herein.

SITE SETTING

The following paragraphs summarize the pertinent features of the site's physiography, geology and hydrogeology, climate, and tundra ecology. A more complete description of these site aspects can be found in Reference #3.

Physiography

The U.S. Air Force station is located north of the Arctic Circle in northwest Alaska (Figure 8.1). The site is approximately 610 miles northwest of Anchorage and approximately 450 miles west-northwest of Fairbanks. The station is situated on a hill (highest elevation roughly 155 ft above local sea level) approximately four miles south of a small town (population: about 3,600) and roughly 1,500 feet from the coastline of a sound.

Geology and Hydrogeology

The station is located on the remnants of an eroded glacial moraine consisting of mixed clays, silts, sands, and gravels. The regional geology consists of coastal deposits of interbedded marine and terrestrial sediments. Permafrost occurs throughout the region, typically several feet below the tundra surface, and the permafrost layer has been reported to be over 200 ft in thickness.[4] Shallow groundwater forms during the warmer seasons in the silty, organic-rich, tundra layers overlying the permafrost. The groundwater beneath the permafrost is reported to be brackish.[4]

Climate

The climate of the region is arctic with a maritime influence.[5] The average annual daily high and low air temperatures are -2.8°C (27°F) and -10°C (14°F), respectively. However, temperatures in excess of 21°C (70°F) and

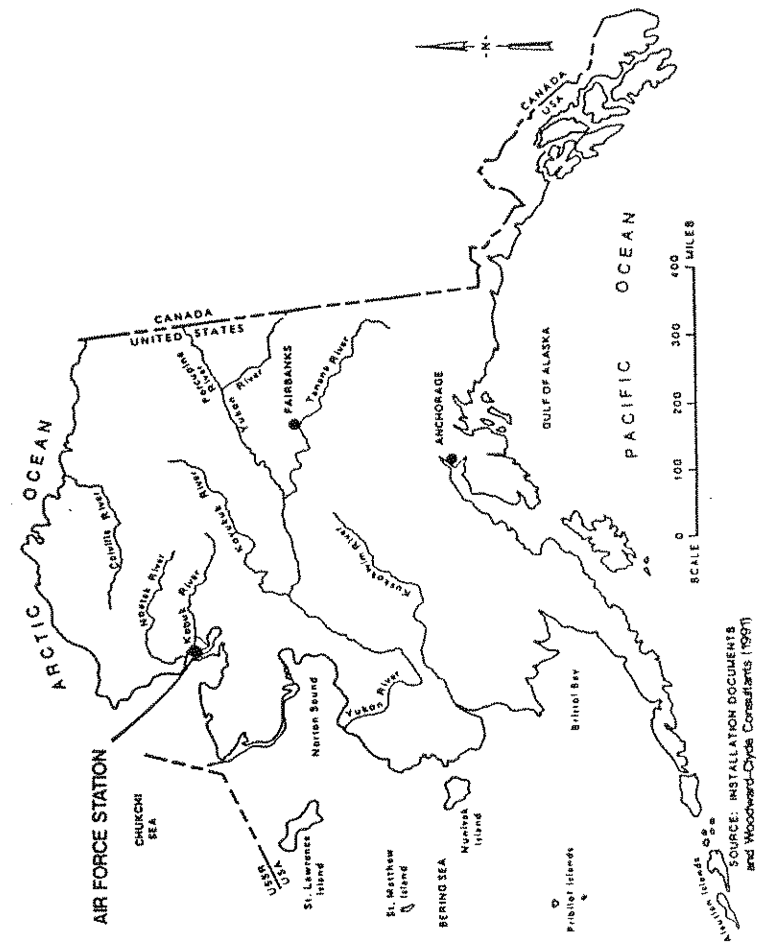


Figure 8.1. Regional location of U.S. Air Force station.

below −23°C (−10°F) have been recorded on individual days. Freezing temperatures typically occur from late September through early June. The mean annual rainfall is 18 cm (7.1 inches) and most of the rainfall occurs in July and August. Snowfall averages 109 cm (43 inches) per year and takes place fairly uniformly over the fall, winter, and early spring.

Tundra Ecology

The tundra is an environmentally sensitive area. It is generally treeless and covered with approximately 1 ft of matted vegetation containing a variety of individual plant species. Vegetative growth and microbial decay take place during the abbreviated spring, summer, and fall seasons. During warmer periods, marshes, small bogs, and other water features may form in many areas of the tundra surface. Persistent water features typically freeze solid during colder periods.

The tundra vegetation is not resilient and can be severely impacted by surface activities. For example, traffic, construction, or excavation can destroy the vegetative cover, expose the underlying soil to erosion and the permafrost to thawing, and may result in the creation of a pock-marked boggy surface. In some cases, long-term damage to the tundra surface can be inadvertently created by careless surface activities.

The microbial ecology of the tundra is essentially confined to the warmer (i.e., unfrozen) seasons. Microorganisms become active with the onset of spring and the thawing of the tundra surface, only to become senescent with the return of freezing temperatures in the fall. An important characteristic of the physiology of arctic microorganisms involves the relationship between changing ambient temperatures and their activity rates.

For most biological systems (including many microorganisms), within a defined temperature range, an increase in temperature of 10°C (18°F) usually results in an increase in the rate of biological activity of between two- and threefold. This temperature/activity relationship has been termed the Q_{10} effect, and most biological systems exhibit Q_{10} values of 2 to 3.[6]

Arctic microorganisms, however, typically exhibit Q_{10} values of approximately 4.[6] That is, for each 10°C increase in temperature with the onset of spring and summer in the arctic, the activity rates of the microorganisms will typically increase approximately fourfold. This capability results in elevated microbial activities during the abbreviated summers characteristic of the arctic. However, the opposite effect is also observed: within a defined temperature range, for every 10°C decrease in temperature, the activity rates of arctic microbes will decline by approximately fourfold. As will be seen, this phenomenon had an influence on the performances of the bioremediation programs implemented at the site.

Bioremediation Approaches and Methods

Two bioremediation approaches were identified as being feasible for treatment of contaminated soil fill and tundra at the site. The approaches, methods of treatment, and sampling plans for the contaminated materials are described below.

Contaminated Soil Fill

The contaminated soil fill was confined to the region immediately downgradient from the location of the diesel fuel spill. The soil exhibited indications that it was heavily contaminated. Because the fill soil could be excavated and quickly replaced with clean fill without appreciably damaging the underlying permafrost, it was decided that this soil could be most rapidly treated by excavating it and biologically treating it in a lined land treatment unit (LTU). With respect to the form of biological treatment to be used for the contaminated fill, the following considerations were taken into account.

Treatment Considerations

The diesel fuel had been present in the fill material for over five years. Each year after the spill, the contaminated soil had been exposed to a leaching action produced by the annual summer percolation of water through the contaminated region. The leaching action would tend to remove those organic constituents of diesel fuel that are more soluble in water, leaving behind a more insoluble fraction associated with the soil. Because microorganisms generally degrade organic compounds in the aqueous phase, it was reasoned that application of a nontoxic, biodegradable surfactant to the residual contamination in the affected soil may render the residues more accessible to the indigenous microorganisms.

A second issue considered in developing the bioremediation plan for the contaminated soil fill was the need to apply nutrients to the soil. There were no site-specific soil nutrient data available in 1989 upon which to assess potential nutrient requirements for the contaminated soil fill. Therefore, as an initial step in stimulating biodegradation rates of the indigenous microorganisms, we decided to periodically apply a dilute solution of micronutrients (i.e., trace elements and vitamins) to the contaminated soil.

1989 Treatment Methods and Sampling Plan

An onsite, mostly paved area that was formerly occupied by a building was selected as the site of the LTU (Figure 8.2). The concrete and fill base of the area was lined with plastic sheeting (6-mil thick). The excavated soil fill was then spread over the lined pad to a uniform thickness of approximately

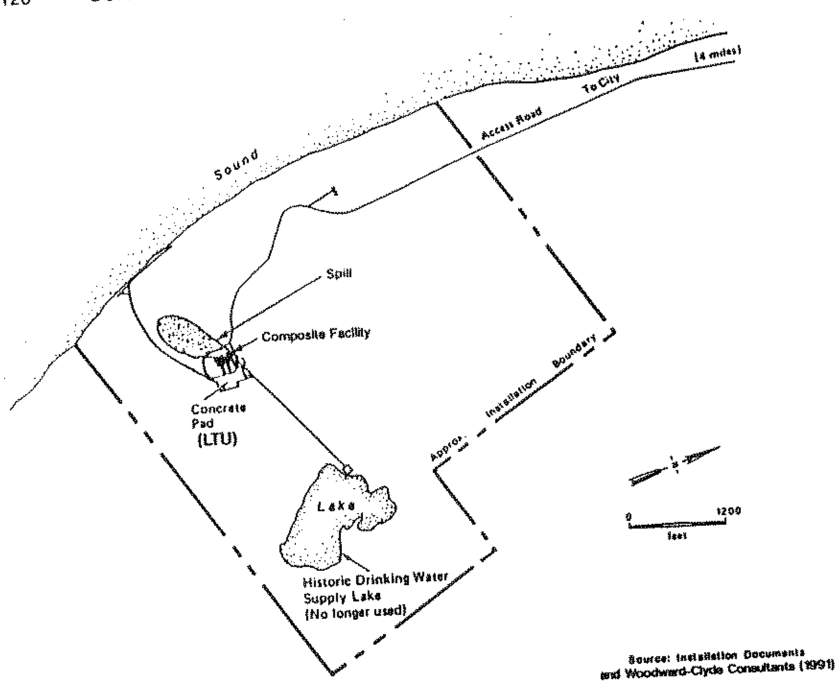


Figure 8.2. U.S. Air Force station site plan and locations of diesel fuel spill and concrete pad.

46 cm (18 inches) in early August 1989. A berm of clean fill material approximately one meter (3 ft) in height was then placed around the perimeter of the LTU to minimize precipitation runoff.

The soil in the LTU was then sampled on August 8, 1989 by collecting nine composite samples and one duplicate sample from randomly selected locations in the LTU. Each composite sample consisted of multiple soil aliquots collected from throughout the soil column in several locations. The samples were analyzed for total petroleum hydrocarbon (TPH) concentrations using method SW3550/418.1 and for soil moisture content using American Society for Testing and Materials (ASTM) method D2216.

All TPH and moisture analyses were performed by ENSECO-Rocky Mountain Analytical Laboratories in Arvada, CO. Strict quality assurance/quality control (QA/QC) procedures (involving collections and analyses of duplicate control samples, single control samples, and method blanks) were followed throughout the entire two-year bioremediation study. Duplicate samples were collected and analyzed for approximately every 10 samples collected, and standard chain-of-custody protocols were followed.

Two composite samples and one duplicate sample were also collected on

August 8 and analyzed for microbial content using four methods: total microbial densities using the acridine orange direct count method,[7] viable microbial densities using the standard plate count procedure (e.g., Meynell and Meynell[8]), densities of fluorescent pseudomonads (method by B.B. Hemmingsen, San Diego State University's Applied Microbiology Laboratory, San Diego, CA), and the densities of phenanthrene-degrading microorganisms using a method developed by Bogardt and Hemmingsen.[9] These analyses were performed to establish initial microbial densities (dry weight basis) in the soil, and the samples were analyzed in San Diego State University's Applied Microbiology Laboratory, San Diego, CA.

After sampling, a dilute solution of a nontoxic, biodegradable surfactant (Toxigon 2000, currently distributed as TI-323 by Technologies International, Scottsdale, AZ) was evenly applied to the soil in the LTU using a gas-powered pump, hosing, and a water truck. The dilution used was 1,250 gal of Toxigon 2000 in 5,000 gal of lake water. The original formulation for the surfactant was listed on the U.S. Environmental Protection Agency's National Contingency Plan (NCP) Product Schedule for use as a dispersant in oil spill situations.

Then, approximately 12 gal of a dilute solution of micronutrients (Medina Soil Activator, Medina Agricultural Products, Inc., Hondo, TX) was evenly applied to the surface of the contaminated soil using a backpack spray unit. The soil activator was mixed with lake water at a ratio of one part activator to four parts water.

A bulldozer was then used to mix the soil in the LTU. The mixing action served to distribute the surfactant and micronutrient solutions and deliver oxygen throughout the contaminated soil mass.

At weekly intervals for six weeks (August to September 1989), the contaminated soil was mixed by the bulldozer to deliver oxygen throughout the soil and promote soil drying. After two and four weeks of treatment and prior to mixing, the micronutrient solution was reapplied as described above. After approximately four and six weeks of soil treatment (September 12 and 26, respectively), eight composite soil samples and one duplicate sample were collected on each occasion for TPH and moisture analyses as described above. Two composite samples and one duplicate sample were collected for microbial content analysis after six weeks of treatment. Treatment was suspended in late September, and the soil in the LTU was covered with a layer of plastic sheeting (6-mil in thickness) for the winter.

1990 Treatment Methods and Sampling Plan

In late July 1990, the plastic sheeting was removed from the LTU and the soil was sampled to establish the initial TPH concentrations prior to treatment in 1990. Nine composite samples and one duplicate sample were collected on July 26, 1990 and analyzed for TPH using method SW3550/418.1 and soil moisture content using ASTM method D2216.

Approximately 20 gal of the dilute micronutrient solution (five parts lake water to one-part Medina Soil Activator) were evenly applied to the soil in the LTU using the backpack sprayer. The soil was then mixed with the bulldozer, and thereafter on a weekly basis, for nine weeks. At the end of the nine-week period (September 24, 1990), nine composite samples and a duplicate sample were collected and analyzed for TPH concentration and moisture content using the methods presented previously. No samples were collected for microbial analysis in 1990.

Contaminated Native Tundra

As discussed previously, the contaminated native tundra was confined to a two-acre region downslope from the location of the pipeline leak. Although most of the diesel fuel flowed in three natural channels that ran down the face of the hillside, a portion of the fuel spread over and penetrated the tundra surfaces outside the channels and destroyed the vegetation (Figure 8.3). Because an active bioremediation program (i.e., involving tilling) was likely to inflict damage to the underlying permafrost, an alternative, passive approach was needed to stimulate in situ bioremediation.

Treatment and Sampling Considerations

Based on the considerations presented in the discussion of the bioremediation approach for treatment of the contaminated soil fill, applications of dilute surfactant and micronutrient solutions were deemed necessary to initiate in situ bioremediation. However, no tilling would be conducted. It was also reasoned that the surfactant application would be most useful if it was applied primarily along the three natural channels through which the diesel fuel primarily flowed. Finally, it was concluded that the periodic applications of the micronutrient solution would be most effective in assisting the restoration of the tundra vegetation if the micronutrients were applied to both the channels and the adjacent denuded tundra areas.

With respect to sampling strategy, it was recognized that periodic sampling of the hillside over which the diesel fuel unevenly spread would tend to produce data sets containing large variabilities in tundra TPH concentrations. Randomly collected, replicate composite soil samples, even collected solely from denuded tundra areas, would likely generate samples containing TPH concentrations extending over a large range. Furthermore, because organic-rich tundra typically contains elevated but variable natural organic and moisture contents (compared to soil), calculations of dry weight concentrations of TPH would be strongly influenced by variability in natural organic and moisture contents. Finally, because the passive in situ bioremediation approach was not anticipated to be as effective as the active treatment approach used in the LTU, sampling emphasis in 1989 was placed on the assessment of the performance of the LTU approach. Therefore, a

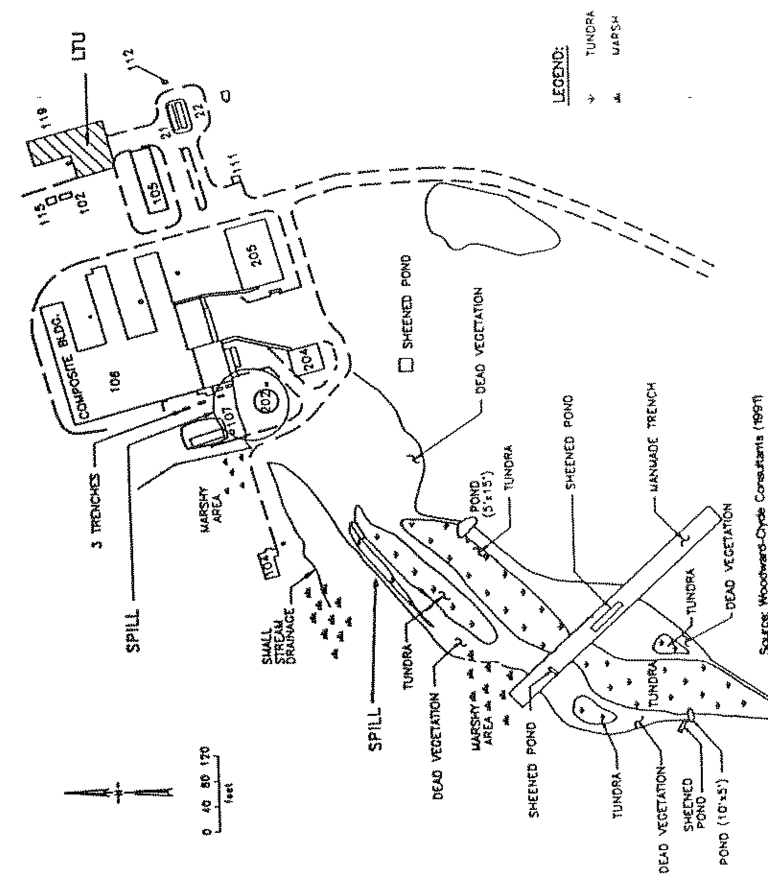


Figure 8.3. Plan view of extent of diesel fuel spill at the U.S. Air Force station in 1989.

limited-scope sampling plan was adopted for the assessment of the 1989 tundra treatment program. In 1990, the sampling plan for the tundra treatment was similar to the plan for the LTU. Details of the sampling plans are presented below.

1989 Treatment Methods and Sampling Plan

On August 8, 1989, the initial concentrations of TPH in denuded tundra areas on the hillside were estimated by collecting four composite samples and one duplicate sample from randomly selected locations within the denuded areas. The samples were analyzed for TPH and soil moisture content using the methods described previously.

After sampling, approximately 550 gal of the dilute surfactant solution (one 55-gal drum of Toxigon 2000 mixed with 500 gal of lake water) was primarily applied to the three natural channels running down the face of the hillside using a gas-powered pump, hosing, and a water truck. Access to the hillside was limited to the area immediately upslope of the impacted tundra area. Therefore, the surfactant solution was applied from the top of the hill. Denuded tundra areas adjacent to the channels were also sprayed with the surfactant solution, although not to the same extent as the channels.

Approximately 12 gal of the dilute micronutrient solution (one part Medina Soil Activator to four parts lake water) were evenly applied to the denuded areas of the hillside. Micronutrients were applied two more times in 1989, after two and four weeks of treatment.

After four and six weeks of treatment (September 12 and 26, 1989, respectively), four composite tundra samples and one duplicate sample were collected on each occasion from residual denuded areas on the hillside and analyzed for TPH and moisture content as described before. No microbial samples were collected. Treatment of the hillside was then suspended for the winter in late September 1989.

1990 Treatment Methods and Sampling Plan

On July 24, 1990, the hillside was sampled for TPH concentrations and moisture contents in residual denuded tundra areas. Tundra regrowth in several areas treated in 1989 was noted. Nine composite samples and one duplicate sample were randomly collected from locations within the denuded tundra area and analyzed for TPH and moisture content using methods described previously.

After sampling, approximately 600 gal of surfactant solution (one part Toxigon 2000 to 15 parts lake water) were sprayed on the denuded tundra areas with an emphasis placed on applying the solution to the three channels. Approximately 18 gal of the micronutrient solution (one part Medina Soil Activator to five parts lake water) were applied to the denuded hillside areas, with an emphasis again placed upon applying the solution to the three channels.

No further treatments were applied to the hillside. After nine weeks (September 24, 1990), nine composite tundra samples and one duplicate sample were collected from the residual denuded areas of the hillside and analyzed for TPH and moisture content as before.

RESULTS

Environmental Temperatures During the Bioremediation Studies

Air temperatures (daily minimum and maximum) were recorded during the study at a nearby meteorological station operated by the National Weather Service (NWS). The data were obtained from the NWS shortly after collection in each year.[10,11]

1989 Data

For the first four weeks of the study, environmental temperatures largely ranged from 10°C to 17°C (50°F to 63°F; Figure 8.4). However, immediately after the September 12 sampling (day 36 of treatment), environmental temperatures declined appreciably, and ranged from approximately 1°C

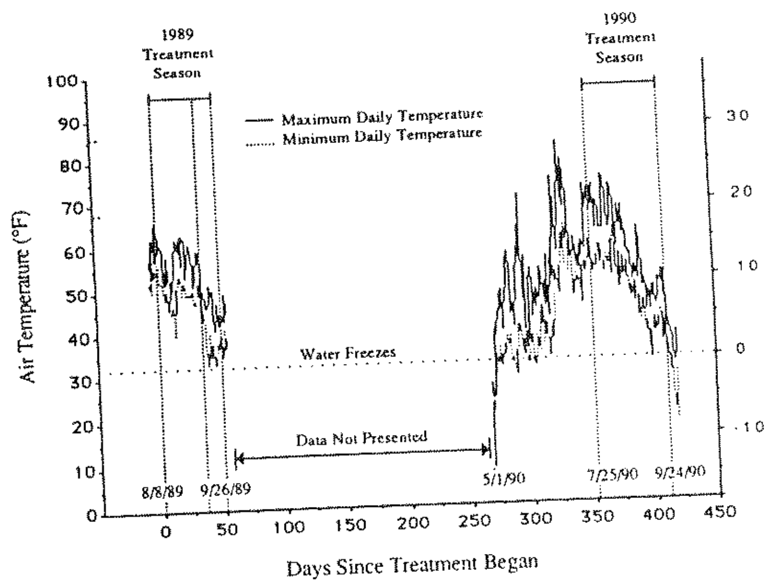


Figure 8.4. Daily maximum and minimum air temperatures in vicinity of the U.S. Air Force station during the 1989 and 1990 bioremediation treatment periods. Vertical dotted lines indicate dates when soil/tundra sample collections were made. (Data source: References 10 and 11.)

(~34°F) to a maximum of 10°C (50°F) for the remaining 14 days of the study.

The average recorded air temperature (±1 standard deviation) from August 8 through September 12, 1989 was 11.6 ± 1.9°C (52.9 ± 3.5°F), whereas the average during the period from September 13 through September 25, 1989 was 5.4 ± 1.3°C (41.7 ± 2.3 °F).

Another indicator of ambient thermal characteristics that is often used in the evaluation of outdoor biological studies is calculation of the cumulative degree-days during the studies. Cumulative centigrade-degree-days (C-degree-days) are calculated as follows:

$$\text{Cumulative C-Degree-Days} = \sum_{i=1}^{i=50} (\text{Average Temperature [°C] on Day i});$$

or on a Fahrenheit basis:

$$\text{Cumulative F-Degree-Days} = \sum_{i=1}^{i=50} ([\text{Average Temperature (°F) on Day i}] - [32°\text{F}]);$$

where i = a day during the 50-day 1989 bioremediation study period.

The freezing temperature (0°C or 32°F) is used as a reference point in the calculation because biological processes (including microbial activity) generally become greatly reduced at the freezing temperature of water.

The cumulative C-degree-days for the entire 50-day study period in 1989 (August 8 through September 25) was 488 C-degree-days (879 F-degree-days) or approximately 10 C-degree-days (~18 F-degree-days) per day (Table 8.1).

For the period August 8 through September 12 (36 days), the cumulative C-degree-day value was 418 C-degree-days (753 F-degree-days) or approximately 12 C-degree-days (~21 F-degree-days) per day, whereas for the period September 13 through September 25 (13 days), the cumulative degree-day value was 70 C-degree-days (126 F-degree-days) or approximately 6 C-degree-days (~10 F-degree-days) per day (Table 8.1).

Therefore, average ambient conditions (as indicated by average and cumulative degree-days) during the first four weeks of the 1989 treatment period were considerably warmer than conditions during the final two weeks of the period. The cold period that occurred during the final two weeks of the 1989 treatment period would have likely reduced microbial activities in the soil, and this may explain why there was no significant reduction in TPH concentrations during this period (Table 8.1).

Table 8.1. Summary of Cumulative and Average Degree-Day Data[a] and Percent Reduction in Contamination Concentration[b] During Portions of the 1989 Bioremediation Treatment Period, Alaska Air Force Station

	First Four Weeks	Last Two Weeks
Number of Treatment Days	36	13
Cumulative C-Degree-Days (F-Degree Days)	418 (753)	70 (126)
Average C-Degree-Day (F-Degree Day)	12 (18)	6 (10)
Percent Reduction in Total Petroleum Hydrocarbon Concentration During Period	44	0

[a]Degree-Day data presented on Centigrade (C-degree-days) and Fahrenheit (F-degree-days) scales. See text for description of calculation method for degree-days.
[b]Measured as total petroleum hydrocarbon concentration; SW3550/418.1 method.

1990 Data

Maximum and minimum daily air temperatures in 1990 are presented in Figure 8.4 starting from May 1. This is done because, although active treatment was not begun until July 24, 1990, the treatment efforts conducted during the previous summer may have produced residual stimulation to the indigenous microorganisms once the soil and the tundra had thawed in 1990. Therefore, the temperature data are presented from the day treatment began in 1989.

Air temperatures essentially increased above the freezing level shortly after May 1. Prior to July 24, air temperatures varied from below freezing to a maximum of approximately 28°C (82°F) and two relatively warm periods were separated by a cooler period (Figure 8.4).

From July 24 through late September, air temperatures generally declined steadily (Figure 8.4). The highest daily air temperature during this period was 23°C (74°F). Soon after the final September 24, 1990 sampling, air temperatures had largely declined below the freezing level.

The cumulative C-degree-days for the entire 1990 treatment period (July 24 through September 24) was 448 C-degree-days (807 F-degree-days), or approximately 7 C-degree-days (13 F-degree-days) per day. Average ambient conditions during the 1990 treatment period (as indicated by cumulative and average daily degree-days) were cooler than the conditions during the 1989 treatment period (Table 8.2).

Precipitation During the Bioremediation Studies

Daily precipitation was also recorded during the bioremediation studies by the NWS station (Figure 8.5). The data were obtained from NWS shortly after completion of each year's treatment period.[10,11]

Table 8.2. Summary of Cumulative and Average Degree-Day Data[a] for the 1989 and 1990 Bioremediation Treatment Periods, Alaska Air Force Station

	1989	1990
Number of Treatment Days	50	63
Cumulative C-Degree-Days (F-Degree-Days)	488 (879)	448 (807)
Average C-Degree-Day (F-Degree-Day)	10 (18)	7 (13)

[a]Degree-Day data presented on Centigrade (C-degree-days) and Fahrenheit (F-degree-days) scales. See text for description of calculation method for degree-days.

1989 Data

August is normally a wet month in the area, and precipitation was recorded at least at trace levels on 27 of 31 days of the month in 1989. Total precipitation during the 1989 study period was approximately 10 cm (3.93 inches), with 6.9 cm (2.71 inches) falling during the August portion of the 1989 study period.

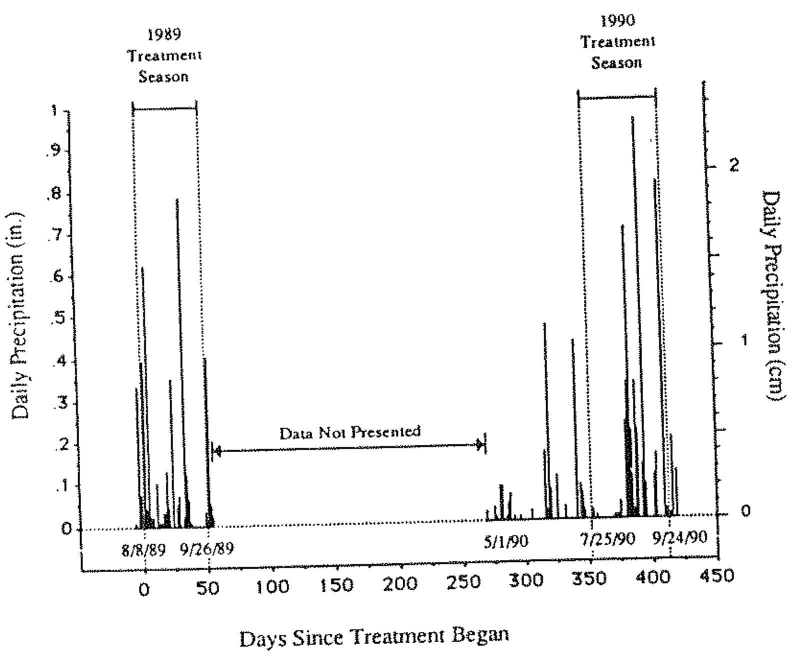


Figure 8.5. Daily precipitation in vicinity of U.S. Air Force station during the 1989 and 1990 bioremediation treatment periods. (Data source: References 10 and 11.)

Table 8.3. Total Petroleum Hydrocarbon Concentrations (Dry Weight Basis) in Soil and Tundra Samples Collected from Land Treatment Unit and Treated Tundra Hillside During the 1989 and 1990 Bioremediation Treatment Periods, Alaska Air Force Station

Sampling Date	No. of Samples	Mean Concentration (mg/kg)	Standard Deviation	Standard Error
Land Treatment Unit				
8 August 1989	9	11,491	4,370	1,457
12 September 1989	9	6,470	1,600	533
26 September 1989	9	6,963	3,210	1,070
25 July 1990	10	4,631	706	223
24 September 1990	10	2,845	661	209
Tundra Hillside				
8 August 1989	5	15,420	12,595	5,633
	4[a]	19,207	10,766	5,383
12 September 1989	5	23,012	42,879	19,176
	4[b]	3,906	4,237	2,119
26 September 1989	5	5,530	3,635	1,626
25 July 1990	10	9,828	7,982	2,524
24 September 1990	10	8,303	7,857	2,485

[a]If sample datum of 271 mg/kg is removed from data set as an apparent outlier.
[b]If sample datum of 99,435 mg/kg is removed from data set as an apparent outlier.

1990 Data

Precipitation was recorded at trace levels or greater on 36 of the 63 days of the 1990 study period. Total precipitation during the 1990 study period amounted to 12.8 cm (5.03 inches), and 12.5 cm (4.93 inches) of this total fell during the final five weeks of the period. On an average daily basis, the 1990 treatment period was wetter than the 1989 period.

LTU Results

Table 8.3 presents a summary of TPH results for the LTU for the 1989–1990 bioremediation treatment periods.

1989 Total Petroleum Hydrocarbon Concentrations

The average concentration (± 1 standard deviation) of total petroleum hydrocarbons (TPH) in the LTU soil at the beginning of the 1989 study period was 11,491 ± 4,370 mg/kg (dry weight basis). The standard error estimate for the initial data (standard deviation divided by n, where n is the number of replicates collected [n = 9]) was 1,457 mg/kg (Figure 8.6).

After approximately four weeks of biological treatment, the average concentration of TPH in the LTU soil was 6,470 ± 1,600 mg/kg (standard error estimate: 533 mg/kg with n = 9). This average value for TPH concentration represents a 44% reduction from the initial average TPH concentration. A statistical analysis of the initial and four week data (Mann-Whitney U test[12]) indicates that the reduction was significant at the 0.001 probability

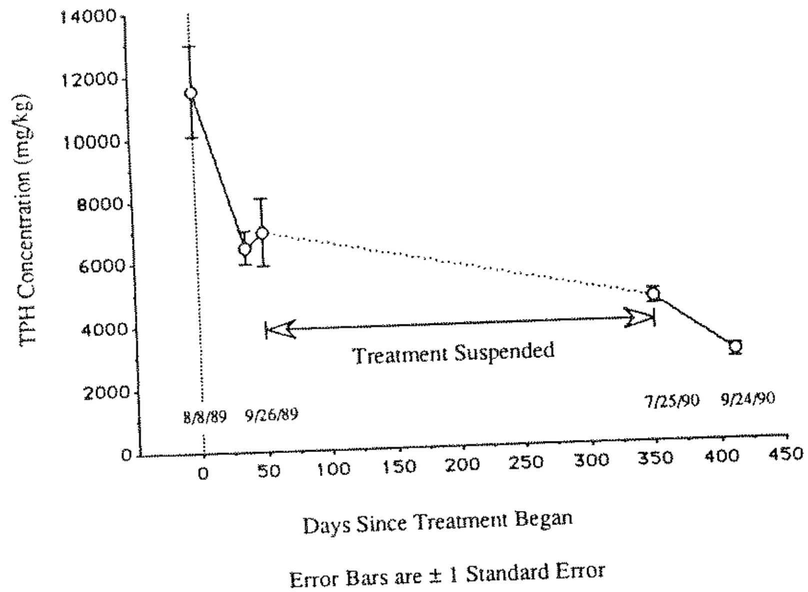


Figure 8.6. Mean (± 1 standard error) concentrations (dry weight basis) of TPHs in soil samples collected from the LTU during the 1989 and 1990 bioremediation treatment periods conducted at the U.S. Air Force station. TPH measured using SW3550/EPA method 418.1.

level. In other words, there is a 99.9% probability that the difference between the initial and four-week TPH concentrations can be attributed to treatment (versus sampling or analytical errors).

After approximately six weeks of biological treatment, the average TPH concentration in the land-treated soil was 6,963 ± 3,210 mg/kg (standard error: 1,070 mg/kg with n = 9) (Figure 8.6). Statistical analyses (Mann-Whitney U test) of the TPH concentrations in the soil replicates collected initially and at four and six weeks of treatment were performed. The six-week soil TPH concentrations were significantly lower than the initial soil TPH concentrations at the 0.025 probability level. Although the arithmetic mean TPH concentration increased from four to six weeks, the increase was not significant at the 0.05 probability level. This analysis indicates that biological treatment did not induce a significant change in TPH concentration in the soil during the final two weeks of treatment in 1989.

1990 Total Petroleum Hydrocarbon Concentrations

The mean TPH concentration at the beginning of the 1990 LTU study period was 4,631 ± 706 mg/kg (standard error: 223 mg/kg with n = 10). Although this mean TPH concentration value was numerically lower

than the mean value recorded at the end of the 1989 treatment period, a statistical analysis (Mann-Whitney U test) indicates that the concentrations were not significantly different at the 0.05 probability level due to scatter among the data sets. The difference in mean values from the end of the 1989 treatment period to the beginning of the 1990 treatment period suggests that some degree of TPH reduction may have occurred in the LTU soil after it thawed and before active treatment had begun in late July.

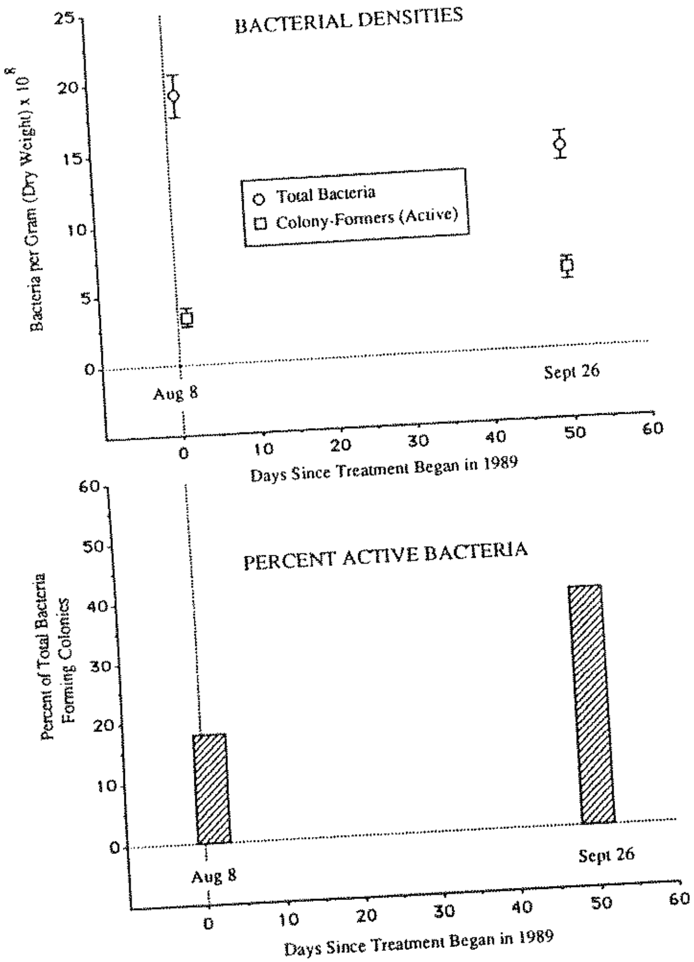
After roughly nine weeks of treatment in 1990, the mean TPH concentration in the LTU soil was 2,845 ± 661 mg/kg (standard error: 209 mg/kg with n = 10). Statistical analysis of the initial and final soil TPH concentrations (Mann-Whitney U test) indicates a significant reduction in mean TPH concentration at the 0.001 probability level.

1989 Microbial Data

The initial average density of total bacteria (i.e., those active, resting, and dead) was 19.1×10^8 bacteria/gram dry wt of soil (Figure 8.7, top graph). Of those, roughly 3.4×10^8 bacteria/gram or ~18% were active (Figure 8.7, bottom graph). The average density of fluorescent pseudomonads (a group of microorganisms that characteristically possesses the capability to degrade hydrocarbons) was 1.6×10^6 bacteria/gram dry wt of soil, and the average density of bacteria capable of degrading phenanthrene (an organic component of diesel fuel) was ~1.4×10^7 bacteria/gram (~0.7% of the total number) (Figure 8.8).

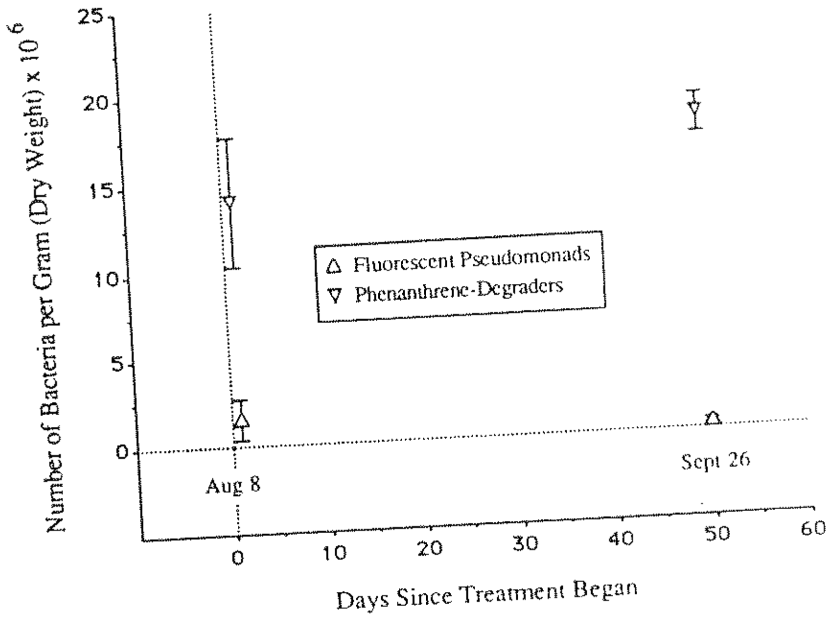
Approximately six weeks after treatment, the average total number of bacteria had declined to approximately 14.3×10^8 bacteria/gram dry wt of soil, whereas the average density of active bacteria had increased to 5.6×10^8 bacteria/gram (Figure 8.7). Although the average densities were different between sampling periods for each type of microbial analysis, neither change was statistically significant due in part to sample variability (Mann-Whitney U test). However, the percent of total bacteria estimated to be active had increased from ~18% at the beginning of the study to ~40% after six weeks, and the average percent active bacteria in the six-week samples was statistically higher than the average percent active bacteria in the initial samples. This analysis indicates that the bioremediation treatment approach had been effective in stimulating the activity of the indigenous bacteria.

The average density of fluorescent pseudomonads declined to 3.5×10^5 bacteria/gram and phenanthrene-degrading bacteria increased in mean density to 1.8×10^7 bacteria/gram (~1.3% of the total density) (Figure 8.8). Due to variability in microbial densities between samples, these changes were not statistically significant (Mann-Whitney U test).



Source: Woodward-Clyde Consultants (1991)

Figure 8.7. Mean (±1 standard error) densities (dry weight basis) of total and colony-forming (active) bacteria (top graph) and percent active bacteria (bottom graph) in soil samples collected from the LTU during the 1989 bioremediation treatment period conducted at the U.S. Air Force station. Total bacterial densities estimated using the acridine orange direct count method of Hobbie et al.[7]; colony-forming bacterial densities estimated using the plate-count method (e.g., Meynell and Meynell[8]).



Error Bars = ± 1 Standard Error

Source: Woodward-Clyde Consultants (1991)

Figure 8.8. Densities of specific microbial groups in soil samples collected from the LTU during the 1989 bioremediation treatment period conducted at the U.S. Air Force station. Densities of fluorescent pseudomonads estimated using a method developed by B.B. Hemmingsen, San Diego State University's Applied Microbiology Laboratory, San Diego, CA. Densities of phenanthrene-degrading bacteria estimated using the method of Bogardt and Hemmingsen.[9]

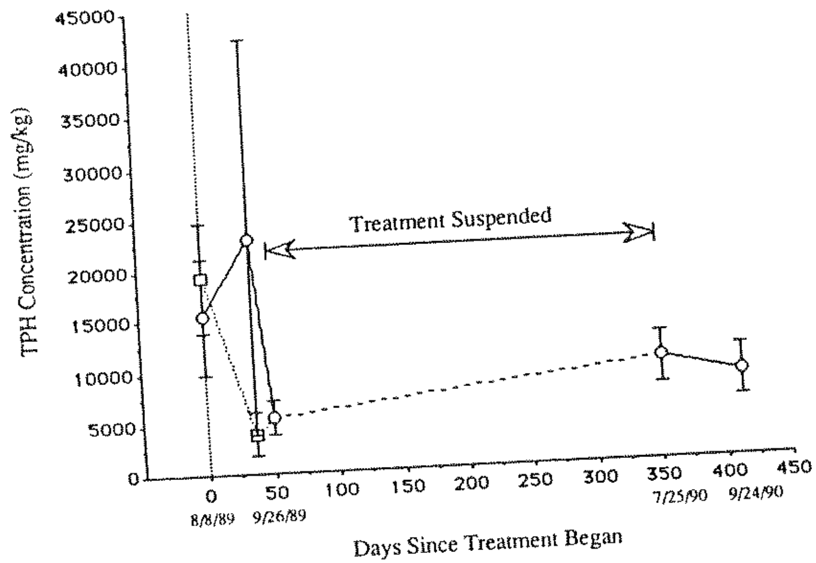
Native Tundra Results

Table 8.3 presents a summary of TPH results for the tundra hillside for the 1989–1990 bioremediation treatment periods.

1989 Total Petroleum Hydrocarbon Concentrations

The average concentration of TPH in the samples collected from the native tundra area at the beginning of the study was 15,420 ± 12,595 mg/kg (standard error: 5,633 mg/kg with n = 5). The large estimate in standard deviation was due in part to one sample that contained a very low TPH concentration (271 mg/kg). If this value is removed from the data set as an outlier, the average initial TPH concentration was 19,207 ± 10,766 mg/kg (standard error: 5,383 mg/kg with n = 4) (Figure 8.9).

As mentioned earlier, a component of the variability observed in tundra samples is variability in natural organic and moisture contents. Soil moisture contents of the tundra data set ranged from 20% to 80% (data not shown), and the highest moisture contents were typically associated with those samples that contained a large fraction of recognizable plant fragments. Upon drying of these naturally organic-laden tundra samples, the water in the plant fragments evaporated, producing a relatively low dry weight to wet weight ratio compared to samples containing low amounts of plant fragments. Thus, when the dry weight concentrations of TPH were calculated for these samples, they were appreciably higher than the samples containing a higher proportion of mineral (nonorganic) debris.



□ Mean of Samples with Apparent Outlier Removed

Error Bars are ± 1 Standard Error

Source: Woodward-Clyde Consultants (1991)

Figure 8.9. Mean (± 1 standard error) concentrations (dry weight basis) of TPHs in tundra samples collected from the treated tundra hillside during the 1989 and 1990 bioremediation treatment periods conducted at the U.S. Air Force station. TPH measured using SW3550/EPA method 418.1.

The presence of plant fragments in the tundra samples also imparts a degree of uncertainty on the results of the analytical method used to quantify TPH (SW3550/EPA method 418.1). The method involves extraction of organic compounds from the sample and analysis of the organic content of the extract using infrared spectroscopy. Although the extraction and cleanup procedures used for the method focus on analysis of nonpolar (presumably petroleum-related) organic compounds, it has been observed that nonpetroleum organic compounds may also be measured by the technique.[13] This is especially true for soil samples that contain an abundance of natural organic materials, such as plant fragments. Therefore, a portion of the "TPH" reported for the tundra samples may be naturally derived organic compounds. The combined potential influences of moisture and natural organic contents on the analytical results of the tundra samples should be taken into consideration during review of the following results.

After approximately four weeks of treatment, the average TPH concentration was 23,012 ± 42,879 mg/kg (standard error: 19,176 mg/kg with n = 5) (Figure 8.9). As in the initial concentration data set for the tundra study, an outlier value (99,435 mg/kg) was identified in the data set. If this value is removed, the mean TPH concentration after four weeks of treatment was 3,906 ± 4,237 mg/kg (standard error: 2,119 mg/kg with n = 4). The difference in TPH concentrations between the initial and four-week samples (with the outliers removed) was statistically significant at the 0.025 probability level (Mann-Whitney U test).

After approximately six weeks of treatment, the average TPH concentration was 5,530 ± 3,635 mg/kg (standard error: 1,626 mg/kg with n = 5). The difference in TPH concentrations between the four- and six-week samples was not significant (Mann-Whitney U test). However, the difference in concentrations between the initial and six-week samples was significant at the 0.05 probability level (Mann-Whitney U test).

1990 Total Petroleum Hydrocarbon Concentrations

The initial mean TPH concentration in the tundra samples collected at the beginning of the 1990 treatment period was 9,828 ± 7,982 mg/kg (standard error: 2,524 mg/kg with n = 10; Figure 8.9). Although the mean TPH concentration was arithmetically higher at the beginning of the 1990 treatment period compared to the end of the 1989 treatment period, the difference was not significant (Mann-Whitney U test). Several samples in the 1990 initial data set were relatively elevated, and these values influenced the mean calculation of that data set.

After approximately nine weeks of treatment in 1990, the average TPH concentration in the tundra samples was 8,303 ± 7,857 mg/kg (standard error: 2,485 mg/kg with n = 10). Statistical analysis indicates that no significant reduction in TPH concentration occurred during the 1990 treatment period.

DISCUSSION

Land Treatment Unit

The 1989 TPH results of the LTU study indicate that land treatment produced roughly a 44% reduction in TPH concentrations during the first four weeks, but that further reductions did not occur during the last two weeks of treatment. The 1990 TPH results indicate that land treatment produced an additional 39% reduction in TPH concentration in the soil during the 1990 study. Thus, the overall reduction in TPH concentration was approximately 75% from August 1989 through September 1990.

Although the 1990 treatment period was approximately three weeks longer than the 1989 treatment period, the percent reduction in soil TPH was lower in 1990 than 1989. The reduced level of TPH reduction observed in the 1990 treatment period may be related to the relatively colder and wetter conditions that occurred during 1990. The 1990 ambient conditions were apparently less conducive for microbial activity compared with the conditions in 1989.

Losses of TPH during the first four weeks of land treatment were probably the result of a combination of biological degradation, volatilization, and leaching. Volatile compounds characteristically comprise approximately 30% of diesel fuel by weight.[14] Therefore, at a maximum, volatilization may have accounted for a loss of 30% of the TPH contamination from the soil. It has been observed that volatilization becomes an important loss mechanism for contaminated soil when environmental temperatures are elevated and soils are relatively dry.[15] These two conditions did not occur during the study. Furthermore, the diesel spill reportedly occurred in 1984, indicating that a major portion of the volatile components may have been already dissipated by 1989. Therefore, the cold, wet nature of the LTU soils during treatment, as well as the age of the diesel spill, suggest that volatilization was not an overly important loss mechanism during the study.

Leaching may have reduced TPH concentrations in the LTU soil. Studies of dissolution and leaching rates of TPH from various soil types are not abundant, although the American Petroleum Institute is currently evaluating this loss mechanism.[15] Although a berm had been installed around the LTU to control runoff, a petroleum sheen was observed in a small flow of water exiting the unit in mid-September,[16] indicating that rainfall and runoff during the first four weeks of treatment may have resulted in some TPH leaching. However, since the majority of organic components in diesel fuel are hydrophobic and because the contaminated soils had been subjected to several years of leaching prior to the beginning of the study, this loss mechanism may not have been significant, even with the initial application of the surfactant solution in 1989.

The other major loss mechanism is enhanced biodegradation. Virtually every organic component in diesel is biodegradable under appropriate environmental conditions.[15] The objective of the land treatment approach used in this study was to create conditions conducive to biodegradation of diesel fuel in soil. It was concluded a priori that the appropriate conditions for this situation included periodic soil mixing to increase contaminant-microbe interaction, enhance oxygen delivery to the soil, and promote soil drying; periodic micronutrient applications to further enhance microbial activity; and addition of a dilute surfactant solution to increase contaminant accessibility to the indigenous microorganisms.

The microbial data indicate that appreciable numbers of hydrocarbon-degrading bacteria were present in the LTU soil throughout the 1989 study period. The combined microbial data also indicate that treatment significantly increased the proportion of active microorganisms in the LTU soil. Furthermore, the average densities of bacteria that were capable of degrading phenanthrene increased during the 1989 study period. These observations indicate that the bioremediation enhancement techniques applied to the LTU soil stimulated microbial activity. The arithmetic mean density of total bacteria presumably declined during the six-week period because the concentration of petroleum hydrocarbons ("food") had also declined over the period.

The objective of enhanced bioremediation is to stimulate microbial activity so that the microorganisms metabolize the targeted organic compounds at a rate greater than would occur naturally. Since microbial activity directly correlates with ambient temperature, climate conditions in the area during the study were anticipated to have a major influence on microbial activity and, hence, the effectiveness of bioremediation treatment. The 1989 and 1990 studies were conducted at the ends of the arctic summers and ambient temperatures, along with microbiological activity, were anticipated to decline during each study period. Indeed, the observation of essentially no appreciable biodegradation during the final two weeks of treatment in 1989, when a period of cold ambient temperatures occurred, is consistent with the theoretical influence that a marked decline in environmental temperatures would have on biodegradation rates.

A second major environmental variable of the 1989/1990 LTU studies was precipitation. As was mentioned previously, August is typically the wettest month of the year in the area. Excavated soils were quite damp when they were placed on the LTU in August 1989, and the precipitation that occurred during that month was more than 2 inches above normal.[11] The 1990 study period also coincided with above-normal precipitation.

Precipitation kept the LTU soil near the saturation point,[16] reducing the effectiveness of soil aeration because oxygen transfer is impeded by the high soil water content. As a result, saturated soils containing elevated levels of organic materials (such as soils containing diesel contamination) often develop anaerobic (no oxygen) conditions because the microbial oxygen consumption rate tends to exceed the rate of oxygen replenishment from the atmosphere. Because petroleum hydrocarbons tend to degrade relatively slowly under anaerobic conditions,[17] the saturated condition of the LTU soil during both study periods may have reduced the rate of diesel fuel biodegradation.

In summary, the results of the 1989/1990 LTU studies indicate that onsite bioremediation produced significant reductions in the concentrations of TPH in the contaminated fill over a relatively short time period, even under the relatively adverse environmental conditions of late arctic summer treatment periods (cold, saturated soil conditions). Presumably, if land treatment is initiated soon after spring thaw, considerably greater reductions in soil TPH concentrations would be realized because treatment would take place under warmer, drier conditions that would be more conducive to elevated biodegradation rates of the petroleum hydrocarbons.

Tundra Treatment

The results of the 1989/1990 bioremediation studies for the tundra area suggest that the bioremediation approach can produce significant initial reductions in TPH concentrations in contaminated tundra. Little additional TPH reduction was observed in 1990. There were several factors associated with the tundra studies that interfere with the evaluation of the treatment approach.

Sampling across the contaminated tundra hillside was focused on those areas that remained denuded. Therefore, with each sampling event, tundra samples were collected in areas more adjacent to the three channels through which the diesel fuel originally flowed. These areas were likely to have higher TPH concentrations than areas at distance from the channels. Therefore, the sampling emphasis placed on denuded areas tended to bias the collection of samples toward those areas containing elevated contamination levels. This could account for the arithmetic increase in tundra TPH concentrations that was observed between the final 1989 sample set and the initial 1990 sample set.

A second influence on the results is the aforementioned variabilities in the contents of natural organic materials and moisture characteristic of tundra samples. These variabilities exerted a large influence on the variability of the calculated dry weight concentrations of TPH in the tundra samples. The outliers identified in the combined data set for the tundra samples may be related to the influences of natural organic materials and moisture contents. As the variability in a sample set increases, the ability of statistical tests to detect significant differences tends to decline.

Third, the negligible additional reduction in TPH concentration observed during the 1990 study may be related to the relatively cool and wet conditions that took place during this period. Such conditions would likely reduce the rate of contaminant biodegradation using a passive in situ approach. In addition, as mentioned for the LTU studies, if treatment is

initiated earlier in the summer, a greater degree of TPH reduction may be realized.

Finally, as discussed before, the analytical method may be measuring natural organic components present in the tundra samples. If this is true, the "TPH" concentration would tend to reflect the total organic carbon concentration versus the diesel fuel concentration. The relative importance of this issue could be evaluated by analyzing organic-rich, tundra samples that have not been contaminated by diesel fuel.

The results do indicate a trend of decreasing TPH concentrations in the tundra over time, although the reductions are not statistically significant. One way to assess the overall effectiveness of the bioremediation approach is to monitor the extent of revegetation in the impacted areas over the next few years. The area of the hillside that was impacted by the diesel fuel spill and treated in 1989 showed considerable revegetation during the summer of 1990. Presumably, if the in situ bioremediation approach appreciably enhances the rate of reduction of TPH concentrations on the hillside areas impacted by the spill, the treated areas will revegetate more rapidly than impacted areas that received no treatment because they were inaccessible.

In summary, the passive, in situ bioremediation approach for the contaminated tundra area appears to have produced a significant initial reduction in TPH concentrations. Additional reductions in 1990 were statistically insignificant; however, cold and wet conditions in 1990 may have influenced the 1990 results. In addition, several factors associated with sampling and analysis were identified which could have had bearing on the tundra evaluation. Validation of the effectiveness of the passive, in situ bioremediation approach for treatment of contaminated tundra may best be documented by following revegetation patterns in impacted areas over the next few summers.

SUMMARY AND CONCLUSIONS

Onsite, open-air bioremediation studies conducted over two successive summers (1989 and 1990) at a U.S. Air Force station in arctic Alaska demonstrated that significant reductions in the concentrations of spilled diesel fuel in soil and tundra can be achieved despite the relatively unfavorable environmental conditions of the region.

Active, aboveground, biological treatment of the contaminated soil fill in a land treatment unit produced an average reduction in soil diesel fuel concentration (as measured by total petroleum hydrocarbons) of approximately 75%. During each summer season, TPH concentrations were reduced by approximately 50% by treatment in the LTU.

Passive, in situ biological treatment of the contaminated tundra hillside was not as effective in reducing average TPH concentrations in the affected tundra. However, sampling and analytical difficulties may have reduced our ability to detect significant reductions in TPH concentrations during the two summer periods. Appreciable regrowth of the tundra vegetation in the impacted areas that were treated in 1989 during the summer of 1990 suggest that the passive, in situ bioremediation approach was assisting in the restoration of the affected hillside area.

An assessment of meteorological conditions during the 1989 and 1990 study periods indicates that the bioremediation approaches could produce additional reductions in TPH if the treatment programs are initiated soon after ambient temperatures increase above freezing.

The results of these studies demonstrate that bioremediation technologies may assist the U.S. Air Force in remediating organic contamination problems in Alaska. Because open-air, onsite treatment can be effective for treating contaminated soil and tundra despite relatively unfavorable environmental conditions, the potential exists that the U.S. Air Force may be able to treat contamination problems relatively inexpensively.

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Bioremediation of Hydrocarbon-Contaminated Soils and Groundwater in Northern Climates

Charles M. Reynolds, W. Alan Braley, Michael D. Travis, Lawrence B. Perry, and Iskandar K. Iskandar

March 1998

CRREL

Abstract: A field demonstration and research project was conducted in Fairbanks, Alaska, to demonstrate, evaluate, and document the construction and operation of three selected bioremediation technologies—landfarming, recirculating leachbeds, and infiltration galleries. Landfarming involves adding water and nutrients to contaminated soil to stimulate microbial activity and contaminant degradation. Infiltration galleries are dynamic in-situ treatment systems designed to stimulate microbial activity and subsequent hydrocarbon degradation by circulating nutrient- and oxygen-amended water through petroleum-contaminated soil. Recirculating leachbeds, in a way similar to slurry reactors, aerate and mix nutrients with contaminated soil, and can be built as on-site bioreactors. Estimated biotreatment costs in the landfarm were between \$20 to \$30 per cubic yard (\$15 to \$23 per cubic meter). Nutrient placement has been demonstrated to be a critical factor, even though the site is tilled and mixed frequently. Success of the infiltration gallery was more difficult to document. Benzene was detected at less than 2 ppb and BTEX levels were less than 5 ppb for water extracted from the pumping well during 1992, which is significantly lower than the 1991 levels. Problems were encountered during the brief operation of the recirculating leach bed, but a similar system has performed well. Relatively simple, low-cost techniques provided significant potential for improving degradation rates.

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Bioremediation of Hydrocarbon-Contaminated Soils and Groundwater in Northern Climates

Charles M. Reynolds, W. Alan Braley, Michael D. Travis,
Lawrence B. Perry, and Iskandar K. Iskandar

March 1998

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

PREFACE

This report was prepared by Dr. Charles M. Reynolds, Research Physical Scientist, Geochemical Sciences Division, Research and Engineering Directorate, U.S. Army Cold Regions Research and Engineering Laboratory; W. Alan Braley, Alaska Department of Transportation and Public Facilities, Fairbanks International Airport, Fairbanks, Alaska; Michael D. Travis, formerly of AGRA Earth and Environmental, Inc., Anchorage, Alaska; Lawrence B. Perry, Physical Science Technician, and Dr. Iskandar K. Iskandar, former Chief, Geochemical Sciences Division, Research and Engineering Directorate, CRREL.

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EXECUTIVE SUMMARY

The objectives of the Construction Productivity Advancement Research (CPAR) field demonstration and research project, *Bioremediation of Hydrocarbon Contaminated Soils and Groundwater in Northern Climates*, were to demonstrate, evaluate, and document the construction and operation of three selected bioremediation technologies—landfarming, recirculating leach beds, and infiltration galleries—in cold regions. Before this CPAR program was begun, bioremediation had not been used extensively in cold regions.

Landfarms are lined, bermed areas where soil is treated by adding and mixing water and nutrients. A collection system may be installed inside the liner to collect leachate, which then can be recirculated. In this project, the leachate was recirculated through a mixing tank for nutrient additions and then through spray irrigation lines onto the surface of the landfarm site. The liner surface was sloped to ensure that the liner directed leachate into the collection system.

Infiltration galleries are dynamic in-situ treatment systems designed to stimulate hydrocarbon degradation by enhancing microbial activity. Microorganisms are stimulated by circulating nutrient and oxygen-amended water through soil contaminated by petroleum. The system used in this project included a groundwater pumping well, nutrient addition and aeration capabilities, and an infiltration gallery to encourage transport of the enhanced groundwater back into the soil.

Recirculating leachbeds are similar to slurry reactors. The concept is to develop a lined containment area to serve as an on-site bioreactor. Either a pit, generally resulting from the excavation, a bermed perimeter, or a combination can be used, depending on available materials. In this project, contaminated soil was placed into the bioreactor and, through an inexpensive PVC distribution system, aerated and nutrient-amended water was recirculated into the bottom of the bioreactor, upwards through the contaminated soil, and then through the overlying ponded and aerated water. Skid-mounted mechanical systems included a mixing tank and circulation pumps for water and air.

The products of this project include field demonstrations of each technology, accompanying documentation on design and construction, results of operation in cold regions, and numerous technology transfer activities, such as site visits and tours during the construction and operation of the treatment facility. The designs have been provided to the U.S. Army Engineer District, Alaska, as well as commercial engineering firms.

To date, the Fairbanks bioremediation test site has completed remediating the first batch of contaminated soil in the landfarm. The estimated costs were between \$20 to \$30 per cubic yard (\$15 to \$23 per cubic meter). Nutrient placement has been demonstrated to be a critical factor, even though the site is tilled and mixed frequently. Relatively simple, low-cost techniques provided significant potential for improving degradation rates. The project findings include an estimate of the spatial variability in degradation rates within the landfarm and measurements of degradation rates obtainable in a cold region landfarm. These results are significant for developing other low-cost bioremediation systems, such as those using combined treatment technologies. Extension to biotreatment systems that include extremely low inputs, such as natural attenuation, has also been considered.

Processes enhanced by operation of the infiltration gallery were more difficult to document. During the operation in 1992, the benzene and BTEX (benzene,

toluene, ethylbenzene and xylene) concentrations in groundwater samples from the six monitoring wells surrounding the infiltration gallery decreased to below detectable limits. Benzene was detected at less than 2 ppb (μg/g) and BTEX levels were less than 5 ppb (μg/g) for water extracted from the pumping well during 1992, which is significantly lower than the 1991 levels.

Problems were encountered during the brief operation of the recirculating leach bed. The air manifold floated to the surface, but this could be readily solved by using a simple system to anchor the aeration piping to the soil surface. Channeling of water was observed in the soils immediately above the water distribution manifold, possibly causing preferential paths in the flow of nutrients and oxygen through small areas rather than through the entire soil. Channeling would slow the overall rate of remediation. Lastly, it may be necessary to install a heavier liner or to provide better protection by installing a cushion fabric or sand.

Bioremediation of Hydrocarbon-Contaminated Soils and Groundwater in Northern Climates

CHARLES M. REYNOLDS, W. ALAN BRALEY, MICHAEL D. TRAVIS, LAWRENCE B. PERRY, AND ISKANDAR K. ISKANDAR

INTRODUCTION

Background

Many contaminated-soil sites in cold regions are isolated and remote. These factors, combined with extreme climatic conditions, make bioremediation difficult. Although there are increasing choices of in-vessel bioremediation schemes available, these often rely on extensive equipment needs and large energy inputs. For use at remote sites in cold regions, a cost-efficient and applicable technology would necessarily be characterized by low input and rugged design. Bioremediation encourages natural soil-mediated processes by addressing the limiting factors. It may be a preferred technology for remediating contaminated soils in severe climates, such as the Arctic and sub-Arctic regions of Alaska or other cold regions, and potentially could be used to treat the bulk of the contaminated soils at these remote sites. Although bioremediation of contaminated soils is a proven and frequently used technology in more temperate regions, the constraints imposed by severely cold climates, where the season for optimum bioremediation conditions typically is short, may reduce the cost benefits.

Objectives and rationale for field research

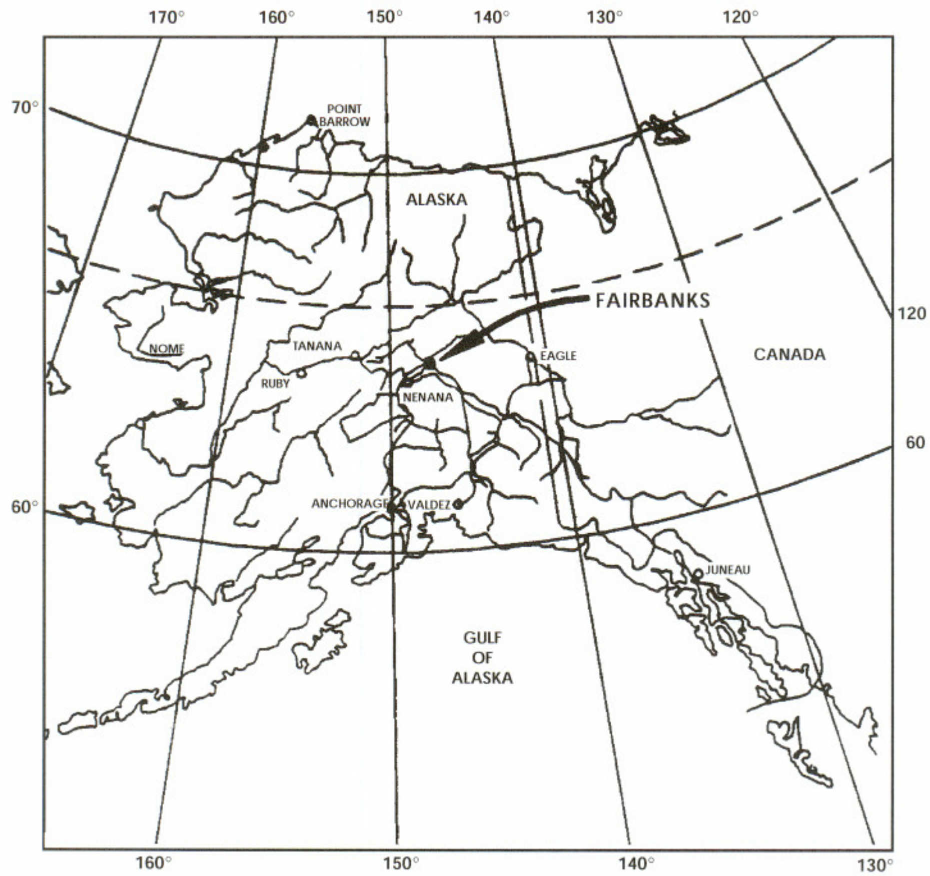
To optimize bioremediation, it is necessary to identify and reduce the factors that limit biodegradation rates. Ways to reduce these limitations are usually found through small-scale laboratory treatability tests, but the success of transferring laboratory results to the field, our ultimate goal, is difficult to quantify. Obtaining a good understanding of the degradation rates at a field site is hindered by the inherent variability in field biological studies.

Landfarms are readily constructed and provide relatively easy sampling, although the soil mixing that is achievable is usually not uniform across an entire landfarm. Regulatory restrictions generally prevent intentional application of petroleum to soils and thereby inhibit studying the effects of different treatments applied to a "uniformly" contaminated soil. To counter this, random samples can be taken and composited, but unless this process is replicated sufficiently, estimates of variability, and therefore estimates of the net effects of treatments taken from the laboratory, can not be made successfully.

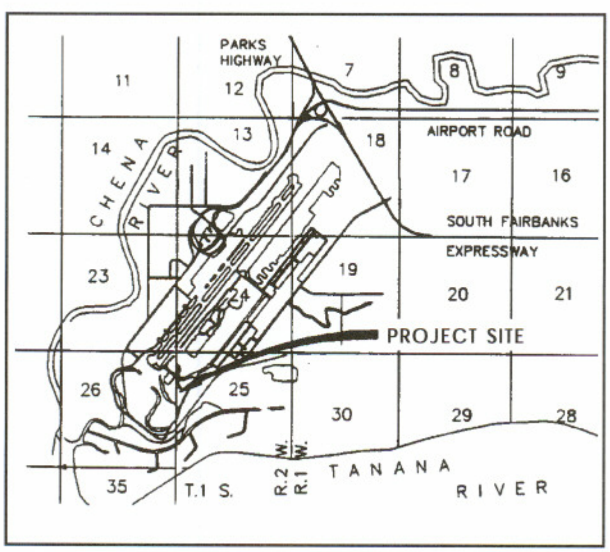
We have incorporated the spatial variability into the monitoring scheme in the landfarm. Process monitoring is more difficult in subsurface systems, owing to the costs of obtaining samples and the limited access to the soil treatment zone. For the infiltration gallery's subsurface system, we used traditional well monitoring techniques. The recirculating leachbed design provided a more aggressive treatment than the infiltration gallery, was a contained system, and provided for better mixing than the infiltration gallery or landfarm.

Project location

The project site, located at the Fairbanks International Airport (FIA) in Fairbanks Alaska, was the previously used crash-fire-rescue (CFR) train-

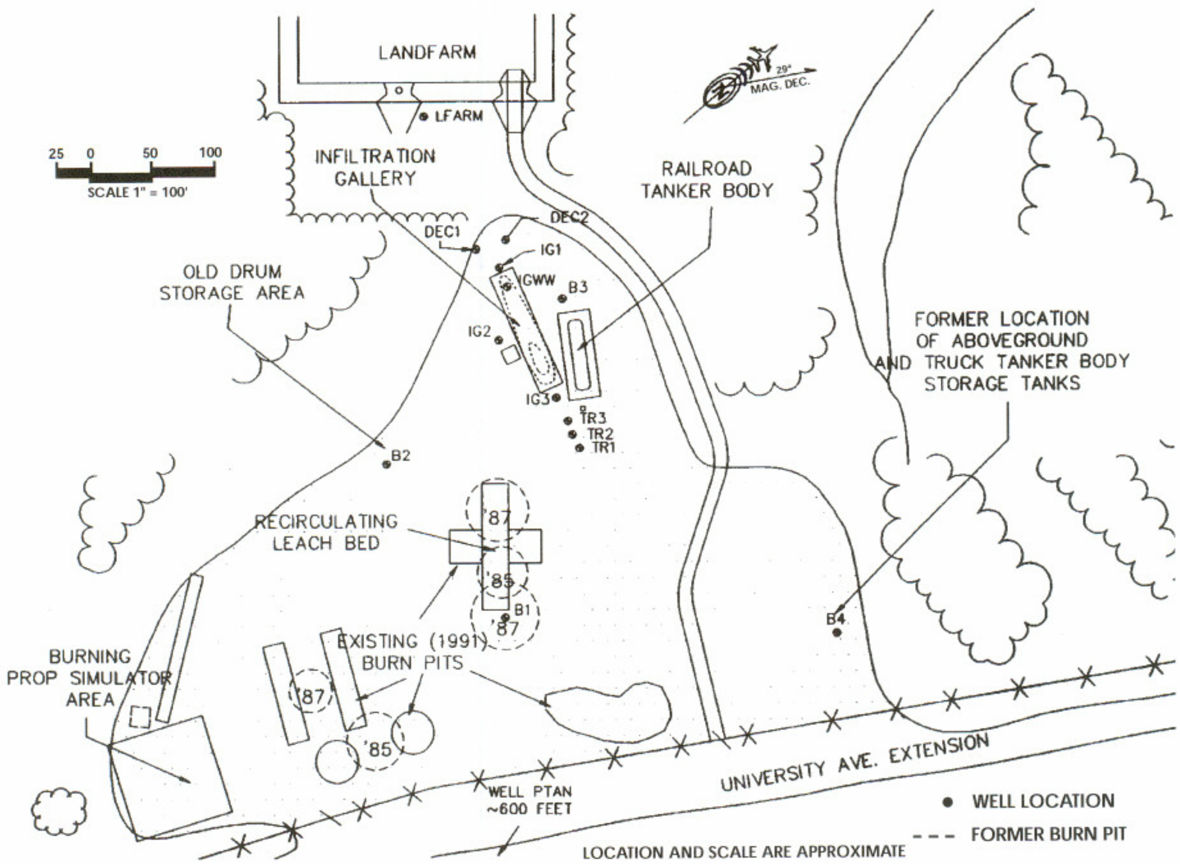


a. Fairbanks, Alaska.



b. Overview of Fairbanks International Airport and CPAR bioremediation project site.

Figure 1. Project location.



c. Fairbanks International Airport CFR training site.

Figure 1 (cont'd).

ing facility. Specifics have been previously documented (Walker and Travis 1990, Braley 1991, Braley 1993, Reynolds 1993, Reynolds et al. 1994). Figure 1 shows the locations of Fairbanks, FIA, and the site of the CFR training facility. FIA is located 3.5 miles (5.6 km) southwest of Fairbanks, Alaska, at latitude 64°49'N. The mean annual air temperature is 26°F (–3.3°C). The mean annual precipitation at FIA is 11.2 in. (28.5 cm), of which approximately half is snowfall that persists on the ground for 5 to 7 months of the year. The site is bounded by the Chena River, Tanana River, and drainage sloughs.

Site history

The CFR facility was used for many years to train personnel from FIA, government agencies, and private firms in fire fighting and rescue techniques appropriate for aircraft disaster. Shallow, unlined burn pits were constructed on the gravel pad and flooded with water and a layer of fuel oil, which was then ignited to serve as a demonstration fire. Following training, fuel remaining in the pits was reignited and permitted to burn. This process allowed unburned fuel to contaminate the soil and groundwater aquifer. Additionally, training included extinguishing burning-prop simulations, which are several fuel nozzles spraying ignited oil above the ground.

Above-ground fuel storage tanks, two truck-tanker bodies, and 55-gal. (208-L) drums, which contained paint and asphalt products, also were located at the site. The two tanker bodies and approximately 500 gal (1900 L) of fuel that leaked from one of the tanker bodies was removed from the site during 1990. An 18,000-gal (68,130-L) railroad tanker body, located at the site within a gravel-berm containment dike, released between 6000 and 10,000 gal (23,000 and 38,000 L) of fuel during May or June 1990 (Fig. 1c).

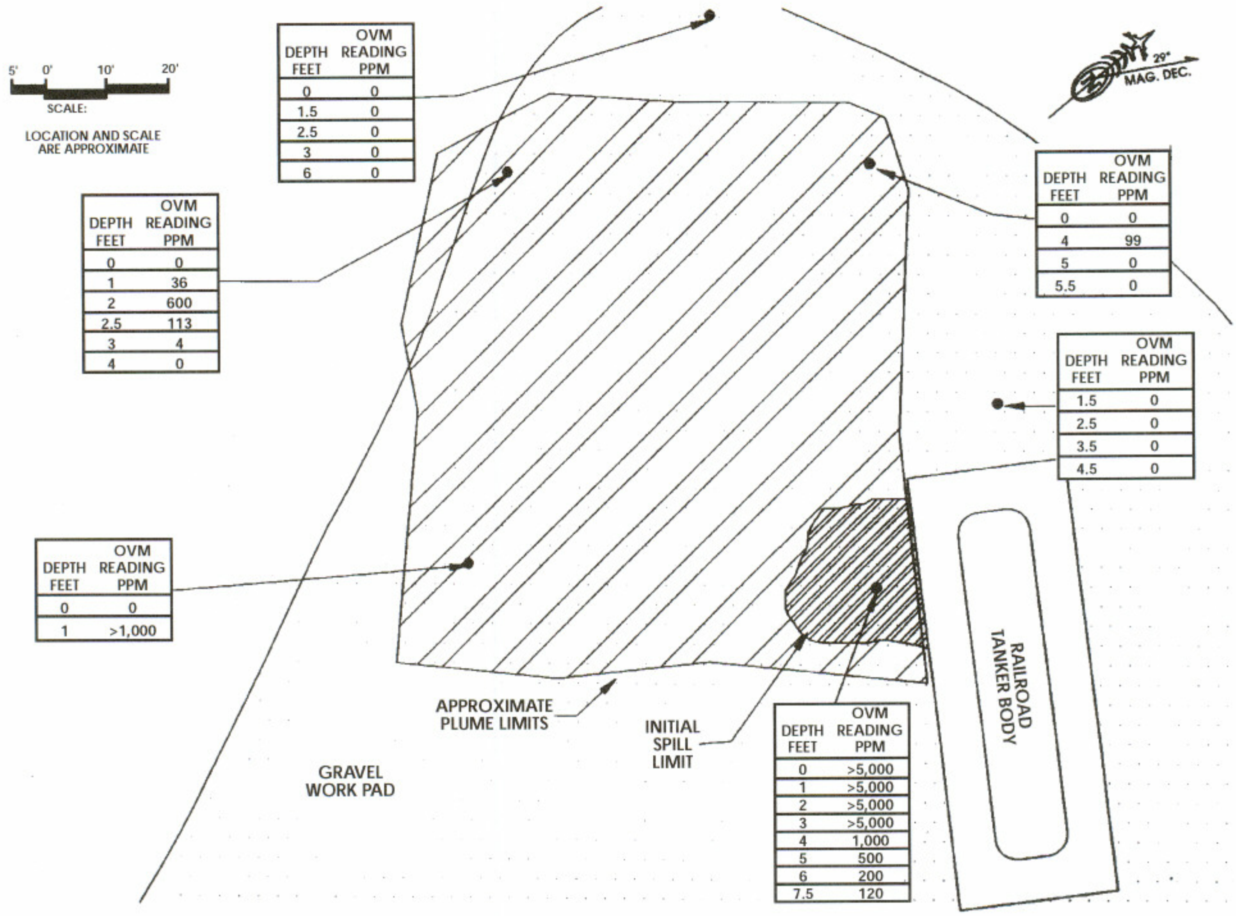


Figure 2. Zone of contaminated soil following tanker spill (OVM is organic vapor meter; 1 ft = 0.3048 m).

Site investigations

Organic vapors in the soils at various depths were analyzed using a hand-held photo-ionization meter to delineate the plume that resulted from the railroad tank car release (Fig. 2). The primary spill covered an area approximately 25 ft (8 m) in diameter and 7.5 ft (2 m) deep. Soils at the groundwater level were contaminated and groundwater was affected by the spill. The fuel oil migrated along the surface of a silt layer located beneath the 2- to 3-ft-thick (0.5- to 1-m-thick) gravel work pad covering the area, resulting in a secondary plume.

During the summer of 1989, a preliminary site investigation (Shannon & Wilson, Inc. 1989) indicated that hydrocarbon contamination was present at the old and new burn pit areas, near the truck tanker body, at the burning prop simulator area, near the railroad tanker body, and at the old drum storage areas (Fig. 1c). The highest concentrations were found in the old and new burn pit areas and at the site of the truck tanker body. Benzene detected in the groundwater was below federal maximum contaminant levels (MCL), and hydrocarbon contamination was primarily confined to the surface soils.

Subsoil and groundwater characteristics

The area that had been used for the fire training activities was generally underlain by gravel that was 2 to 3 ft (0.5 to 1 m) thick. Other portions of the area were underlain by silt, sandy silt, sand, and silty sand. Soil borings and excavations at some locations indicated lenses of sandy gravel. The water table fluctuates 5 to 7 ft (1.5 to 2 m), depending on the stages of the Tanana and Chena Rivers, and has been measured as high as 2 to 3 ft (0.5 to 1 m) from the surface at some locations within the site. July 1989 measurements showed a gradient of approximately 0.25 m per 1000 m toward the northwest (Shannon & Wilson, Inc. 1989). These findings generally agreed with those obtained at a site located approximately 0.5 miles (0.8 km) to the northwest of the CFR area (Dames & Moore 1992), where monitoring over 12 months indicated a gradient of 1.1 to 4.2 ft/mile (0.2 to 0.8 m/km) to the west–northwest.

Four groundwater monitoring wells, denoted B1–B4, were installed at the site in 1989, and during 1991, an additional five monitoring wells, denoted IG1–IG3 and DEC1 and DEC2, were installed in conjunction with the construction of the infiltration gallery. In 1992 three wells, denoted TR1 through TR3, were placed with individual sampling tubes at 1-ft (30-cm) intervals along the length of the well casing. An additional well, PTAN, was installed approximately 750 ft (229 m) up-gradient of the site. During summer 1991, two groundwater pumping wells, IGWW and LFARM, were installed at the site in conjunction with construction of the remediation facilities (Fig. 1c).

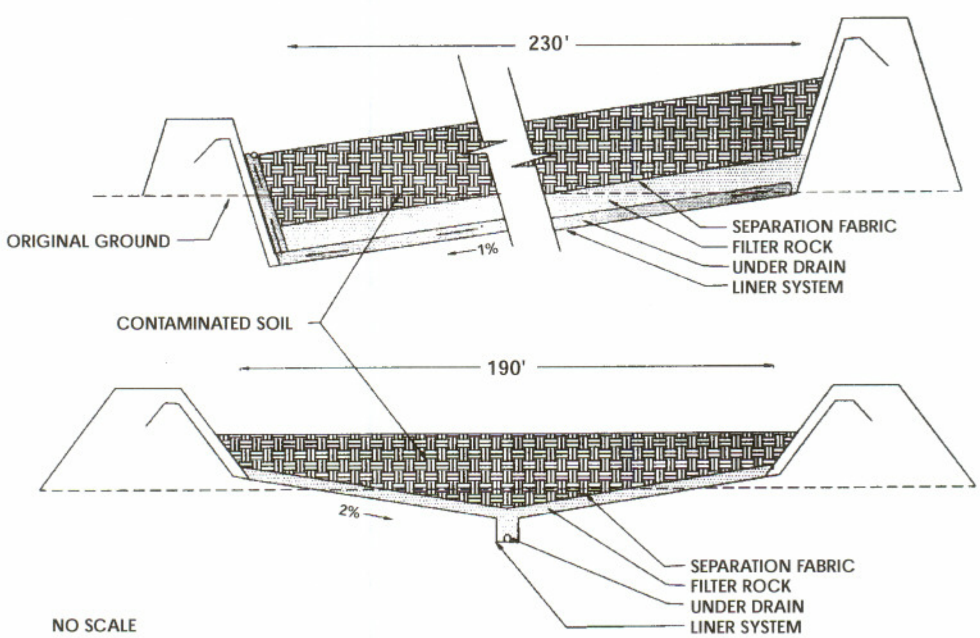
FIELD REMEDIATION PROCEDURES

The treatment technologies used at the site were two ex-situ methods, landfarming and a recirculating leachbed, and an in-situ method, an infiltration gallery, for saturated soils. The design of these systems was completed in early 1991 and a construction contract was awarded in April 1991 (Anonymous 1991). Construction started in late April 1991, but exceptionally high groundwater resulting from heavy snowfalls during the winter of 1990–91 delayed completion. Because of the construction delay, the facilities began to operate during the first two weeks of August 1991.

Landfarm

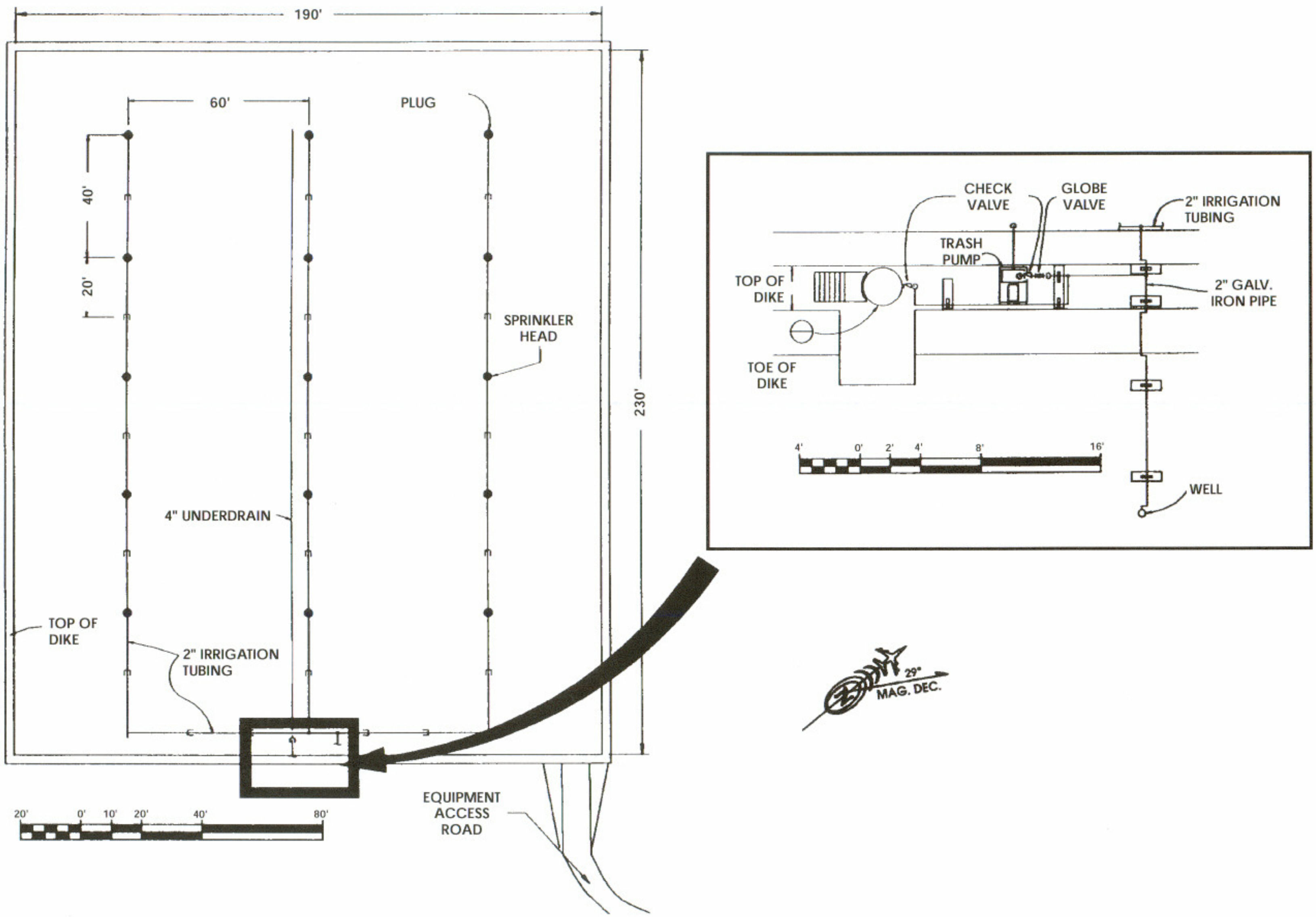
Design

The landfarm is a lined, bermed area that is 190 by 230 ft (58 by 70 m). The liner is 60-mil (1.524-mm-thick) high-density polyethylene (HDPE) and is protected at the top and bottom by 12-oz (4.07-g/m^2) fabric. A 1-ft (30-cm) layer of filter rock covers the liner to aid drainage. To prevent clogging, the filter rock is separated from the overlying contaminated soils by nonwoven geotextile separation fabric (Fig. 3). A system was installed inside the liner to collect and recirculate leachate. Berms are sufficiently high to contain projected annual precipitation. Leachate recirculation is routed through a mixing tank for nutrient additions and then through spray irrigation lines on the surface of the landfarm site. The soil surface under the liner is sloped to ensure



a. Construction specifications.

Figure 3. Landfarm (1 ft = 0.3048 m).



b. Irrigation system.
Figure 3 (cont'd). Landfarm (1 ft = 0.3048 m, 1 in. = 2.54 cm).

that the liner directs leachate into the collection system (Fig. 3a).

Construction

After vegetation was cleared from the landfarm site, the native sandy-silt material was excavated to attain the design contours at the bottom of the landfarm. Excavated material was used to form the surrounding dike. The lowest point in the structure was approximately 2.5 ft (0.76 m) below the original surface of the mineral soils, and the soils in the lower portions of the structure were saturated by groundwater. Construction of the facility was delayed to allow the groundwater elevation to recede.

After the groundwater level receded, the native soils were compacted, a separation fabric was placed atop the sandy-silt in the lower half of the excavation, a 1-ft (30-cm) lift of embankment material was placed over the bottom of the entire excavation, and the berm height was also increased. A layer of 12-oz (4.07-g/m^2) cushion fabric was placed before HDPE liner sections were positioned parallel to the 230-ft (70-m) axis of the landfarm, with seams overlapping 5–6 in. (13–15 cm). Heat-welds were made along the seams and weld integrity was tested. Following weld testing, a cushion fabric was placed over the HDPE liner and a 1-ft (30-cm) layer of filter rock covered with a layer of nonwoven separation fabric was added.

The leachate recovery system was a 4-in. (10-cm) perforated PVC pipe placed in the trench at the center of the landfarm parallel to the 230-ft (70-m) axis. A riser at the lower end of the landfarm was used for pumping water from the leachate system. The riser was connected by a 1-hp (10-kg cal/min) trash pump to a fertilizer mix tank installed on a 2-ft-high (61-cm-high) platform. A 30-ft (9-m) irrigation well for adding supplemental water to the landfarm and a surface irrigation system were installed. Surface irrigation was through 2-in. (5-cm) aluminum pipes and rotating sprinkler heads. The nutrient mixture was gravity fed to the irrigation piping. Water could be delivered to the irrigation system from the well, fertilizer tank, or the drain system (Fig. 3b).

Soil treatment

Approximately 500 yd^3 (382 m^3) of soil, previously stockpiled during cleanup of the fuel spill next to the railroad tanker body, and approximately 3200 yd^3 (2500 m^3) of soil excavated and transported from the old burn pit area were moved into the landfarm. The extent of this excavation in the burn pit area is shown in Figure 4. The contaminated soil was disked weekly with a 2-ft-diam. (60-cm-diam.) disk for aeration and nutrient mixing. The disk mixed the upper 8 to 12 in. (20 to 30 cm) of soil. Each week, 25 lb (11.35 kg) of ammonium nitrate (NH_4NO_3) and 2 lb (0.908 kg) of potassium (potassium sulfate) were mixed with 150 gal (568 L) of water and allowed to flow into the irrigation piping. The well pump was activated to disperse the fertilizer mixture over the landfarm area. Irrigation water was added to the landfarm several times during August to keep the soil's moisture content at 25–85% of field capacity.

The 1992 operational season began in mid-April; a wheeled loader and a large snowblower were used to remove approximately 80 in. (2 m) of snow from the landfarm. An additional 15 in. (38 cm) of snow fell after the winter accumulation was removed. Meltwater, coupled with the moisture from rainfall in late August and September 1991, saturated the material in the landfarm and delayed tillage until 23 June. The rate of fertilizer application was increased to 600 lb (272 kg) of ammonium nitrate, 150 lb (68 kg) of triple super-phosphate, and 50 lb (23 kg) of potassium each month. Applying fertilizer through the irrigation system during 1991 resulted in uneven coverage because of leaky joints in the irrigation pipe, so dry fertilizer was applied in 1992. A tractor-mounted broadcast spreader was used, followed by tillage.

Process monitoring

Landfarming is one of the most commonly used and accepted soil biotreatment techniques in temperate regions (Kuroda and Nusz 1994), yet information on landfarming that would expedite its application to cold regions was sparse. For these reasons, we emphasized characterization of the landfarm and the governing processes within it.

Microbial activity. We characterized the microbial activity at the landfarm by four methods. A most probable number (MPN) sheen screen technique was used to enumerate the oil-degrading population. Radio-respirometry was used to determine the potential to mineralize specific hydrocarbons. Nonspecific microbial activity in the field was estimated by measuring evolved carbon dioxide (CO_2). This was done by alkali-trapping and both gravimetric and gas chromato-

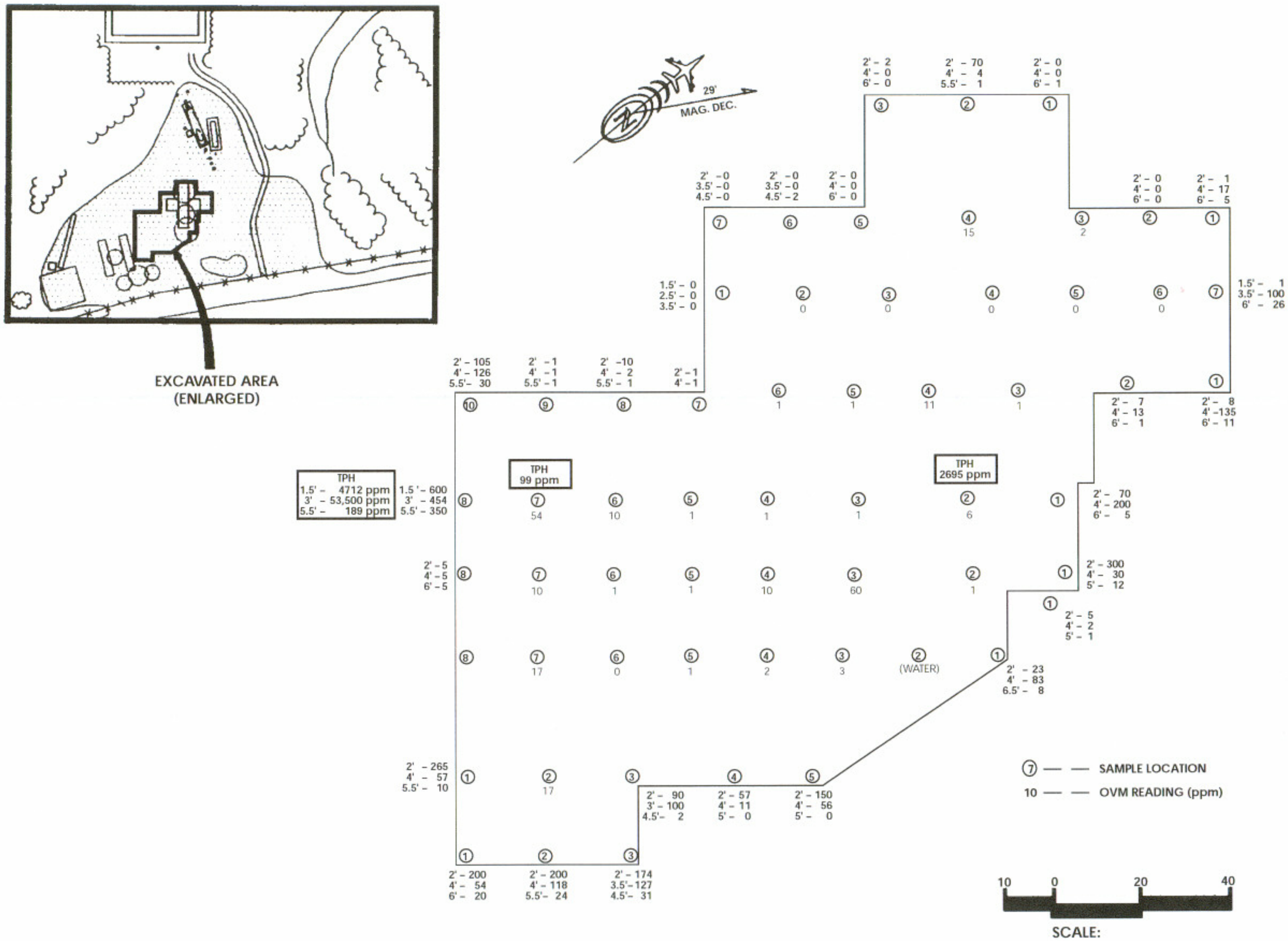


Figure 4. Areas of soil excavation for landfarm treatment (TPH is total petroleum hydrocarbon levels and OVM is organic vapor meter) (1 ft = 0.3048 m).

gram analysis. In August 1991, five composite soil samples were collected at six times and analyzed using radio-respirometric assays and sheen screen techniques. Field measurements of CO_2 evolution were made on seven different occasions.

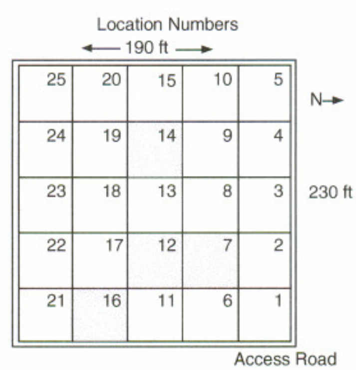
Contaminant degradation rates. Contaminant degradation was also estimated by measuring dichromate-oxidizable organic carbon and gravimetric total petroleum hydrocarbon (TPH) levels. At approximately monthly sampling intervals, 25 composite samples were collected in a grid pattern and analyzed. Laboratory results were then examined using geostatistical methods. Soil extract hydrocarbon analyses were also performed by an independent testing laboratory on soil samples collected by FIA personnel. During 1991, samples were analyzed for TPH by an infrared method. Soil samples collected during 1992 were analyzed for diesel range petroleum hydrocarbons (DRPH), gasoline range petroleum hydrocarbons (GRPH), and benzene, toluene, ethylbenzene, and xylene (BTEX).

Organic vapor emissions. Headspace gas concentrations were measured for samples collected on 18 August 1992, using an organic vapor meter (OVM) calibrated for benzene. On 20 August 1992, samples were collected for laboratory analysis of DRPH concentrations. No detectable DRPHs were measured in these samples (Table 1). These results indicated that material in the landfarm reached appropriate cleanup levels for closure sampling and disposal.

Table 1. Landfarm analytical results.

Date	TPH (mg/kg)	GRPH (mg/kg)	DRPH (mg/kg)	B (mg/kg)	T (mg/kg)	E (mg/kg)	X (mg/kg)
			Location 12				
21 Aug 91	1100						
28 Aug 91	1700						
18 Sep 91	770						
01 Oct 91	1100						
15 Jul 92		29*	2300	0.06	0.15	<DL	0.29
20 Aug 92			<DL*				
			Location 14				
21 Aug 91	4000						
28 Aug 91	3500						
18 Sep 91	1000						
01 Oct 91	900						
15 Jul 92		7†	55	0.02	0.07	0.03	0.08
20 Aug 92			<DL				
			Location 7				
20 Aug 92			<DL				
			Location 16				
20 Aug 92			<DL				

* Below detection limits.
† Light deisel.



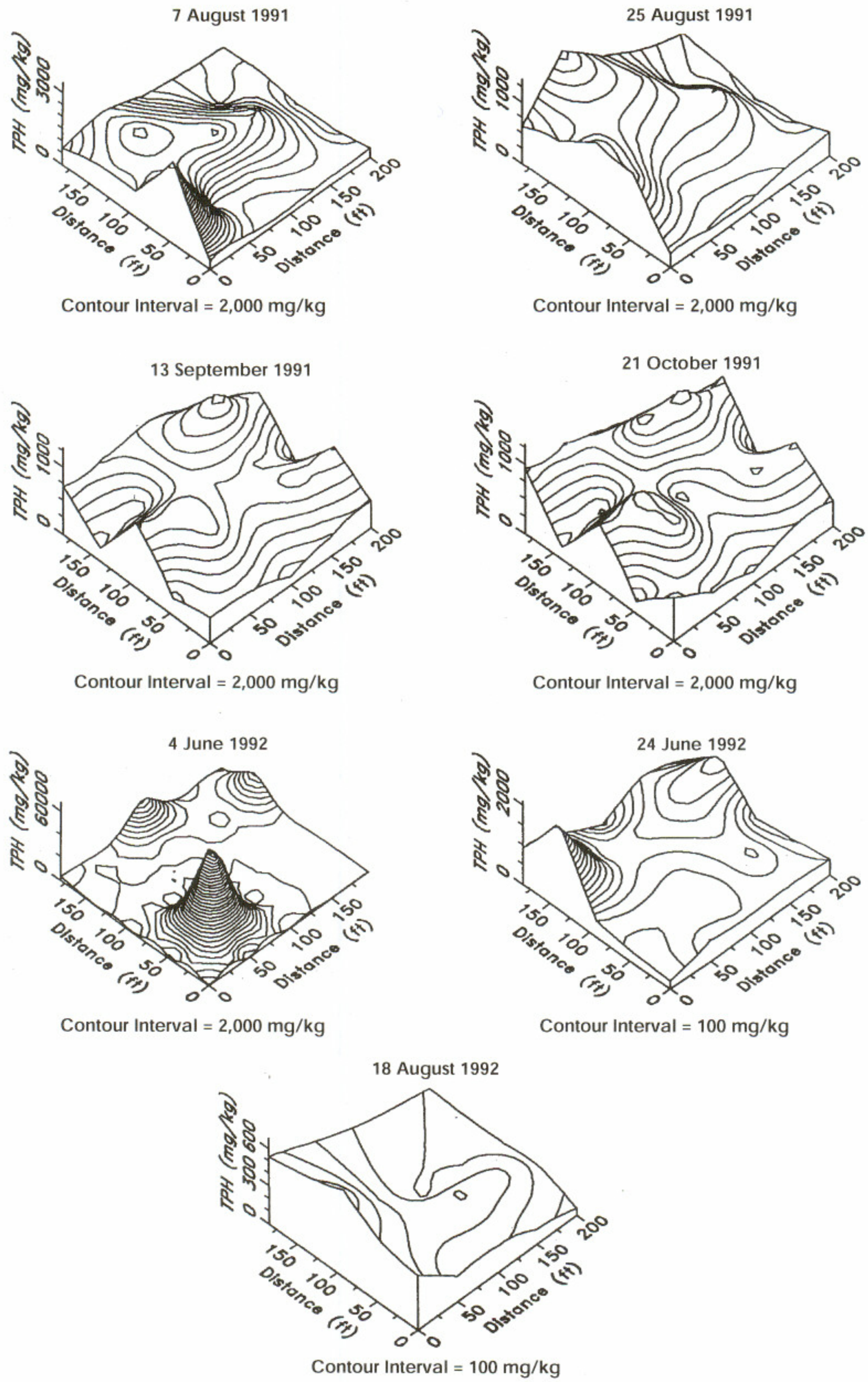


Figure 5. Soil TPH levels.

Treatment results

Microbial activity. First year data from the University of Alaska cooperators in this study revealed no increase in mineralization potentials or microbial numbers attributable to the addition of nitrogen, irrigation, or tilling (Rawls-McAfee and Brown 1992). In 1992, 180 soil samples were collected for radio-respirometric assays (Brown et al. 1991) and sheen screen analysis. The results indicated an increase in the mineralization potentials and numbers of microorganism, which is consistent with biodegradation.

Contaminant levels. Soil carbon levels showed a decline in organic carbon and the TPH levels through 1991 and 1992 (Fig. 5). To address the spatial variability issue, CRREL researchers estimated biodegradation rates from a 25-point grid on a 1-acre (4047-m^3) landfarm. A variety of analytical means were used. The simplest and least costly method, using dichromate oxidizable carbon, yielded estimated degradation rates that varied substantially throughout the site.

Three critical observations were noted. First, the degradation of organic carbon was readily measured, even though with a relatively crude technique such as dichromate oxidizable carbon. Second, the measured degradation rates, expressed as half-lives, varied by seven-fold within a 1-acre (4047-m^3) site. Third, there was a pattern in the variability; the center of the site had a much shorter half-life. Sampling locations and results for paired soil hydrocarbon analyses are shown in Table 1. These tests indicated a decline in soil hydrocarbon concentrations through the two seasons.

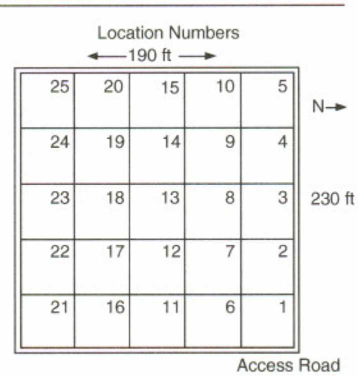
Organic vapor emissions. These results are shown in Table 2. Organic vapors were detected at low concentrations in 4 of the 25 samples analyzed. Additional soil organic vapor analysis typically resulted in low levels.

Infiltration gallery

The infiltration gallery is a dynamic in-situ treatment system designed to stimulate hydrocarbon degrading bacteria by circulating nutrient and oxygen-amended water through petroleum-contaminated soil. The infiltration gallery was installed in the area of the fuel spill next to the railroad tanker body. The soil excavated from this area was moved into the landfarm for treatment, and the infiltration gallery was used to treat the surrounding soil that was less intensively contaminated. The infiltration gallery has a groundwater pumping well located downgradient from the location of the spill. Nutrients are added to water pumped from the well. The water is then infiltrated from a 20- by 100-ft (6- by 30-m) gallery through petroleum-contaminated soils. Oxygen is added to the water within the infiltration gallery by aeration.

Table 2. Results of organic vapor meter survey for the landfarm, 18 August 1992.

Loc.	*Conc. (ppm)*	*Loc.*	*Conc. (ppm)*	*Loc.*	*Conc. (ppm)*	*Loc.*	*Conc. (ppm)*	*Loc.*	*Conc. (ppm)*
1	0	6	1	11	5	16	0	21	0
2	0	7	20	12	0	17	0	22	0
3	0	8	0	13	0	18	0	23	0
4	0	9	0	14	0	19	0	24	0
5	0	10	0	15	0	20	0	25	0



Design

Design views of the infiltration gallery, pumping well, and piping systems are shown in Figure 6. To promote infiltration of water through the sides and bottom of the gallery, it is filled with 2–5 in. (5–13 cm) cobbles and a low percentage of finer materials. The pumping well is designed to draw water from a depth of 15–20 ft (5–6 m) below the original ground surface and to produce 35–45 gal/min (133–170 L/min) of flow. This water is distributed in the infiltration gallery through the system of 4-in. (10-cm) perforated pipes located 1 ft (30 cm) below the surface of the infiltration rock. Nutrients are mixed in a 500-gal (1893-L) tank located in the equipment shed next to the gallery. The nutrient solution is injected into the pumped water stream prior to infiltration using a chemical feed pump. Oxygen is added to the water in the infiltration gallery by 4-in. (10-cm) perforated pipe located near the bottom of the gallery. Air is supplied to the aeration piping by two 10-hp (100-kg cal/min) blowers.

Construction

The gallery was constructed by excavating an area 25 by 100 ft, 6–7 ft deep (7.5 by 30 m, about 2 m deep). High groundwater was encountered during excavation, limiting the depth of excavation. Material removed during the excavation was suspected of having been contaminated by the prior fuel spill and was placed directly into the landfarm. Following excavation, approximately 1 ft (30 cm) of the 2–5 in. (5–13 cm) infiltration rock was placed on the bottom of the gallery. The aeration manifold was then positioned and infiltration rock added to 1 ft (30 cm) below the final grade of the structure. The water distribution piping was then placed and infiltration rock added to achieve the final design grade. A 1-ft (30-cm) berm was placed around the gallery to prevent surface runoff from carrying fines into the infiltration rock. When the gallery was completed, the pumping well was installed and the equipment shelter housing the fertilizer mix tank, blowers, and electrical distribution panel was installed on site.

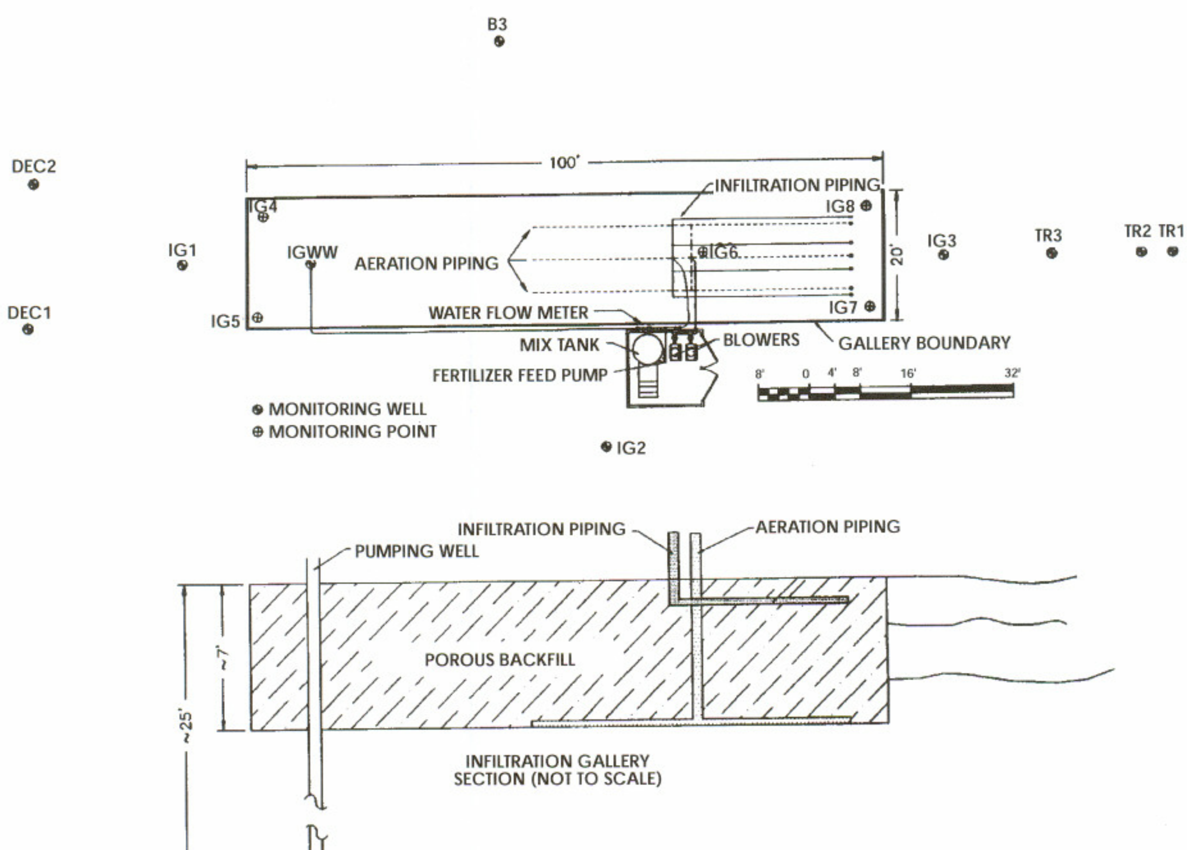


Figure 6. Infiltration gallery and monitoring wells (1 ft = 0.3048 m).

Table 3. Infiltration gallery discharge monitoring.

Date	*Benzene* (µg/L)		*Btex* (µg/L)		NO_3 (mg/L)	
	1 Dec	*2 Dec*	*1 Dec*	*2 Dec*	*1 Dec*	*2 Dec*
a. 1991						
10 Aug	1.0	0.9	1.0	0.9	<DL*	1.38
23 Aug	—	—	—	—	—	—
26 Aug	—	—	—	—	0.05	0.28
03 Sep	<DL	<DL	<DL	<DL	0.43	0.45
10 Sep	—	—	—	—	2.10	4.10
17 Sep	<DL	<DL	<DL	<DL	3.83	7.08
23 Sep	—	—	—	—	7.30	7.85
01 Oct	<DL	<DL	<DL	<DL	2.10	6.78
04 Oct	—	—	—	—	—	—
07 Oct	—	—	—	—	0.80	6.50
b. 1992						
19 Jun	<DL	<DL	<DL	<DL	0.7	1.1
26 Jun	—	—	—	—	—	—
01 Jul	—	—	—	—	1.7	1.8
06 Jul	—	—	—	—	—	—
09 Jul	0.2	<DL	0.6	<DL	8.6	6.9
16 Jul	—	—	—	—	6.5	5.1
17 Jul	—	—	—	—	—	—
23 Jul	<DL	<DL	<DL	<DL	2.8	2.8
30 Jul	—	—	—	—	0.7	0.7
06 Aug	<DL	<DL	<DL	<DL	2.8	1.2
06 Aug	—	—	—	—	—	—
13 Aug	—	—	—	—	5.38	5.59
18 Aug	—	—	—	—	—	—
20 Aug	<DL	<DL	<DL	<DL	<DL	6.6
24 Aug	—	—	—	—	—	—
28 Aug	—	—	—	—	4.2	3.5
03 Sep	<DL	<DL	<DL	<DL	0.5	0.8
11 Sep	—	—	—	—	<DL	0.6
16 Sep	<DL	<DL	<DL	<DL	0.55	0.8
01 Oct	—	—	—	—	<DL	<DL

* Below detection limits.

Operation

The infiltration gallery operation consists of pumping groundwater at a rate of approximately 40 gal/min (151 L/min) from the pumping well and infiltrating the water through petroleum-contaminated soils surrounding the gallery. A fertilizer solution is prepared in the mix tank, such that when it is injected into the stream of water to be infiltrated, the final concentration of nitrogen is 40 ppm (mg/kg). The N:P:K ratio used in the nutrient solution is 10:1:1.

On 23 August 1991, the system was activated and operated continuously until 7 October. Phosphate fertilizer was not added during 1991. The system was also operated from 23 June through 1 October 1992. During this time, the concentration of ammonium nitrate input was reduced several times because of high concentrations of NO_3 measured in the monitoring wells. Problems were also encountered when the nutrient feed pump clogged several times.

Monitoring

Parameters monitored at the infiltration gallery included soil and groundwater temperatures to a depth of 20 ft (6.1 m), nutrient feed rate and concentrations, pumping well flow rate, and groundwater elevation in and outside the gallery. Groundwater chemistry monitoring included concentrations of Cl, NO_3, PO_4, SO_4, Ca, Mg, Na, K, Fe, Br, F, Pb, O_2, nitrate, TPH, and aromatic hydrocarbons for samples extracted from the six monitoring wells surrounding the gallery and the pumping well. The numbers of hydrocarbon degrading microorganisms and microbial mineralization potential for groundwater samples extracted from several of the infiltration gallery monitoring wells were also measured during both operating seasons. The locations of the wells and points used to monitor the infiltration gallery operation are shown in Figure 6.

Frequent monitoring of benzene, BTEX, and nitrate in the groundwater at monitoring wells DEC1 and DEC2 was required for compliance with the State Waste Treatment/Disposal Permit necessary to operate the infiltration gallery. Table 3 shows the results of this monitoring for 1991 and 1992. If nitrate concentrations exceeded 5 ppm (mg/kg), the permit required action be taken to reduce the concentration; if concentrations exceeded 10 ppm (mg/kg) (federal MCL), the permit required that the system be shut off. The concentration of nitrate was found to rise quickly at the monitoring wells, reaching action levels within 2–3 weeks of startup. The measured concentrations never exceeded 10 ppm (mg/kg). Benzene and BTEX were detected only once in these wells after initial startup in 1991. These measured levels of BTEX were substantially below the federal MCL.

Before the system began operating in 1991, benzene was detected at concentrations of less than 1 ppb (µg/kg) in the monitoring wells sampled. After the system had operated for 10 days, benzene and BTEX were no longer detected in the monitoring wells. After 3 days of operation, benzene levels in the pumping well were measured at 12 ppb (µg/kg). This well was not sampled before startup. The levels of benzene in the pumping well remained near 10 ppb (µg/kg) throughout the 1991 operating season. Benzene and BTEX not being detected in the infiltration gallery monitoring wells during operation tells us that aromatic hydrocarbons were being removed by the infiltration gallery or by microbial degradation.

Before the operation began in 1992, benzene and BTEX levels were found at concentrations similar to those measured prior to operation in 1991(1 ppb [μg/kg]) in the monitoring wells surrounding the gallery. Benzene was not detected and 1.8 ppb (μg/kg) BTEX was detected in the pumping well before operation in 1992. Similar to the 1991 season, benzene and BTEX were generally below detectable limits in the six monitoring wells surrounding the infiltration gallery during the nearly 100 days of operation in 1992. Benzene was detected at less than 2 ppb (μg/kg) and BTEX levels were less than 5 ppb (μg/kg) for water extracted from the pumping well during 1992, which is significantly lower than the 1991 levels.

The size of the microbial population before startup of the infiltration gallery in 1991 was higher (counts of hydrocarbon-degrading microorganisms in groundwater samples collected next to the infiltration gallery) than in samples from other monitoring wells on and off the site. A similar trend was observed in the mineralization potentials. After startup, our estimates of microbial population numbers and mineralization potential declined significantly at the monitoring wells near the infiltration gallery.

The observed rapid transport of nitrate away from the gallery and the decline of microbial population and activity levels showed us that the water being pumped from deeper in the aquifer flows across the surface of the groundwater table some distance from the gallery. As a result, the microbial population possibly was being moved from the site faster than it could regenerate. To quantify the hydrological influence of the infiltration gallery in terms of flow rates, radius of influence, and dilution factors, groundwater tracer studies were developed for the 1992 operating season.

Two groundwater tracer studies, conducted in conjunction with the infiltration gallery, determined the flow pattern and flow rate of the nutrient-enriched water as it moved away from the infiltration gallery and was drawn towards the groundwater pumping well. The primary tracer study introduced sodium bromide into the stream of water flowing to the infiltration gallery, beginning on 21 July 1992. The concentration of sodium bromide at the point of mixing was 4 ppm (mg/kg). Injection was stopped on 1 August 1992. Frequent monitoring of the bromide concentrations in 15 wells and monitoring points surrounding the gallery continued until 13 August 1992.

The second tracer study introduced 1000 L of a 330 ppm (mg/kg) solution of water and sodium fluoride into an injection well that was hydrologically up-gradient of the infiltration gallery. The tracer was injected during a 1-hour, 39-minute period on 8 July 1992. Fluoride concentration was monitored in wells next to the point of injection for several weeks after.

Groundwater sampling

The wells mentioned in the previous paragraph were constructed with PVC pipe. The B, IG, DEC, and TR series wells were constructed with flush-threaded PVC pipe. The screened interval of the wells consists of machine-cut slots in the PVC pipe, with silica sand used as the outside packing. The upper portion of the TR series wells is cased in a 1-ft-diam. (30-cm) pipe that extends above the ground surface, terminating in a lockable sampling shelter. The B, IG, and DEC series wells are sealed with bentonite pellets, and capped at the surface with a cement–bentonite slurry seal. Construction details of the PTAN well are not readily available. We assumed the construction of this well to be similar to that of the IG series wells.

Results

During July 1989, Shannon & Wilson sampled the B series wells for purgeable aromatics and purgeable halogens. From fall 1990 to the present, personnel from the Department of Natural Resources (DNR), Division of Water, sampled groundwater at the site. Initially, only wells PTAN, B1, B2, and B4 were sampled. Well B3 was added during spring 1991. Monitoring at the IG and DEC series wells commenced during August 1991 in conjunction with the startup of the infiltration gallery.

Samples collected by DNR were analyzed by the Alaska Division of Water, Water Quality Laboratory in Fairbanks, Alaska, and by Northern Testing Laboratories (NTL), also located in Fairbanks. Parameters measured by DNR included field measurements of conductivity, dissolved oxygen, temperature, and pH. Analyses by the Water Quality Laboratory include the concentrations of Cl, NO_3, PO_4, SO_4, Ca, Mg, Na, K, Fe, Br, F, Pb, alkalinity, and TPH. Aromatic hydrocarbons and nitrate analyses, which were required for compliance with the water discharge permit needed to operate of the infiltration gallery, were conducted by NTL.

Recirculating leach bed

The recirculating leach bed is a closed-cell system that circulates nutrient-amended water through contaminated soil. Air diffusers add oxygen to the water. The system was designed so that the lined cell and associated piping could be abandoned in place once soils had been remediated. The above-ground mechanical equipment, which is the primary cost associated with this type of system, could then be used at other locations.

Recirculating leachbeds are similar to slurry reactors. The concept is to build a lined containment area to serve as a bioreactor (Fig. 7). Either a pit (generally resulting from the excavation), a bermed perimeter, or a combination can be used, depending on available materials. Contaminated soil is placed into the bioreactor and, through an inexpensive PVC distribution system, aerated and nutrient-amended water is recirculated into the bottom of the bioreactor, upwards through the contaminated soil, and then through overlying ponded and aerated water. Skid-mounted mechanical systems include a mixing tank and circulation pumps for water and air.

Design

The 26- × 26-ft (8- × 8-m) pit was lined with a nominal 20-mil (0.508-mm-thick), woven, black

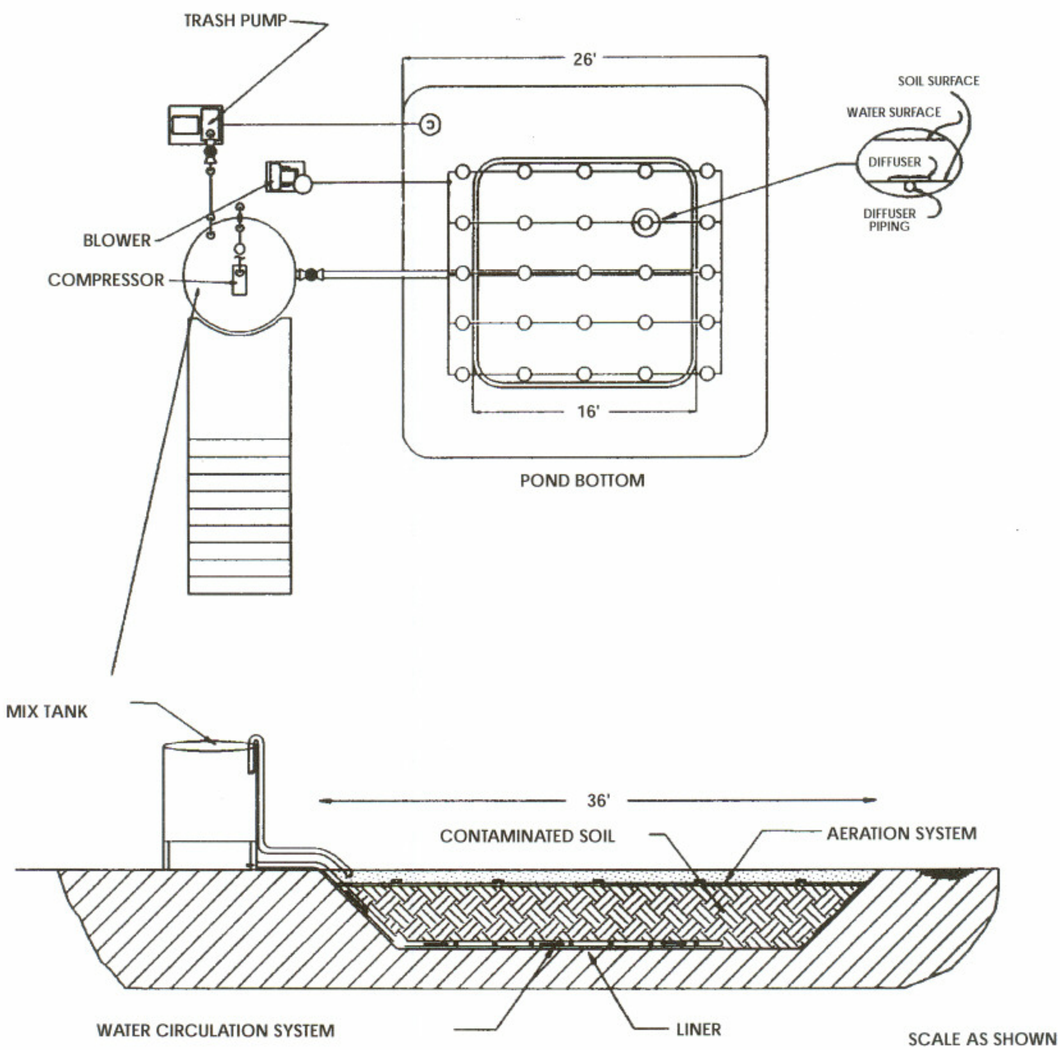


Figure 7. Recirculating leachbed system (1 ft = 0.3048 m).

HDPE scrim, coated on both sides with black HDPE. A water distribution system of 4-in. (10-cm) perforated schedule 40 PVC pipe was placed on top of the liner and covered with contaminated soil. An air header constructed of 4-in. (10-cm) schedule 40 PVC pipe was placed just below the surface of the contaminated soil, with 25 air diffusers attached to the piping located 4 in. (10-cm) above the soil surface. Water is added to the pit, saturating the contaminated soil, and submerging the air diffusers.

Water is circulated through the system using a 1-hp (10-kg cal/min) trash pump to extract water from the surface of the leach bed. The water is pumped to a 1000-gal (3785-L) fertilizer mix tank and is allowed to flow by gravity from the bottom of the tank to the water distribution piping in the bottom of the pit. The water then percolates up through the soil mass carrying nutrients and oxygen to the hydrocarbon degrading bacteria. A 9-kW emersion heater is placed in the tank to elevate the temperature of the circulating water.

Air is supplied to the diffusers by a 2.5-hp (25-kg cal/min) regenerative blower. Aeration was also provided in the mix tank by an air compressor, attached to a single air diffuser located in the bottom of the tank.

Construction

The leach bed was installed at the location of the cross-shaped burn pit (Fig. 1c). Contaminated material in the area was excavated and moved to the landfarm facility and the area was back-filled with mechanically compacted sandy-silt material. The leach bed pit was then excavated and recompacted. The liner was factory seamed and arrived at the site as a single 55- × 55-ft (16.75- × 16.75-m) sheet. The liner was fitted into the excavation and the water distribution manifold was placed at the bottom of the pit. Approximately 150 yd^3 (115 m^3) of contaminated soil that was stockpiled in the landfarm was placed in the pit. The air distribution header was buried by hand at the surface of the contaminated material and the skid-mounted mechanical equipment was moved to the site and plumbed to the air and water distribution systems.

Operation

Beginning on 9 August 1991, water was pumped from the infiltration gallery well to fill the leach bed system. Initially, the air manifold floated to the surface and sandbags were used to anchor it in place. On 12 and 13 August, water continued to be pumped into the pit until the water level was approximately 1 ft (30 cm) above the surface of the contaminated soil. On 17 August the water level had receded and more water was added. After water had to be added several times, it was apparent that the liner system had leaked. Approximately 35,000 gal (132,000 L) of water was pumped into the pit. This is enough to fill the empty pit. Although the cause of the leak has not been verified, several possibilities exist: mechanical damage during placement of the contaminated soil with the backhoe; tearing of the liner at a seam as it was loaded with soil; puncturing of the liner by rocks in the fill material because the liner was not protected by sand or cushion fabric; or cracks in the thin HDPE coating covering the scrim when the liner was folded into the corners of the pit.

Result

Although we encountered problems with the recirculating leachbed at the FIA site, a member of our research team was involved in designing and operating another recirculating leachbed at more northerly location. At this location, TPH levels in a diesel- and waste-oil-contaminated soil decreased from between 300 and 47,000 mg/kg to between 240 and 570 mg/kg in 5 weeks at Anatuvuk Pass, in northern Alaskan. Corresponding values for petroleum and hydrocarbon-degrading microorganisms, as determined by the sheen screen technique (Brown and Braddock 1990), increased from 1.8×10^4/g to 4.5×10^6/g. Final diesel-range organics, after 8 weeks of treatment, were less than 200 mg/kg.

DISCUSSION AND CONCLUSIONS

Landfarm

The results from the landfarm treatment are promising and significant. A seven-fold variability in rates suggested that the slower rates could be improved to match or approach the faster rates. Faster degradation rates would reduce the time and cost required for treatment and consequently reduce the chance of leaching or off-site migration during treatment. At least part of the difference in rates may be ascribable to moisture and nutrient additions. Evidence of this is seen in the pattern of the degradation variability, which appeared to correspond to the pattern of irrigation and fertilization. Owing to the nature of the couplings in the irrigation lines, the center of the site was more heavily treated than the edges.

The greatest operational problem that we encountered in the landfarm so far is the management of excessive soil moisture. Spring snow removal is the only way of limiting water input from precipitation. High soil-moisture content during the early summer may not allow tillage, shortening an already brief operating season. Evaporation of excess moisture may be enhanced by pumping water from the drain system, and spraying it on the surface of the landfarm. However, the pumping rate for the underdrain system is limited by the rate of water percolation through the filter rock to the perforated drainage pipe.

On the basis of testing and observation, landfarming of the petroleum-contaminated soils from the old burn pit site appears to be a viable method of remediation. With appropriate nutrient amendments, the landfarm may be used to remediate 1100 to 1600 yd^3 (841 to 1223 m^3) of material during one summer season.

Infiltration gallery

Because of the difficulty in obtaining sufficient data from an in-situ, saturated system, it is difficult to draw any definite conclusions regarding the operation of the infiltration gallery. However, some general observations can be made. The significant reduction in the iron (Fe) concentrations in the groundwater during operation of the facility tells us that iron is precipitating. This was expected, but, to date, it has not excessively plugged the gallery walls or bottom. There has been some mounding of water in the gallery, indicating that the precipitation of iron is slowing the movement of water away from the gallery.

Dissolved oxygen concentrations at the gallery monitoring wells remained low (less than 10 mg/L) throughout the operating periods. Oxygen concentrations were slightly higher in the wells closer to the gallery, showing the influence of the aeration system. Also, phosphate (PO_4) was not detected at any of the wells during the period when it was added to the infiltration water at a final concentration of approximately 4 mg/L. These factors would be expected to lower the total population of microorganisms and slow their metabolic processes.

Plans are to continue monitoring of groundwater concentrations of aromatic hydrocarbons in wells next to the infiltration gallery. Soil contaminant levels around the gallery will be quantified to see if more treatment is required. Further operation of the infiltration gallery will be based on continued monitoring.

Recirculating leachbed

We encountered three problems during the brief operation of the leachbed. First, the air manifold floated to the surface. This should be anchored using cables and "deadmen" in future installations. Second, "piping" of water was observed in the soils immediately above the water distribution manifold. This will short-circuit the flow of nutrients and oxygen through the entire soil mass, potentially slowing the rate of remediation. Third, it may be necessary to install a heavier liner and to provide better protection for it by installing cushion fabric or a layer of sand.

The more rapid remediation attained with the recirculating leachbed can be used alone or in conjunction with landfarming and could provide an expedient means to treat highly contaminated soil. This would increase the potential for landfarming of the remaining soil without liner requirements.

Because of the relatively small amount of soil that the leachbed can remediate relative to the quantity of contaminated soil located at the CFR site, there are no plans to reconstruct it. Contaminated soils in the pit will be moved to the landfarm in the future. The equipment used with the leach bed may be useful for remediating fuel-contaminated water generated in conjunction with fire training exercises at the new lined fire-training pit recently constructed at FIA.

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13. ABSTRACT (*Maximum 200 words*)

A field demonstration and research project was conducted in Fairbanks, Alaska, to demonstrate, evaluate, and document the construction and operation of three selected bioremediation technologies—landfarming, recirculating leachbeds, and infiltration galleries. Landfarming involves adding water and nutrients to contaminated soil to stimulate microbial activity and contaminant degradation. Infiltration galleries are dynamic in-situ treatment systems designed to stimulate microbial activity and subsequent hydrocarbon degradation by circulating nutrient- and oxygen-amended water through petroleum-contaminated soil. Recirculating leachbeds, in a way similar to slurry reactors, aerate and mix nutrients with contaminated soil, and can be built as on-site bioreactors. Estimated biotreatment costs in the landfarm were between $20 to $30 per cubic yard ($15 to $23 per cubic meter). Nutrient placement has been demonstrated to be a critical factor, even though the site is tilled and mixed frequently. Success of the infiltration gallery was more difficult to document. Benzene was detected at less than 2 ppb and BTEX levels were less than 5 ppb for water extracted from the pumping well during 1992, which is significantly lower than the 1991 levels. Problems were encountered during the brief operation of the recirculating leach bed, but a similar system has performed well. Relatively simple, low-cost techniques provided significant potential for improving degradation rates.

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