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RECLAMATION OF ABANDONED TAILINGS AT A NORTHERN MINESITE

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ABSTRACT

In the past, the long-term environmental impacts of mining operations were not as well understood as they are today. Some of the practices that were generally accepted throughout Canada would probably not meet today's standards for environmental protection.

The implementation of Canada's Green Plan allowed the Department of Indian Affairs and Northern Development (DIAND) to access funds to investigate remedial options for some of these sites. One of the components of the Green Plan is the Arctic Environmental Strategy (AES) which is being implemented by DIAND.

The abandoned Discovery Mine site near Yellowknife, N.W.T., includes tailings that are acid generating and contaminated with mercury. Studies conducted at the Discovery site between 1976 and 1986 concluded that continuing erosion of the tailings is resulting in ongoing mercury contamination of the adjacent Giauque Lake sediments and that the fish in Giauque Lake are sufficiently contaminated with mercury to render them unsafe for human consumption.

In August 1991, DIAND commissioned a study to develop reclamation options and to estimate the implementation costs to physically stabilize the tailings, minimize acid rock drainage, and prevent further contamination of the lake sediments.

This paper describes the federal programs leading to the classification of contaminated sites and the allocation of funds for rehabilitation. The reclamation options developed for the Discovery site are presented with their engineering and environmental implications.

INTRODUCTION

Studies conducted at the Discovery Mine site near Yellowknife, NWT, since the mine's closure in 1969 have concluded that the Discovery tailings are acid generating and contaminated with mercury, that the continuing erosion of tailings is resulting in ongoing mercury contamination of the lake sediments, and that the fish in Giauque Lake are sufficiently contaminated with mercury to render them unsafe for human consumption. When the mine was in production the bulk of the tailings were deposited on land. The drainage and erosion products from these on-land tailings, for the most part, do not enter Giauque Lake. However, during the last few years of operation, the tailings were deposited into Giauque Lake, forming a large delta that continues to erode into the lake.

The development of Canada's Green Plan has provided access to funds to address waste disposal problems at old mine sites in the NWT. These funds allowed the Department of Indian Affairs and Northern Development to commission a study, funded in cooperation with Environment Canada, to develop reclamation options and to estimate the implementation costs to physically stabilize the tailings, minimize acid mine drainage, and prevent further contamination of lake sediments.

MIME HISTORY

The Discovery Mine site is located near the western shore of Giauque Lake, approximately 84 km NNE of Yellowknife, NWT (see Figure 1). The mineral claims were originally staked in 1944 after the discovery of gold bearing quartz veins in the area. Shaft sinking commenced in 1946 and a mill of 100 tons per day capacity was erected in 1949. Production of gold commenced in 1950. The mine was developed to below 4,000 feet. In 1969 economical reserves were exhausted. Over 1,000,000 tons of ore had been milled to recover over 1,000,000 ounces of gold.

The milling process consisted of mercury amalgamation and cyanidation. Originally, tailings were disposed of on land. In 1965 a dam was breached and, until the mine was closed in 1969, tailings were deposited into Giauque Lake forming a fan of tailings in the lake. Approximately 2.5 tons of mercury were used in milling during the operational phase of the mine.

ENVIRONMENTAL IMPACT OF THE MINE

Under the current environmental regulatory regime in the NWT, such mining operations would not be permitted. In the past, the long-term environmental impacts of mining operations were not as well understood as they are today. Some of the practices that were generally accepted throughout Canada would probably not meet today's standard for environmental protection.

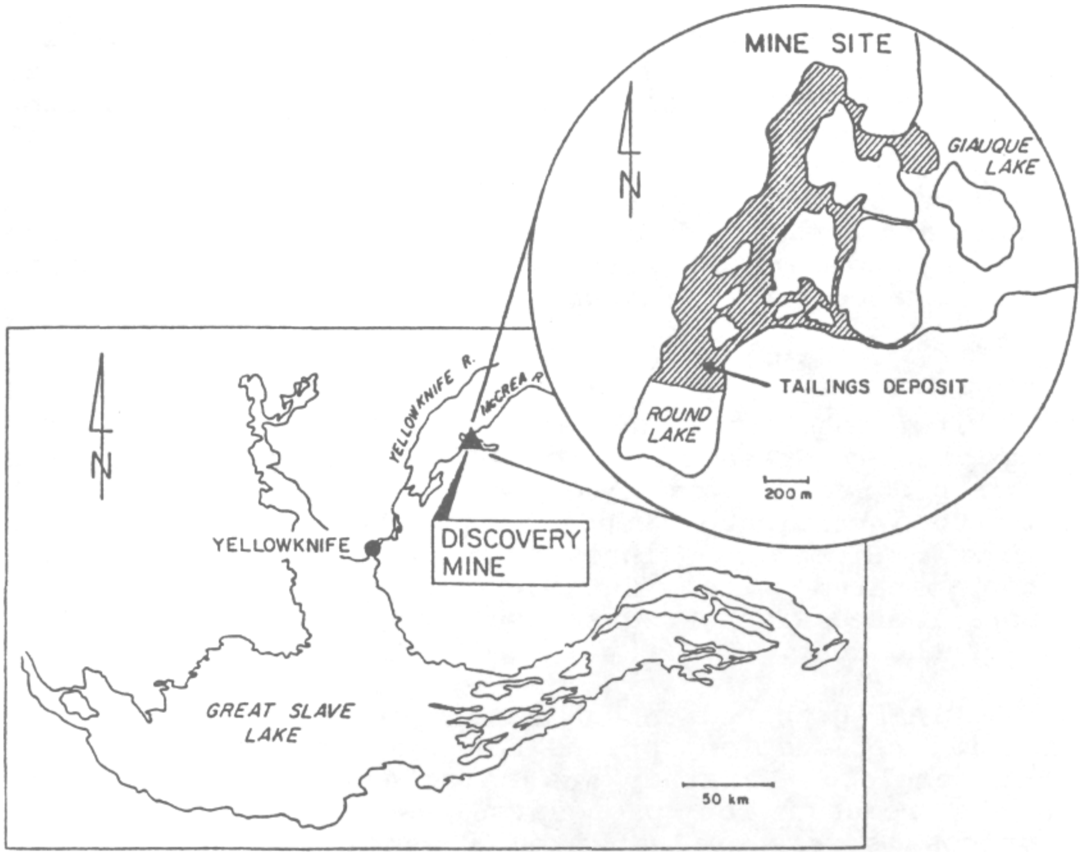

Figure 1. Discovery Mine - Location Plan

Several studies were conducted over the past 20 years to determine the effects of the Discovery operation on the surrounding environment (Moore and Sutherland, 1978; Hale et al., 1979; Hall and Sutherland, 1989). These studies revealed that:

- the sediments in Giauque Lake are contaminated with mercury and other heavy metals.
- the fish in Giaugue Lake are contaminated with mercury;
- metals and mercury contamination of the sediments in Giaugue Lake originates from the Discovery tailings;
- iron sulphide minerals contained within the tailings are undergoing oxidation and releasing metals and acidity to surface water systems;
- metal levels, while elevated in surface drainage and water collected from test pits on the tailings, are not significantly above detection limits in Giaugue Lake or downstream water systems; and
- mercury contamination of aguatic biota in Giaugue Lake originates in the contaminated sediments.

The studies concluded that, to prevent further impact and to allow the lake a chance to recover, the tailings needed to be stabilized to stop erosion and to minimize the acid generation and further mercury contamination.

Due to the extent of mercury contamination, Giauque Lake has been closed to sport and domestic fishing for several years and has been described as a contaminated site under the Environment Canada National Contaminated Site Program.

INITIATION OF STUDIES

The Arctic Environmental Strategy (AES), one component of Canada's recently implemented Green Plan, contains the Action on Waste Program. This program allowed DIAND, which implements the AES, to access funds to investigate remedial options for sites such as Discovery Mine. Since the Discovery property was listed as a national contaminated site, funds from Environment Canada's National Contaminated Site Program could be accessed as well, to support 50% of the cost.

Subsequently, DIAND gathered enough funding to commission a study of the potential reclamation options for the Discovery Mine site. The party to complete the study was selected through the normal processes. A request for proposals was advertised and the submitted proposals were evaluated by a panel of employees from DIAND, the Department of Environment, the Department of Fisheries and Oceans, and the Government of the Northwest Territories, all having expertise in the areas of mine reclamation and pollution control.

This process resulted in a contract being awarded to Klohn Leonoff Ltd. of Vancouver, B.C. in August 1991. Field work was completed in September 1991 and a final report was submitted to DIAND in early January 1992.

DEVELOPMENT OF ALTERNATIVES

Site Description

The climate in the Yellowknife area is characterized by long winters and relatively mild summers. The precipitation in the basin is very light with an annual average of 200-300 mm. The area is covered by ice and snow for as much as eight months of the year. The snowmelt occurs rapidly and generates intense, short duration runoff.

In the immediate area of Discovery Mine, soils are limited in extent as bedrock is generally at, or very near the surface. Mineral soils were observed in the valley bottoms to the north of the minesite and southeast of the tailings area. Most of these soils have an organic surface of varying thickness. Granular borrow material is available from a large esker approximately 2.5

km east of the minesite. Sand and gravel was previously borrowed from this location.

Tailings Delineation

The tailings pond was constructed by pumping the mine tailings to dyked areas where solids would settle; the effluent drained to Round Lake and to Giauque Lake. The tailings impoundment stretches south from the minesite over about 1.6 km (see Figure 1) . An estimated 1.1 million tonnes of tailings were deposited in this "on-land" area (approximately 750 000 m), covering an area of about 275 000 m . From 1965 until the Mine's closure in 1969 the tailings were discharged along the northeast arm of the impoundment and drained directly into Giauque Lake. During this period approximately 220 000 m of tailings were deposited in Giauque Lake, forming an "in-lake" tailings fan east of the minesite.

Several erosion channels have cut through the tailings deposit along various drainage paths on the main tailings area and on the tailings fan in Giauque Lake. Airphotographs indicate that these channels were formed during tailings discharge, or within one or two years after deposition, while the saturated tailings were settling and draining and generally still in a loose state. The ongoing rate of erosion occurring within these ditches is likely minimal, as most runoff flowing in these channels occurs during spring snowmelt or during the occasional rain storm. Wind erosion is actively displacing some tailings, as evidenced from the small sand dunes and sand ripples observed at various places on the tailings and, in particular, next to the minesite. Since deposition has stopped, the tailings delta in Giauque Lake has been and continues to be actively eroded by wind, runoff water from the minesite, and waves along its shores, particularly the north shore which is exposed to the prevailing northeast winds.

Preliminary Evaluation and Screening of Options

The objectives of developing reclamation alternatives are

- to physically stabilize the on-land tailings and to prevent wind and water erosion;
- to physically stabilize the in-lake tailings and to prevent further erosion of the tailings into Giauque Lake;
- to minimize the generation of acid drainage; and
- to reclaim the on-land and in-lake tailings so that they could be abandoned with a minimum requirement for long-term maintenance and monitoring.

Prior to developing rehabilitation concepts, an inventory of conventional and innovative erosion protection and acid rock drainage (ARD) reduction and control techniques was developed. These techniques ranged from standard erosion protection with riprap, engineered soil and water covers and lime treatment of ARD, to less proven concepts such as underground disposal of tailings in old mine workings and in situ freezing. Several reclamation options were then conceptually developed for the on-land and in-lake tailings by combining various methods and technologies. The options were evaluated and screened, leading to the selection of several options for more detailed consideration.

RECLAMATION OPTIONS FOR ON-LAMD TAILINGS

Option I - Reveqetation on Gravel/Soil Cover

The intent of this option is to eliminate wind erosion, reduce water erosion and improve the aesthetics of the on-land tailings by placing sand and gravel and a thin veneer of topsoil over all exposed tailings and revegetating the area. To cover the 27.5 ha of on-land tailings, approximately 82 500 m^3 of sand and gravel and 27 500 m *of* soil would be required. The sand and gravel would be borrowed, as found, from the esker deposit 2.5 km east of the site. The topsoil would be borrowed from the lacustrine deposit southeast of the tailings impoundment.

Covering the tailings with an erosion protective layer and vegetating the surface would be a simple, relatively inexpensive reclamation method. It would prevent wind erosion of the tailings and would provide some protection against water erosion. This reclamation option would allow the site to return to its natural setting, thereby improving the appearance of the area.

Some erosion may still result during severe runoff events in the absence of armoured drainage channels. A simple cover would not be expected to significantly reduce rates of oxygen diffusion or infiltration of water during normal or high runoff events. Evapotranspiration would play a minor role in controlling infiltration of water to the tailings. In the absence of drainage control, the performance of this option in minimization of ARD and erosion would be expected to decline over time without regular maintenance and replacement of materials.

Option II - Surface Protection. Vegetation and Drainage Control

In this option, the emphasis is on drainage control and erosion protection. To prevent further erosion of the tailings by intense short-duration runoff occurring during snowmelt and heavy rainfall events, existing drainage channels, naturally carved into the tailings by runoff, would be reshaped and protected with rock and filter materials. Most of the drainage from the on-land tailings area would be directed to Round lake. The total length of improved ditches would be about 3000 m.

The exposed tailings would be covered by a layer of sand and gravel and a veneer of topsoil. Approximately 75 000 m of sand and gravel and 25 000 m of soil would be required. The sand and gravel would be borrowed, *as* found, from the esker deposit. The topsoil would be borrowed from the lacustrine deposit southeast of the site.

This simple concept provides greater control of erosion than Option I, improves the appearance of the site and is anticipated to perform well in the long term. Limitations of this option are primarily associated with minimization of ARD. The granular layer, more porous than tailings, will allow greater infiltration and reduce surface runoff. Greater infiltration of water to the tailings would support ARD processes occurring in the tailings by transporting oxygen to and oxidation products away from mineral surfaces. However, due to low average annual precipitation rates and the tendency of the infiltrating water to migrate horizontally upon contact with the less permeable tailings, the overall impact on ARD may not be significant.

Option III - In Situ Freezing

The primary advantage of this option is in the minimization of ARD by maintaining the tailings in a frozen state. In addition, this option eliminates erosion and improves the appearance of the area through revegetation. A granular blanket placed over frozen tailings would raise the active freeze-thaw zone above the tailings surface.

The on-land tailings material would be covered with a 1.5 m thick layer of sand and gravel. The placement of the cover would be done during the winter while the tailings are frozen. The sand and gravel cover would then act as an insulator to prevent thawing of the tailings. The 420 000 m of sand and gravel required would be borrowed from the esker deposit east of the site. Slopes of about 1% to either side of the cover would prevent ponding on the surface and reduce percolation through the sand and gravel. Runoff would be diverted in drainage ditches along the perimeter of the cover. The area would then be revegetated by placing a veneer of topsoil over the sand and gravel, as described in Option I. About 28 000 m of soil would be required.

There are uncertainties in the freezing technology, limiting the ability to fully evaluate its potential. Insulating frozen soils and tailings for access during warm weather is a common practice for mining, construction and logging operations in areas of discontinuous permafrost. Freezing cells of tailings for abandonment by upward migration of permafrost is a proven technology in areas of continuous permafrost. However, maintaining tailings perpetually frozen under an insulating blanket is not a widely employed technology. The required thickness of the insulating layer is dependent on local conditions and the grain size of the blanket material. Waste rock is more commonly used than granular material and likely requires a thinner layer. Oxidation of tailings is an exothermic process which may complicate the conditions necessary for uniform freezing throughout the tailings mass. Zones of groundwater discharge and tailings next to bodies of water may not freeze completely.

RECLAMATION OPTIONS FOR IN-LAKE TAILINGS

Option I - Erosion Control and Riprap on North Shore

This option is designed to prevent erosion of the tailings delta and provide a revegetated cover. A riprap protection zone would be placed to control runoff coming down from the minesite to the west onto the fan. The runoff would be directed south within an existing drainage channel. This channel would be straightened and lined with a filter zone of sand and gravel overlain by 0.5 m of coarse gravel for erosion protection. An eroded channel draining to the north of the fan would be filled and plugged with the tailings material to prevent drainage onto the north shore. The north shore would be protected from wave action with riprap. Sand and gravel would be placed along the north slope of the delta extending about 70 m from the present shoreline to the edge of the beach slope. Riprap would be placed over the sand and gravel to form a 1.2 m to 1.5 m protection zone along the entire north shore of the delta. About 9000 m of sand and gravel and 21 000 m of riprap would be used. The remaining surface of the delta above water would be covered with 0.3 m of sand and gravel and revegetated directly on the sand and gravel.

This option would virtually eliminate present erosion of the tailings fan and associated deposition of tailings into Giauque Lake. Although the acidified runoff from the fan would be reduced, there would continue to be some groundwater flow to the lake resulting from fluctuation in lake level. After reclamation, the tailings fan would better match the natural surroundings both aesthetically and functionally. Shoreline protection with riprap is common practice in a wide range of circumstances and has a high level of success.

The disadvantage of shoreline stabilization with riprap is that, in the long term, the riprap could degrade and could require replacement. Also, this material would have to be quarried. Should the drainage ditch to the south side of the fan become blocked, the runoff may overtop and erode the protective layer.

Option II - Erosion Control and Imported Sand and Gravel Beach on North Shore

This option is very similar to Option I but considers a different method for protecting the north shore. The drainage flowing onto the delta would be controlled and rerouted as in Option I. Protection from wave action would be provided by a sand and gravel beach. A sand and gravel berm would be constructed at the edge of the beach slope. The berm would have a 30 m wide crest, 3H:1V slopes, and would extend 1 m above high lake level. The area between the berm and the shoreline would be filled with sand and gravel. Approximately 60 000 m of sand and gravel would be borrowed from the esker for this application. Wave action would reshape the berm over time and the exposed slope of the berm would be flattened and a natural stable beach slope would form. A permanent sandy beach approximately 1 m deep would cover the tailings fan along the entire north shore. The remaining surface of the delta, above water, would be covered with 0.3 m of sand and gravel and be revegetated.

This concept has the advantage that the shoreline protection would not degrade with time and would not require replacement. Since the artificial beach would be constructed of borrowed material, there would be no requirement for quarrying. Flat beaches are proven energy dissipators in nature and stabilize with wave action over time. Beach construction with granular deposition is commonplace and highly successful with long flat beaches.

Option III - Containment Within Dykes

Two dykes would be built to protect the north shore of the tailings fan from erosion by wave action, and contain the tailings material within the bay between the mainland and the main island. A narrow and shallow section of open water to the south of the main island would allow the water level within the bay to fluctuate and provide drainage during heavy runoff. The tailings eroded from the fan during high runoff would settle within the bay.

The bottom of Giauque lake in the vicinity of the tailings delta is bedrock. The dykes would be constructed of sand and gravel placed on the bedrock foundation. Protection from wave action would be provided by a 1.2 m to 1.5 m layer of riprap, placed on a 0.5 m thick filter zone of sand and gravel. The dykes would have 3H:1V slopes and about a 6m wide crest. A 1.5 m freeboard above high lake level has been allowed to prevent erosion by overtopping of the dykes by waves. The volumes required for these two dykes were estimated at 45000 m^3 of sand and gravel, 6200 m^3 of filter material and 9400 m^3 of riprap.

Construction of the dykes would form a breakwater for the tailings fan resulting in a significant reduction in the rate of erosion of the north shore. With this type of protection, natural vegetation of the north shore may develop in the same way as is occurring on the south shore of the fan. Dykes would limit migration of any fines eroding from the tailings fan, primarily to the small enclosed bay. However, construction of dykes would not have any significant impact on ARD and erosion of the drainage channels would continue, although eroded materials would be confined to the inner bay. By confining the products of erosion to the area of Giauque Lake contained by the dykes, the impact of erosion would not extend to the rest of the lake.

DISCUSSION AND CONCLUSIONS

The ultimate goal in reclaiming the tailings on the Discovery Mine site is to lower the level of mercury in the fish in Giauque Lake. To assess the effectiveness of the proposed remedial options, it is therefore important to understand the mechanisms by which mercury has been, and is deposited into the Giauque Lake sediments and how it enters the food chain.

The translocation of mercury from the tailings to the bottom of the lake was initiated primarily by disposal of tailings directly into Giauque Lake during the period 1965 to 1969. It has continued to a much lesser extent through erosion and other physical transport mechanisms since then. Complete elimination of mercury inputs to the lake would gradually reduce overall contamination in sediments, due to losses incurred through methylation and uptake by aquatic biota. In time, the contamination problem would be reduced through the burial of the contaminated sediments under new uncontaminated deposits, although the deposition process might take a very long time. A quantitative evaluation of the relative quantities of further contaminants available to the erosion process, as compared to the total contamination already in the lake should be a consideration in evaluating the proposed remedial measures.

Although rehabilitation methods capable of preventing erosion, minimizing ARD and reclaiming the tailings could be implemented, it would be prudent to understand the original sources of mercury contamination and to determine the significance of the rehabilitation methods relative to the existing level of mercury contamination in Giauque Lake before committing funds to a major construction project. This understanding and the subsequent evaluation of the rehabilitation concepts would then ensure that any money spent on rehabilitating the tailings would actually result in lower mercury levels in the fish of Giauque Lake.

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