A CASE HISTORY OF AN ACID GENERATION ABATEMENT PROGRAM FOR AN ABANDONED COPPER MINE

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ABSTRACT

This paper discusses a program that was initiated to improve the water quality of receiving waters below an abandoned copper mine on Vancouver Island in British Columbia. The poor quality of the water is the result of Acid Mine Drainage (AMD) from an open pit and associated waste dumps at the minesite. The program was further developed to determine the effectiveness of till covers as an abatement measure.

The first phase of the abatement program, which was commenced in August 1988, consisted of the consolidation of the waste rock, the placement of a glacial till cover and the installation of diversion ditches and drains. Surface application of limestone was also used to control pH levels in the creek during construction activities and as a short-term seepage treatment measure.

Instrumentation installed at the site includes gas/temperature wells, lysimeters and continuous flow recording devices. The monitoring program is ongoing and further activities at the site are planned for the 1989 construction season.

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INTRODUCTION

For some sulphide-bearing rocks, the processes of chemical and bacterial oxidation of sulphides in the presence of water results in the production of low-pH water which dissolves metals contained in the host rock. Dissolved metals, such as zinc or copper, are then transported to downstream receiving waters. This is the phenomenon which is known as Acid Mine Drainage (AMD).

AMD has become the topic of considerable concern in British Columbia over the past decade. It is reported that there are 5 operating and at least 6 abandoned mines in British Columbia which produce acid drainage. Concern regarding the impact of AMD has developed over this period also in other parts of Canada and elsewhere in the world where AMD is experienced. As a result, considerable research is being applied to the problem.

AMD from an open pit and waste dumps at an abandoned Mount Washington mine on Vancouver Island, B.C., was identified in 1986 (Kangasniemi and Erickson) as a major contributor of contaminant loading, particularly copper, in the Tsolum River. Total copper concentrations, at certain times of the year, were found to be toxic to salmonid. Decreases in fish returns to the Headquarter Creek hatchery and the declining steelhead fishery were attributed to the AMD.

In 1987 Steffen Robertson and Kirsten (SRK) completed a study for the Mount Washington minesite which evaluated several alternative AMD abatement options. Based on the findings of the study, an AMD abatement program for the Mount Washington minesite was commissioned by the B.C. Ministry of Energy Mines & Petroleum Resources (MEMPR) in May 1988. The objective of the program was to improve the water quality of the Tsolum River and to determine the effectiveness of till covers as an abatement measure.

SITE DESCRIPTION AND HISTORY

The Mount Washington mine site is located on the eastern side of the Insular Mountain Range at the headwaters of the Tsolum and Oyster Rivers. The site is about 1.5 km north of the Mount Washington ski resort and 25 km northwest from Courtenay, British Columbia. The site is accessible from the road serving the Mount Washington ski resort, but snow conditions preclude ground access during seven months of the year. A general location of the minesite, in relation to local access and drainage systems, is presented on Figure 1.

The minesite occurs at the northern end of the physiographic feature known as Forbidden Plateau. The local high ground is Mount Washington at an altitude of 1,590 m. A northwesterly trending ridge extends from the peak to the vicinity of the minesite. Across the minesite, which is located on the crest of the ridge, the ground surface varies from 1375 m to about 1320 m. The eastern and western flanks of the ridge are steep-sided, and drop away from the crest at slopes of up to 22 degrees. To the north, the front of the ridge drops in a series of steps.

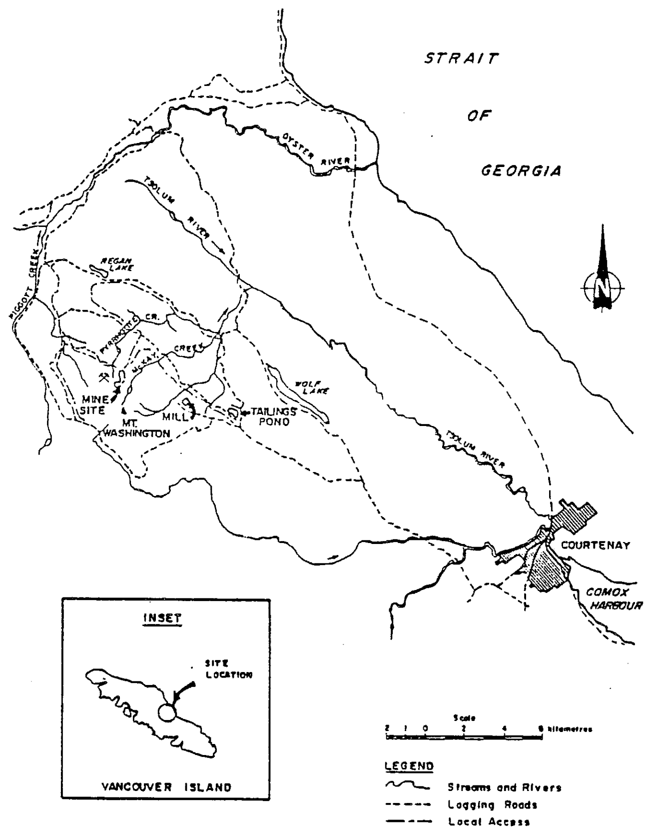

FIGURE I VICINITY MAP

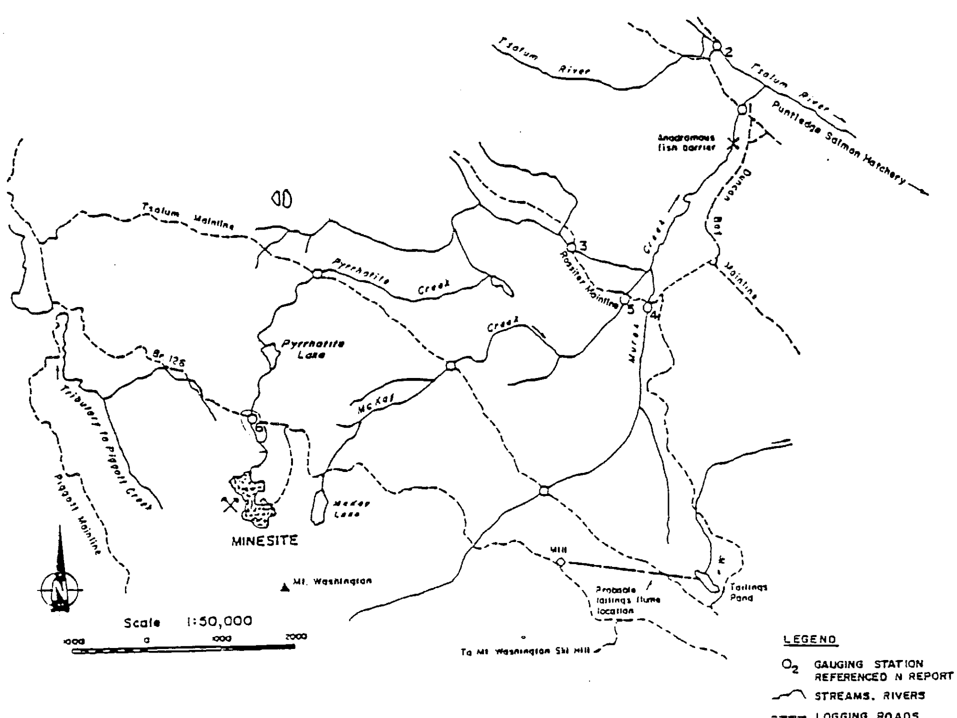

FIGURE 2 MINE SITE DRAINAGE AND GAUGING LOCATIONS

Around the ridge, each flank drains to a different stream watershed. The northern and eastern flanks are the catchments for streams ultimately discharging to the Tsolum River. The western flank of the ridge drains to Piggott Creek, a tributary of the Oyster River. Figure 2 shows a more detailed layout of the minesite, and the drainage basins.

The bedrock underlying the site consists of marine extruded volcanics of the Karmutsen Group, marine sedimentary units of the Comox Group, and dioritic plugs and sills related to Tertiary intrusions. The surface has been sculpted by alpine glaciation, and, accordingly, the surficial deposits consist of morainal deposits and soils derived by insitu weathering. Soil development is sparse.

The minesite consists of two blocks: a southern block containing the main open pit with a waste dump along the southern perimeter, and a northern block containing a shallower open pit with two major waste dumps in addition to several smaller piles of waste rock. The south pit is estimated to be 24 metres in depth and covers an area of about 2 ha. Drainage from this pit and the dumps does not appear to contribute significant AMD and this area was not included in the abatement study.

The North Pit and waste dumps, which can be seen in the aerial photograph on Figure 3, cover an area of about 7.4 ha. Locally, pit excavation reaches a depth of up to 10 m, but, in general, excavation is less than 5 m deep. The pit covers an area of about 4.4 ha at the southern end of the block, while the two major waste dumps - the East and West Dumps - had been developed over 3 ha around the northern perimeter of the block. Within the pit area, several small piles of waste rock were left. From north to south across the north pit and waste dumps, the ground surface drops about 60 m.

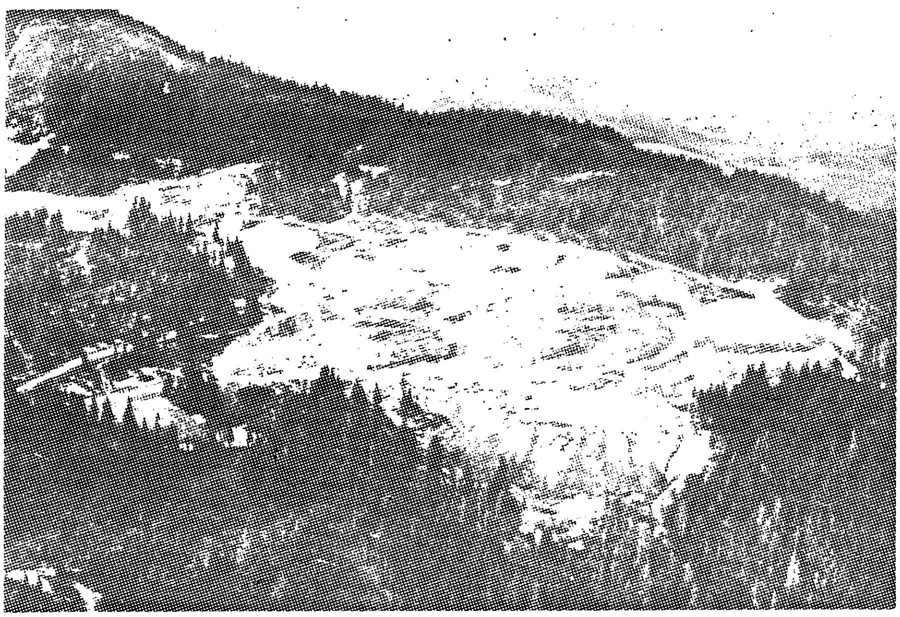

Figure 3. Aerial View of North Pit and Dumps before Reclamation.

Activity in the vicinity of the mine dates back to the 1930's when initial exploratory work was undertaken. Mining commenced in 1964 and ended in November 1966. Ore was processed through a 750 tpd mill between 1965 and March 1967, and the associated mining produced 1.03 million tons of waste rock and overburden.

WASTE CHARACTERIZATION

The bedrock is relatively homogeneous consisting primarily of felsic volcanics which, in places, is heavily weathered and extensively oxidized. The sulphide minerals occurring in the rock comprise pyrite, chalcopyrite, pyrrhotite and arsenopyrite. The waste material in the piles consists mainly of a pit-run material obtained by blasting and excavation of the adjacent bedrock, varying in size from 10 mm to 40 mm. In places, however, large boulders up to 1 metre in diameter were uncovered.

The chemistry of the seeps along the toe of waste dumps provided reasonable evidence of the presence of acid generating materials at the minesite. Seep surveys, completed prior to commencement of the abatement program, registered average pH values of 3.3; sulphate levels in the order of 400 mg/l; and copper concentrations of 17 mg/l. Acid base accounting tests completed on rock samples collected from within the pit areas indicated that the net neutralization potential of the waste material varied from -5 up to -290 kg of calcium carbonate equivalent per tonne of sample. These results indicated that on average the waste rock had a relatively high potential for acid generation.

ACID DRAINAGE

The contaminant transportation mechanism at the study area is a combination of seepage and surface runoff from snowmelt and precipitation. The drainage system appears to involve local recharge of perched flow paths in both the pit and the dumps, well above the deeper regional groundwater (estimated at greater than 30 m). The total contaminant loading at the toe of the dumps is generated from infiltration leaching of the stockpiled waste material and from the seeps in the pit area. Water quality analyses of the seeps in the pit area indicates the discharge is acid and high in metal content before it enters the waste material in the dump.

Acid drainage from the dumps and the pit area are within the Pyrrhotite Creek catchment and contribute a significant contaminant load to the creek. The Pyrrhotite Creek chemistry indicates low pH, high copper and moderate sulphate levels. A plot of the copper levels in Pyrrhotite Creek at a recording station 1 kilometre below the minesite, is presented on Figure 4.

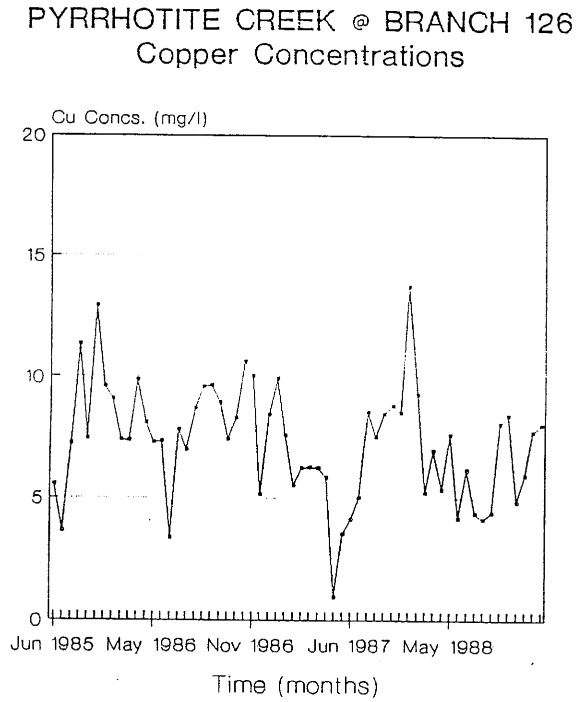

Figure 4. Copper Levels in Pyrrhotite Cr

ABATEMENT PLAN

Chemical oxidation requires the presence of reactive sulphide, water and oxygen. Biological oxidation can considerably increase the rate of acid production under favourable conditions. Thiobacillus ferrooxidans is the most important of a number of bacteria species which promote acid generation. This species of bacteria requires oxygen and is not effective in anaerobic conditions or where oxygen is precluded. Biological oxidation increases considerably once the pH drops below about 3.5.

It follows that acid generation can be controlled or reduced by:

- removal of sulphide
- exclusion or limitation of water
- exclusion or limitation of oxygen
- exclusion of bacterial activity.

The method selected for the control of AMD at the Mount Washington minesite was the construction of a low permeability compacted till cover over the waste material. The objective of the cover was to reduce access of water and oxygen to the waste material. Although the cover would not exclude water and oxygen to the extent that acid generation could not occur, the migration of AMD would be significantly reduced.

The plan involved collecting mine waste from the existing stockpiles and from the pit floor and consolidating the material into one dump. A 1-metre cover of compacted till would then be placed over the consolidated waste and an internal interceptor drain would be installed along the toe of the dump to control internal discharge. The collected seepage would be directed into a till-lined sump and discharged to Pyrrhotite Creek via a neutralization channel containing limestone. A till-lined diversion ditch would be constructed below the pit area to intercept seepage and runoff before it entered the dump.

The program also required the installation of gas monitoring wells within the dump and continuous flow recording devices and lysimeters.

DESIGN ASPECTS

The till cover was designed as two 500 mm thick layers. The lower layer would be compacted to 95 percent of the Modified Proctor maximum dry density and would function as a low permeability barrier to infiltration. The upper or cover layer would have a relatively high permeability and would be compacted to 90 percent of the Modified Proctor maximum dry density. The cover layer would allow sufficient moisture to reach the barrier layer, preventing cracking of the barrier layer.

Estimates of the surface runoff, subsurface drainage and infiltration for the till cover were developed using the Hydrologic Evaluation of Landfill Performance (HELP) program developed by E.P.A. The model accepts climatological, soil and design data and accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. A typical profile of the till cover and dump used in the model is shown on Figure 5.

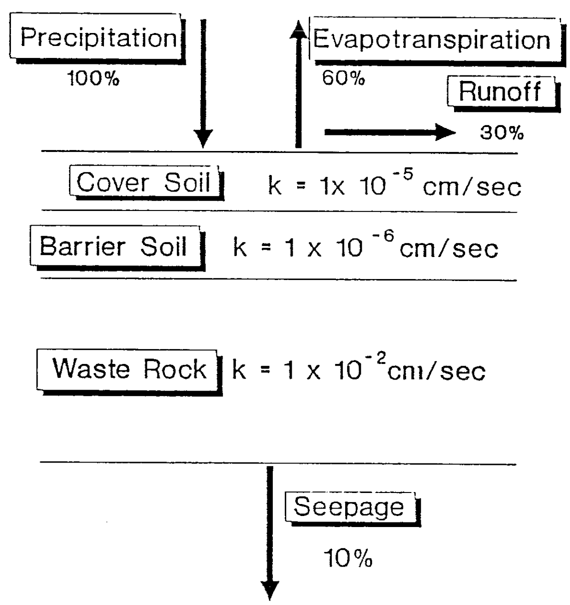

Figure 5. Typical Section for Infiltration Barrier

The design configuration for the dump required downstream slopes of 3:1 (horizontal to vertical). Compaction of the till covers on slopes steeper than this was considered impractical. The backslope of the dump was designed with a gradient of 5 percent to provide reasonable drainage without causing erosion. A typical section through the dump is shown on Figure 6.

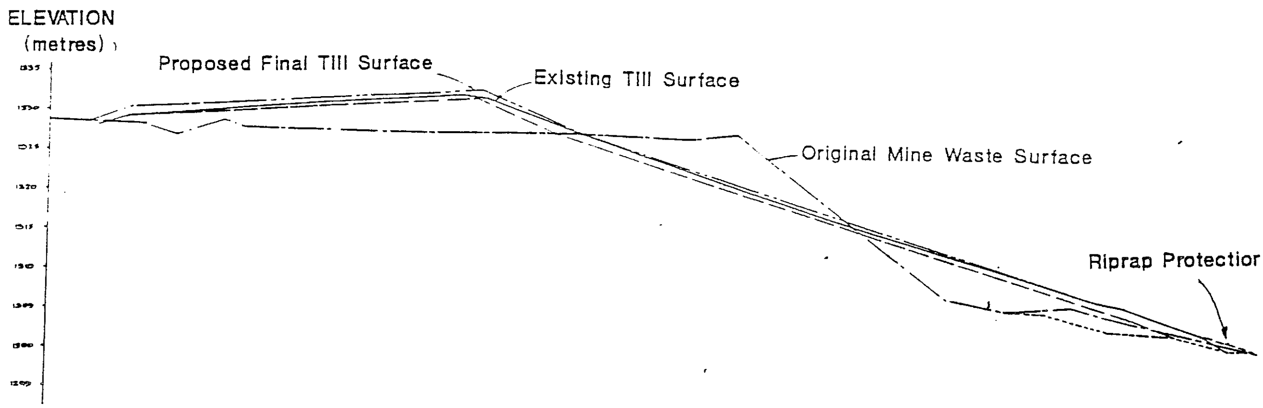

Figure 6. Typical Section Through Dump

The original design called for a central diversion ditch to intercept seepage and runoff from the pit area and surface drainage from the backslope of the dump. The design required the ditch to extend 500 mm into the bedrock with the invert and north flank of the ditch sealed with a gunite liner. Test pits excavated during construction, however, indicated that the depth of minewaste in the pit area was deeper than originally believed. Observations of the seep patterns within the pit during both wet and dry periods indicated that the seepage flows over the bedrock surface and then disappears back into the highly porous mine waste or fractured insitu bedrock. In an attempt to intercept the seepage, the ditch was realigned to follow the bedrock contour, as shown on Figure 7. The ditch was also downgraded to a temporary till-lined diversion ditch which would be replaced during the 1989 construction season with a permanent impervious channel.

The toe interceptor drain was designed to collect seepage from the dump and concentrate the flow to a sump located at the toe of the dump., The sump located within the dump would be sealed with glacial till and backfilled with drain rock. The outlet would be a 150 mm plastic overflow pipe. The sump was designed to allow discharge through the pipe while inhibiting air or oxygen entry. A typical section through the sump and overflow pipe is shown on Figure 8.

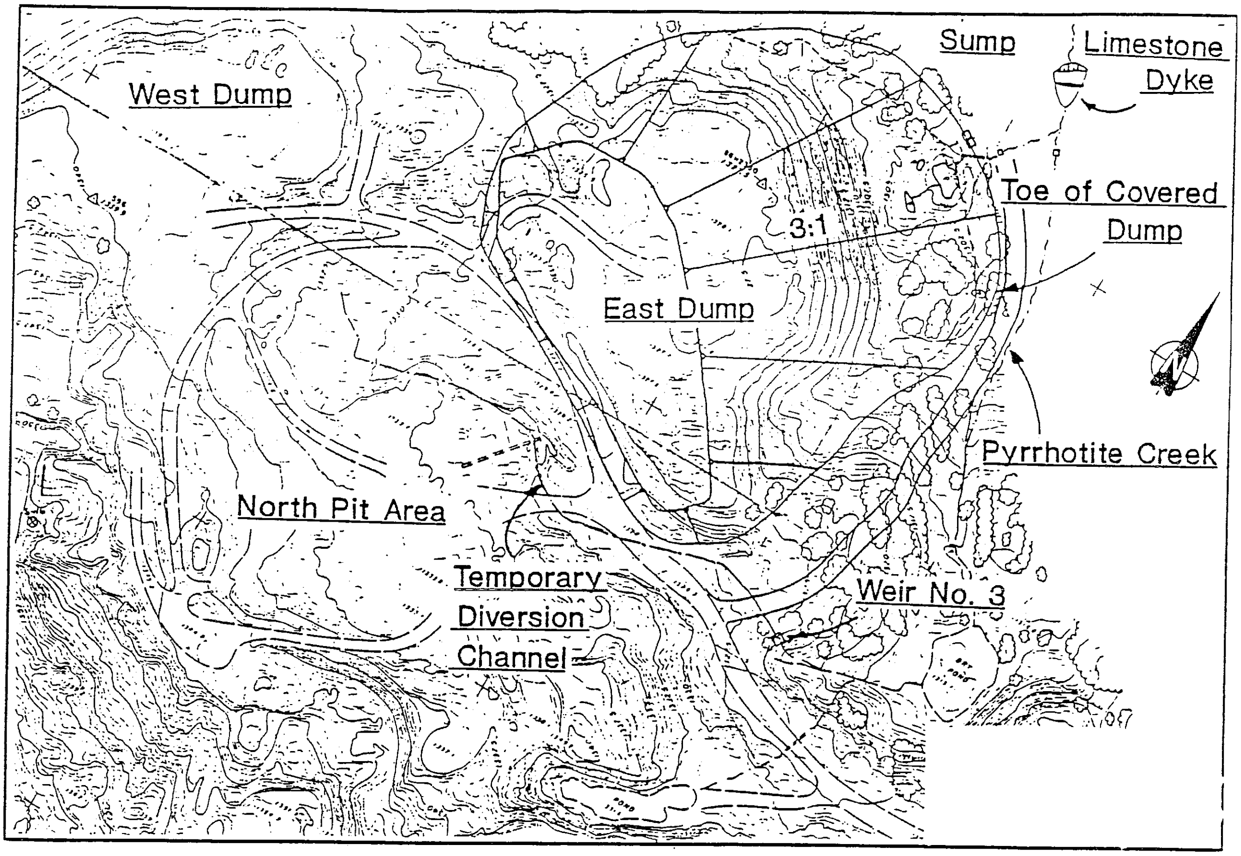

Figure 7. Site Plan East Dump and North Pit

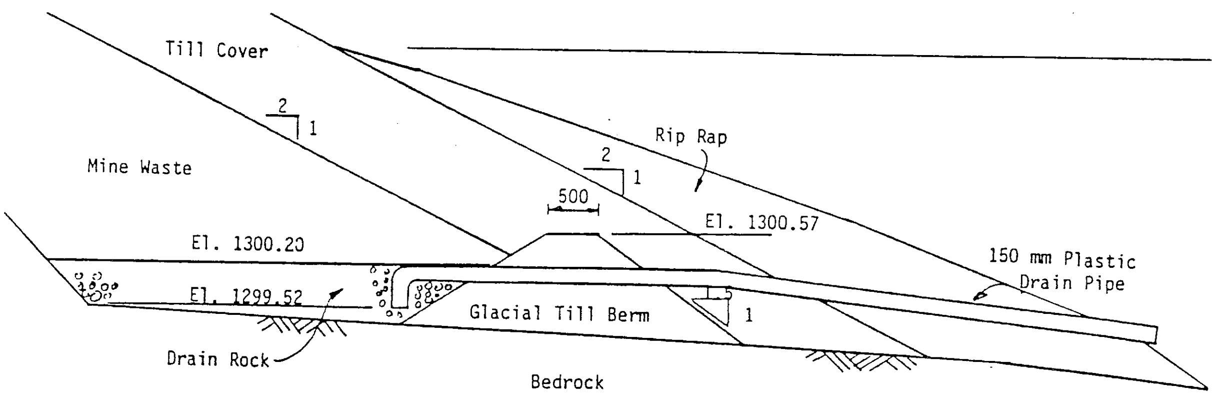

Figure 8. Sump Detail.

CONSTRUCTION ACTIVITIES

Construction of Phase 1 of the minesite reclamation was completed between July and October 1988. During this period, the following major elements were constructed:

- Construction of 176 m of toe seepage collection ditch, sump and neutralization channel;
- Collection and consolidation of about 22,000 cubic metres of mine waste;
- Mixing of limestone with the mine waste material at a rate of mix of 0.5 percent by weight (10 kg per cubic metre of waste);
- Placement of 6,600 cubic metres of glacial till cover;
- Construction of 210 m of lined diversion ditch within the pit floor area;
- Construction of a limestone flow-through dam as a temporary pH control measure.

An aerial view taken midway during construction indicating the various activities is shown on Figure 9. Earthmoving equipment are shown placing and spreading the waste rock on the northerly face of the dump. The white patches are areas which have been treated with limestone. A portion of the seepage collection ditch is visible around the left toe of the dump.

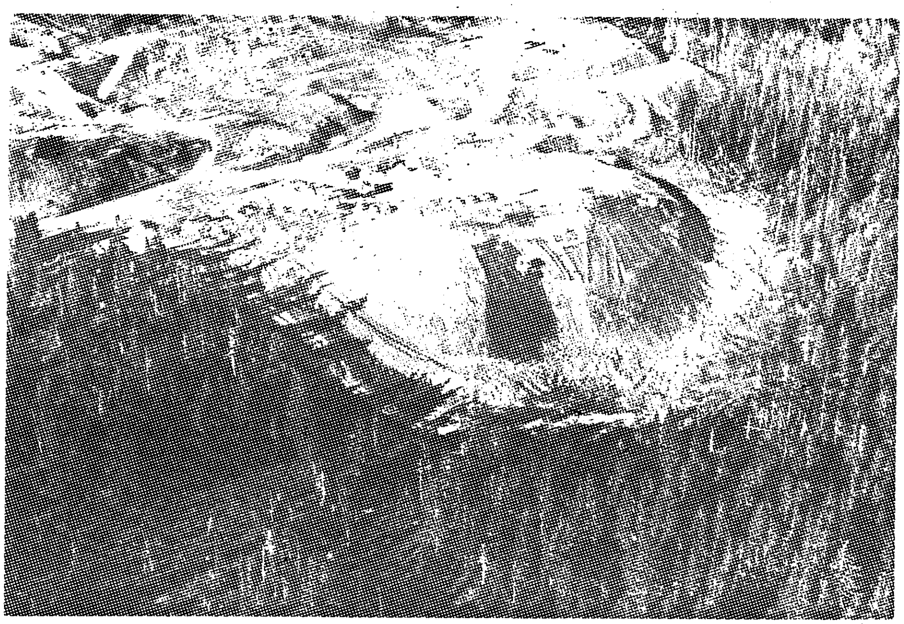

Figure 9. Aerial View of East Dump and North Pit during Reclamation.

Wet weather towards the end of the 1988 construction season halted till placement with only about 40 percent of the design volume of till placed. The till cover will be completed during the 1989 construction season.

CONCLUSIONS

It was recognized that disturbance of the waste rock during excavation and recontouring would result in flushing of additional acid generated products when precipitation or groundwater subsequently flowed through the waste rock. To suppress these effects, the designs for the minesite reclamation required that finely ground limestone be spread over the surface receiving waste rock and be mixed with any waste rock which was moved. Provision was made to monitor pH in the stream below the East Dump and for dosing the stream with sodium carbonate, to increase pH, in the event that construction significantly increased the acid drainage.

As mentioned earlier, the pH of the seepage water at the toe of the East Dump, prior to construction, averaged about 3.3. During recontouring and placement of waste rock, spot pH measurements of discharge from the sump pipes indicated pH values in the order of 5.1 to 5.5. It was concluded, therefore, that the limestone addition was successful in buffering and increasing pH, at least during the construction phase. The provision for dosing the stream, as a pH control measure, was not used.

The B.C. Water Management Branch has sampled water from the seeps and in Pyrrhotite Creek prior to and during the 1988 construction activities. However, the period of record including and following the 1988 construction is too short to conclusively demonstrate an improvement in water quality. Further, because the till cover was not completed to the thickness required in the design, the effectiveness of the cover is, as yet, difficult to assess.

The activities planned for the 1989 season involve completion of the till cover, construction of a permanent diversion channel, a groundwater study and placement of a till cover over the pit floor area between the proposed diversion ditch and the existing dump.

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