ABSTRACT

While Inco has been reclaiming mining impacted land for many decades, an in-depth planning process for the closure of its operating sites, along with a commitment to rehabilitate its inactive sites, began in the 1990's. Changes to the Mining Act in 1991 required mining companies to submit detailed closure plans for all active properties, and as such Inco submitted 15 plans between 1994 and 1998. Further changes to this legislation in 2000 led to the resubmission of all of these plans as certified documents in 2001.

This paper will review Inco's process for developing closure plans for the Ontario Division, including descriptions of the technical studies completed in support of the plans, and the rationale for the selection of closure concepts. The paper will also outline some of the research initiatives that Inco has undertaken over the years to assist in developing cost-effective and environmentally responsible closure techniques. Examples of closure plan implementation at a variety of sites will be provided.

INTRODUCTION

Inco began mining in the Sudbury Basin as a newly formed company in 1902, however it was nearly 100 years later that the first closure plans were developed, outlining the work that will be undertaken to decommissioning these sites. Closure planning for Inco's Ontario Division operations began in the early 1990's, following significant changes made to the Ontario Mining Act with respect to the rehabilitation of mining and processing facilities. In 1994, the closure plan for the Crean Hill Mine was submitted, followed by 14 other plans by 1998. The $4.5 million dollar closure project spanned a period of 4 years, and included the completion of many technical studies as well as research initiatives to aid in the development of the closure concepts.

In Ontario, the active Inco operations consisted of fourteen mines, two mills, a smelter, three refineries and a tailings facility. For the purposes of closure planning, some facilities were grouped together because of their proximity to one another and the resultant interdependence with respect to infrastructure, underground workings and drainage basins. In total, 15 closure plans were submitted for the following sites:
Crean Hill Mine (1994)
Whistle Mine (1995)
Shebandowan Mine and Mill (1996)
Creighton Mine (1998)
McCreedy West, Levack, Coleman, McCreedy East Mines (1998)
North Mine (1998)
South Mine (1998)
Clarabelle Mill (1998)
Copper Cliff Smelter (1998)
Copper Cliff Copper Refinery (1998)
Copper Cliff Nickel Refinery (1998)
Port Colborne Refinery (1998)
Central Tailings Area (1998)

CLOSURE PLAN DEVELOPMENT

Many issues were taken into consideration in the development of the closure plans, including the safety hazard associated with open pits and crown pillars, the variability in expected facility life across the Division, the interdependencies between the sites and most significantly, the issue of Acid Mine Drainage (AMD) from both waste rock and tailings. Preliminary surveys were completed in order estimate the volume of waste materials (waste rock, slag and tailings) stored at all of our sites as well as location and size of potential resources such as open pits and stopes, and topographic lows that would facilitate the flooding of materials. Initially, several closure concepts were developed, along with ballpark estimates to assist with the comparison of alternatives.

The contract for the development of closure plans for 14 of the 15 closure plans was awarded to Klohn-Crippen Consultants in 1994. (The first closure plan was developed in-house and submitted in 1994). The first phase of the project was a detailed data collection project, in which extensive background information was gathered for each site and assessed to determine where the gaps were. As a result of this gap analysis, a number of technical studies were initiated at each site:
Hydrological and Hydrogeological Studies
• Geomechanical and Geotechnical Studies
• Waste Rock Characterization
• Environmental Baseline Studies

These studies were completed between 1995 and 1997, the results of which were used to identify potential areas of concern, both physical and chemical, and to highlight the issues that would have to be addressed when developing the closure concepts. Where contaminant plumes were identified, for example, the plan called for cut-off walls, collection ditches or submerged drains. Where surface water receptors showed signs of degradation, potential sources of contamination were identified for removal or capping. The ultimate goal of each plan is to address all safety and environmental concerns, and to revert the site to some semblance of its pre-mining state, or a suitable alternative.

Preliminary engineering and estimating was completed for a number of closure alternatives, again taking into consideration the cost of each to assist with the selection of the preferred alternative. The selected alternative was developed and further refined for inclusion in the final plan, but ultimately the plans are still only conceptual in nature. Most sites are decades away from closure, with many changes expected to take place over the years. The closure plans are assumed to be living documents, with amendments to be submitted to reflect the changes that take place on site, as well as changes to the concepts as technological advances are made.

RESUBMISSION OF CLOSURE PLANS - 2001

The review process for the closure plans under the 1991 legislation was quite arduous and time consuming, for both the government and industry. By June of 2000, at which time the Mining Act was revised once again, just over half of the Inco closure plans had been reviewed, and only one officially accepted. As a result of the change in legislation, any closure plans not previously "accepted", and for which financial assurance had not been provided, would have to be resubmitted as "certified" plans. Inco then agreed to a new schedule for resubmission of all 15 of its closure plans, and opted to self-assure (an allowable form of financial assurance) for the first half-life of the operation where possible.

The closure plans previously submitted were returned, and Inco re-wrote the plans to reflect the required changes in formatting, as well as actual changes that had taken place at each of the sites. In addition,
certain sections of the closure plans now require "certification" by qualified professionals, to ensure that the information provided in the plan meets the requirements of Regulation 240/00 as well as the Mine Rehabilitation Code. In some instances, the previous work did in fact meet the requirements, but in other cases, certified work plans were presented, outlining the additional work that would be required to fulfill our obligations under the Act, along with a schedule for completion. The most significant deficiency identified pertained to groundwater characterization, where additional detail is needed to define the spatial extent of groundwater contaminant plumes, the degree of plume attenuation capacity and arrival times at suspected receptors. Groundwater investigations will be initiated this fall, and will continue into 2003. Other studies, including geomechanical investigations and waste rock characterizations, are scheduled for 2002. The results of these studies will be used to further develop the closure plans, and help to focus current progressive rehabilitation activities.

RESEARCH INITIATIVES TO SUPPORT REHABILITATION PLANS

Over the years, Inco has initiated a variety of R&D projects in conjunction with a variety of Universities, to aid in the development of environmentally sound, cost-effective closure measures. Much of the focus of the research work has centred on methods of closure for the Central Tailings basin, which represents the greatest long-term liability for the Division. The basin currently contains in excess of 480 million tonnes of tailings, and grows by approximately 6 million tonnes each year. Treatment of the seepage from the basin is expected to continue into perpetuity. Examples of research conducted on the tailings are given below.

**Low Sulphur Tailings Test Plots.** The use of low sulphur tailings as a cover material was examined by constructing lysimeter test plots using tailings of different sulphur contents, and monitoring the seepage water quality from each. It was found that while pH improved with a reduction in sulphur content, the metal content in the lowest sulphur tailings remained elevated.

**Submerged/Anoxic Seepage Collection System.** A submerged water collection system was designed to capture seepage from the toe of a tailings dam, prior to exiting the dam. Collection of this effluent prior to exposure to atmospheric conditions would mean a reduction in oxidation and precipitate formation at the dam toe, thereby reducing clogging of the toe drains. This would in turn prevent increases in the phreatic surface within the dams, and improve dam stability. In addition, this system would allow the separation of clean surface runoff from contaminated toe seepage, and hence reduce the volume of water.
requiring treatment. This methodology has been proposed for a number of our shorter perimeter dams in the tailings basin.

**Biodiversity Studies.** A number of studies have been launched over the years to examine the biodiversity of both plant and animal life within the revegetated areas of the tailings facility. Reclamation work traditionally involves a lime, fertilizer and seed application, followed up by straw mulching to assist in germination and seed protection. Once grasses are established, pine seedlings are planted. While deciduous varieties have invaded over time naturally, the basin is still predominantly an evergreen forest. In order to determine whether this monoculture would be sustainable over time, studies that examined the populations of spiders, mites and beetles on the forest floor were undertaken. These species, if present in sufficient number and variety, would indicate a healthy ecosystem. Results to date have shown such a trend. Inco continues to progressively reclaim inactive areas of the tailings basin.

**Water Cover Research.** Inco has supported a number of water cover research projects, undertaken by groups such as CANMET and the University of Western Ontario. A water cover is currently being used at the Shebandowan Mine Site, as a means of decommissioning the tailings basin. Research conducted on the resuspension of tailings as a result of wind/wave action, as it pertains to minimum water depth and wave break placement, was utilized when implementing the closure concept for the area.

**Biosolids as a Cover Material.** Experimental plots were constructed utilizing biosolids from the pulp and paper industry as a cover material on tailings. Vegetation growth on the plots has been phenomenal, and monitoring of tailings porewater quality and metal uptake in the plants is ongoing.

**Tailings. Waste Rock and Slag Co-mix as a Cover Material.** A project is currently underway to investigate the use of tailings, waste rock and slag together as geotechnically/geochemically sound cover material for tailings and possibly waste rock. Instrumented test plots will be constructed if a viable mix can be identified.

**CLOSURE PLAN IMPLEMENTATION**

As sites approach the end of their expected mine life, the closure concepts are further refined by completing detailed engineering and estimating, and then move into implementing the plans. Inco is currently in the process of decommissioning three of its sites - the Whistle Open Pit operation, the Shebandowan Mine and Mill in Thunder Bay, and the Crean Hill Mine.
Whistle Mine Closure Implementation

Inco’s Whistle Mine was an open pit operation located approximately 20 miles north of the City of Sudbury. The site was mined from 1988 to 1991 and again from 1994 to 1998, producing nearly 5 million tons of ore and over 7 million tons or 4 million cubic yards of waste rock. The waste rock was stored in two waste dumps immediately North of the open pit, covering an area of approximately 35 acres. The open pit itself had an estimated volume of 4,150,000 cubic yards, and covered an area of 1,045,900 square feet (Figure 1).

![Figure 1: Whistle Mine Site - Open Pit Operation](image)

Closure plans for this site include the relocation of the waste rock into the void and the placement of an engineered cover over the filled pit to reduce both oxygen and water infiltration. Waste rock relocation began in August of 2000, and involved placement of the rock in 8 foot lifts; material was dumped, spread, and compacted in shallow lifts in order to avoid excessive settlement in the fill material once the cover has been placed (Figures 2 and 3). The final lift of waste rock will be reduced to four feet and will comprise smaller sized particles to facilitate better compaction and a smoother surface for the cover.
Geochemical modelling was conducted by SENES to simulate the pit filling process and determine the predicted pit water quality after closure. The results showed that the addition of two pounds of lime per ton of waste rock will effectively neutralize the acidity as well as lower the concentration of metals in the pit water overflow. Consequently, lime was added at the prescribed rate to each load of waste rock prior to dumping. Acidity testing of the waste rock was conducted on a regular basis to ensure that the lime addition rates were appropriate.

Figure 2: Whistle Mine Pit Filling - May 2001
Figure 3: Whistle Pit Filling - June 2002

Original ground beneath the old waste rock storage area was machine cleaned, leaving behind a substantial volume of oxidized waste rock and metal contaminated soils. The bedrock ridges are now being washed to further reduce the potential for long term flushing of contaminants (Figure 4). The area will later be limed and seeded to promote the regreening of the area.
The final cover for the pit will consist of a barrier material with a low hydraulic conductivity to minimize the infiltration of water into the pit, as well as a coarse-grained layer that will act as an evaporative break and ensure the saturation of the barrier material. The cover design also includes a geotextile that will separate the waste rock from the barrier material and add an element of tensile strength to the cover in the event of greater-than-expected settlement of the waste rock.

Test plots were constructed on site in 2000 to test a variety of potential barrier materials: a sand-bentonite mixture, a silt/trace clay and a geosynthetic clay liner (GCL) (Figures 5-7). The plots have been extensively instrumented with lysimeters, an O₂/CO₂ gas measurement system, soil suction and temperature sensors, in-situ volumetric water content sensors, a surface runoff collection and monitoring system as well as a meteorological station. The performance of the various covers has been monitored for the last few years to determine the most suitable material for full-scale use. Final design of the cover will be completed this year. Similar performance monitoring instrumentation will be installed in the final pit cover.
Figure 5: Whistle Test Plot Construction - Liner

Figure 6: Whistle Test Plot Construction - Waste Rock Pad and Lysimeters
Waste rock relocation and the cleaning of original ground are expected to be complete in 2002. The pit cover is scheduled for installation in 2003, and long term monitoring of the cover performance will begin. In the interim, additional geochemical modelling is planned to refine predictions of water quality from the filled and covered pit.

CONCLUSIONS

Inco continues to participate in research initiatives in order to develop decommissioning strategies that will be effective in the long-term. Ongoing monitoring of sites during and after rehabilitation is also an important component of closure planning for the Division. Performance monitoring of both wet and dry covers utilized at various mines will guide us in the development of plans for other sites that are destined for closure. Closure plans will continue to be revised on a regular basis to incorporate the knowledge that is gained through these studies and mine closure implementations.