SUSTAINABLE LONG TERM CLOSURE AND RECLAMATION SOLUTIONS AT MANIBRIDGE MINE SITE IN MANITOBA

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Abstract: This paper presents the strategies and technologies applied in implementing the closure and land reclamation of the former Manibridge Mine site. The Manibridge Mine is an inactive nickel mine site, located approximately 130 km south of Thompson, Manitoba, near the Town of Wabowden. The former mine operated between 1971 and 1977, producing approximately 14 million pounds of nickel and 0.55 million pounds of copper. The mine was closed in 1977 and has been inactive ever since. The site is located near several lakes used for fishing and other recreational pursuits. In 2004 Falconbridge Limited submitted a Closure Plan to the Manitoba Mines Branch under Regulation MR67/99, which was approved by the Provincial regulators. Since then, implementation of the closure plan and rehabilitation of the site has been carried out.

This paper describes the reclamation process underway, from the preparation of the closure plan to the implementation, and to the post-closure monitoring program that Xstrata will be undertaking starting in summer of 2007. The paper details the solutions arrived at to provide cost effective methods and technologies that met construction challenges and safety concerns. These solutions were aimed at ensuring long term stability of the main site features. This case study will further describe the implementation of sustainable solutions and the community involvement approach adopted for the reclamation and revegetation of the site. The adopted approach is to allow for a maintenance-free, accessible and safe post-closure life for the former mine site.

Key Words: Mine closure, closure plan, water quality, dam safety, sustainability, spillway design, rehabilitation, revegetation, tree planting, community involvement.

Introduction

Background Information and Site History

The Manibridge Mine site is located approximately 130 km south of Thompson, just southeast of the Town of Wabowden in central Manitoba, between Provincial Trunk Highway No. 6 and Clarke Lake, as shown in Figure 1.

Falconbridge Nickel Mines Ltd. commenced a systematic exploration program in the area of the Manibridge mine in 1959. This area is the southern part of the Precambrian area of north-central Manitoba referred to as the Thompson Nickel Belt. Following geophysical and diamond drilling...
exploration effort, an ore-grade nickel mineralization zone was discovered in the late 1960s containing 1,409,100 tons of ore grading 2.55% nickel and 0.27% copper. The Manibridge Mine operated between 1971 and 1977 at a rated capacity of approximately 1,000 tons per day, producing approximately 50,000 tons of concentrate annually, containing about 14 million pounds of nickel and 0.55 million pounds of copper.

The mine ceased operations in April 1977 with the exhaustion of the known economic ore reserve and has been inactive ever since. Gross-scale demolition works of site infrastructure occurred soon after closure. All major surface infrastructure and buildings were subsequently removed, leaving behind concrete foundations and the tailings impoundment. Hazardous materials were removed from the underground mine workings which were subsequently allowed to naturally flood. The three entryways into the underground mine workings (a 433 m deep vertical shaft and two ventilation raises) were subsequently sealed with the installation of concrete caps. Figure 2 presents a general view of the main surface facilities present in the early 1970s at the site while in operation.
Figure 2: General view of Manibridge mine site in operation (circa 1971).

Site Location

The Manibridge Mine site is located approximately 130 km south of the City of Thompson, just southeast of the Town of Wabowden in central Manitoba, between Provincial Trunk Highway No. 6 and Clarke Lake, at latitude 54° 42’ N and longitude 98° 50’ W. It is at the north end of Lake Winnipeg, approximately 610 km north of the City of Winnipeg. Figure 1 presents a general site location map showing the mine site location in relation to the City of Thompson and PTH #6.

General Site Conditions and Characteristics

The Manibridge mine site encompasses a total area of approximately 270 acres. The tailings impoundment covers an area of approximately 65 acres while the former mine site surface facilities occupied an area of approximately 15 ha for a total disturbed area of approximately 80 acres out of the total 270 acres site. Figure 3 presents an aerial photo of the site, with visible surface facilities including the access roads, the mine yard, and the tailings pond.
The mine site area was originally a native boreal forest with numerous small bogs and lakes. The former mine site was relatively flat lying with bedrock outcrops present at the west and east sides of the site. The area formerly occupied by the service building is typically marshy during wet periods.

The topography in the region of the site varies from nearly level to rolling, with undulating and hummocky terrain being most common, and is mainly controlled by bedrock. Topography is subdued by the development of organic landforms (bogs and fens) in depressions and on gentle slopes and the drainage pattern is, in general, poorly defined. The vegetation in the area consists of trees and low brush. Lakes of various sizes are common in the area. The larger lakes in the immediate vicinity include Clarke Lake, Lily Pad Lake, Conlin Lake, Kiski Lake, Gormley Lake and Setting Lake. Major rivers include the Muhigan, Grass and Nelson; many smaller streams carrying waters from fens and bogs drain into the lakes and rivers. The mine site is located primarily within the Muhigan River drainage.

The site has a continental climate typical of the Central Canada Region, with long, cold winters and short, cool summers. Average temperatures range from -25 deg Celsius in December to +16 deg. Celsius in July. Meteorological data from Thompson Airport indicate an average annual total precipitation of 523
mm (20.6 in), comprising of 67% rainfall and 33% snowfall, on average. Rainfall occurs mainly in the summer months.

**Regional and Local Geology**

The Manibridge nickel deposit is located 2 km east of the Setting Lake lineament and approximately 10 km west of the Churchill-Superior province boundary. Between these geologic features the area is underlain by wide belts of mixed, banded and granitized granodiorite gneissess and associated syntectonic felsic intrusions.

In general, the Manibridge nickel deposit occurs on the southeast or hanging-wall side of an elongate serpentinized ultramafic body in the Churchill-Superior province boundary zone. The ultramafic rock is associated with considerable pegmatite and the wallrocks consist of amphibole gneiss, amphibolite, pegmatite and their mylonitized equivalents.

The general overburden soil stratigraphy at the Manibridge, as noted in descending order from the ground surface, includes fills and organic soils, high plastic Lake Agassiz clays, silty sands and silts above bedrock horizon.

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**Manibridge Mine Closure Plan**

**Regulatory Framework and Objectives**

In January 2004, Xstrata submitted a Closure Plan to the Manitoba Mines Branch. The Mines Branch completed a review of this Plan and accepted it as a “road map” for the completion of reclamation at this site. It is the objective of the closure plan to return the Site and all of its claims on the property to the Province of Manitoba.

The closure plan prepared for Manibridge Mine site was developed to conform to the Mines and Minerals Act (C.C.S.M.c.M162), Manitoba Regulation 67/99, Mine Closure Regulation, as well as to “A Guide to the Management of Tailings Facilities” by the Mining Association of Canada and the “Dam Safety Guidelines” by the Canadian Dam Association.

Rehabilitation of the Manibridge site in a safe and environmentally sound manner is intended to achieve the following objectives:

- To ensure protection of public health and safety;
- To reduce or prevent ongoing environmental degradation associated with the site; and
- To rehabilitate the land to allow for a productive end use.

The scope of work laid out in the closure plan included, among other, mitigation measures related to some of the mine site’s major features remaining at the site, such as the crown pillar subsidence, several imposing building foundations, ore bin foundations, head frame and vent raise foundations, hoist house foundations, tailings impoundment area, access roads and mine yard, clean-up and revegetation of the site. Figure 4 presents some of the remaining surface facilities at the site, as of 2005. Returning the site to the Province of Manitoba will not take place until all remaining reclamation activity has been completed and ongoing environmental monitoring demonstrates that this site is not resulting in any degradation to the surrounding environment.

Based on acceptance of the Closure Plan by the Manitoba Mines Branch, the reclamation work was tendered and awarded during the early fall of 2005. In November 2005, the reclamation work was initiated following the initial plan. The following sections describe the major works performed and the sustainable solutions arrived at to provide cost effective methods and technologies that met construction
challenges and safety concerns. These solutions were aimed at ensuring long term stability of the main site features.

Figure 4: Manibridge mine site in the winter of 2005, with part of the remaining surface infrastructures in the background.

**Investigations and Field Work**

A number of assessments have been conducted at the Manibridge mine site during its operation and since its closure in April 1977. These assessments have included an acid-base accounting of the tailings, surface water quality at the site and nearby lakes, an underground radiation survey, and numerous inspections to ensure the on-going safety of the site.

Since the mine was closed in 1977, the mine site has been inspected by the District Mining Engineer of the Mines Branch on several occasions. A review of these inspection reports during the period of 1977 to 1984 also documents the rehabilitation measures undertaken by Falconbridge during this time period. The inspection reports describe the decommissioning of the structures, the progression of the subsidence at the crown pillar, the removal of hazardous and non-hazardous materials from the site, and various rehabilitation measures.

AMEC commenced site inspections and activities at the site in 2001, for the preparation of the closure plan, including baseline monitoring for surface and groundwater quality. As part of the development of this mine closure plan, AMEC conducted additional field investigations in 2003, including among other, sampling of the tailings for Static Acid-Base Accounting analyses, sampling of the potentially hydrocarbon contaminated soils at USTs locations, additional surface water quality sampling, and surveying of the tailings impoundment dike. In addition, concrete quantities were estimated, old concrete caps were cored and investigated, and a site inventory was tabulated. A number of laboratory tests were completed both in house and at specialized outside labs. It is noteworthy to mention that:

- under the BC MEM Acid-Base Accounting (ABA) Screening Criteria, all tailings samples were classified as having no acid generating potential (NPR>4, NNP >20.0) and strongly acid consuming. Paste pH indicates no net acidity has been generated even after 25 years.
• Surface water quality at each sample point met the MMER discharge criteria for all applicable parameters. MMER discharge criteria (Federal Fisheries Act) were applied for comparative purposes only, as this site is not covered by a current water license or permit that establishes allowable effluent discharge levels.

• CCME guidelines for the protection of freshwater aquatic life (FAQ) were also applied for comparison purposes. The results suggested the parameters of concern at this location can be narrowed to copper, zinc and iron. All other measured parameters were below CCME FAQ guidelines for all samples. All parameters for all samples were below the CCME guideline values for protection of livestock.

Dam Safety Review

A Dam Safety Review (DSR) was carried out by AMEC in the fall of 2004. The tailings disposal area was constructed adjacent to the mill, covering approximately 65 acres, and being surrounded by a low perimeter dyke (see Figure 5). The tailings disposal area received the overflow (slimes) from the first stage of cycloning after the flotation circuit, with the sand fraction being used for cemented backfill of underground openings. The dykes appear to have been developed in two stages, following a reasonably comprehensive site investigation program for that time. The design section comprised largely locally borrowed silt zone that was compacted in lifts with rockfill placed on both the upstream and downstream faces. The dykes are typically low, squat structures. It is considered that the dyke design and construction were advanced for the state-of-practice that would have prevailed at the time of site development. A survey of the south dyke crest has been undertaken to establish potential spillway locations, since a decant tower appears to be the sole water management element.

Figure 5: Manibridge mine tailings impoundment dykes (left) and ponded water (right).

Taking into consideration, among other, the location and accessibility to the site, the existing and expected (future) conditions of the ring dyke, the classification of the dykes, Xstrata’s dam safety program, and generally acceptable dam safety standards, the following conclusions are drawn from the results of the DSR carried out for dykes that create the tailings impoundment at the former Manibridge Mine:

• the dykes appear to have been adequately designed and constructed to standards that would be currently acceptable;
• the dykes are in good condition, and
• the dykes are classified in a very low consequence (‘hazard’) category.

Taking into consideration the dam classification and the site conditions, assumed to be consistent with the foreseeable future, the following recommendations were made and implemented:
• a dam safety program was outlined and implemented;
• a water balance was determined and completed for the site, for spillway design purposes;
• plans for a dry spillway were developed; the plans for the spillway address, among other issues, the potential impact of beaver activity, ice build-up and other winter specific conditions.

New Spillway Design and Construction

In assuming a conservative position, a Probable Maximum Precipitation (PMP) event was used to design the permanent spillway for a long term performance. Using the Thompson climate station data, a 24-hour PMP of 259 mm was estimated using the Hershfield method, established and supported by the World Meteorological Organization. The closure spillway is now located along the south dyke and designed to both facilitate existing roadway access and to permit flow passage into the existing effluent ditch that drains into Lily Pad Lake. In order to minimize beaver activity and to maintain vehicular traffic access along the south dyke, the spillway crest includes a wide base width of 10 m, and mild side slopes between 5H:1V to 10H:1V.

The maximum freeboard allowance between the spillway and dyke crest was calculated to be 1.0 m. Spillway crest, channel and stilling basin armorine was designed for maximum velocities and erosion control associated with the PMP storm. Sound and well graded cobbles and riprap material was designed to be used in conjunction with the underlying geosynthetic to limit fines migration. The spillway was completed in November 2005 (Figure 6).

![Figure 6: Closure spillway during construction (left) and in its final form.](image)

New Concrete Shaft Caps

AMEC evaluated and selected to re-cap the shaft and the two vent raises, as the old caps were in poor condition and did not meet current regulatory standards. In lieu of demolishing and replacing the old caps with new, cast in place concrete caps, AMEC chose to leave the old caps in place, build appropriate footings around them, and place designed pre-cast concrete caps over the old ones, as shown in Figure 7. The caps were manufactured at Lafarge’s Winnipeg plant and were delivered by trailers to the site. An attempt was made in December 2005 to prepare the vent raise areas for installation of the precast concrete
caps but cold weather prevented soil, from around the perimeter of these areas, from being removed. In addition, it was determined through excavation, that the mine shaft opening was larger than originally anticipated. In this regard, additional site work around the mine shaft was required in order to permit installation of the pre-cast concrete covers. This work was undertaken during the summer of 2006 and the caps were subsequently installed. Appropriate warning signage was also installed at each of the three locations.

Figure 7: Installing new pre-cast concrete caps on a vent raise (left) and on the old shaft.

Revegetation Program

Xstrata and AMEC retained the services of Native Plants Solutions (a division of Ducks Unlimited) to carry out site investigations, field and greenhouse trials, and prepare a suitable seed mix design for the revegetation of the mine site (tailings area, and mine yard) using a minimum amount of soil amendment. Permanent stabilization of the seedbed with a sustainable vegetative cover for erosion and dust control, improving visual impact, and recreating micro-habitat are the underlying objectives of the revegetation of the tailings and mine yard areas. The successful re-establishment of native grass vegetation as a component of this revegetation plan will contribute to suitable, long lasting cover. The seed mix design was derived after analysis of a variety of species tested in both the greenhouse and field trials, in addition to the investigation of native grass species growing in and around the tailings site.

Species richness and plant diversity contribute to increased structural diversity and patchiness. These desirable habitat features were considered and designed into the revegetation seed mix. A seed mix was designed for the site specific conditions at Manibrige mine based on the results of the 2005 greenhouse and test plot trials. The seed mix included both native plants and non-invasive, cultivated species. Both the tailings impoundment and the mine site area were re-vegetated in 2006, for a total area of approximately 80 acres. Specifications and details of the 2006 re-vegetation program prepared by NPS included, among other:

- Organic soil amendment (approximately 5 to 10 cm thick) which was stockpiled in the winter on the frozen tailings and spread in the spring and summer with lighter equipment. Organics were tilled to an average depth of 50 to 75 mm into the underlying substrate/fill material;
- The seed mix included eight native (fescue, tall grass, brome, etc) and six cultivated (timothy, alfalfa, barley, etc) species, and was mechanically placed (drilled) at a rate of 17 lbs / acre (see Figure 8);
• A granular ammonium phosphate formulation of 11-52-0 was broadcasted at an application rate of 150 pounds per acre;
• Area was compacted lightly after seeding.

Early results show promising results, with dense, healthy vegetation growing both on the tailings pond (Figure 8) and on the mine yard.

![Image](image1.png) ![Image](image2.png)

Figure 8: Revegetation program in progress using mechanical seeding (left), and its interim results at the test plot on the dry tailings section.

**Community Involvement and Partnership Program**

In addition to the revegetation program, Xstrata and AMEC have coordinated a partnership with Manitoba Conservation whereas Xstrata supplied 4,000 tree seedlings while Manitoba Conservation’s Natural Resources Branch supplied 8,000 seedlings. The trees were planted by AMEC personnel with the aid of Manitoba Conservation staff, The Boys and Girls Club of Thompson, MB, as well as students from the Wabowden public school. School children were bussed to the site, supplied with information about the history of the mine property, and taught how to plant seedlings in a two-day educational event that took place in the summer of 2007. In total, 10,000 white spruce, black spruce and jack pine seedlings were planted within the tailings impoundment area, and another 2,000 were planted and across the mine site and mine yard.

**Acknowledgements**

The authors wish to sincerely acknowledge Xstrata Nickel for allowing publishing the information. Special thanks are extended to Michael Patterson, John Stroiazzo and Mark Wiseman of Xstrata, with whom AMEC personnel worked closely throughout the years on this project. Their insight and support is appreciated.