ABSTRACT

This paper describes the process employed and the work undertaken to enable the surrender of the mine permit relating to the two tailings deposits at the abandoned Red Mountain Mine site near Rossland, BC. The first phase of the work undertaken was to provide urgent remedial work for protection of the environment, primarily through rehabilitation or replacement of surface water drainage systems. The second phase was to upgrade the water management systems to the appropriate level given their consequences of failure. The final phase of work is to ensure long term geotechnical stability of the facilities to the same level of risk. Establishment of a sustaining fund will facilitate long term monitoring and maintenance of the facilities.

INTRODUCTION

This paper describes the work undertaken to enable the surrender of the mine permit for the two tailings deposits at the abandoned Red Mountain Mine site near Rossland, BC. The mine is located approximately 4 km northwest of Rossland in the West Kootenay district of south-central British Columbia. The two tailings facilities are referred to as Good Friday, which is a side valley impoundment, and Jumbo, which is a cross-valley impoundment. Both are located in the headwaters of the Little Sheep Creek valley, 11 km upstream from the US border, as can be seen in Figure 1.

Historical Background

Mining by both underground and open pit methods has been conducted for many years in the general area. Gold mining had been prevalent in the early part of the century. In 1964 a number of claims were staked and a molybdenum deposit was outlined on a property assembled by Torwest Resources Limited. The property was then transformed to Red Mountain Mines Limited which was incorporated on April 20, 1965. The shareholders of the company were; Torwest (a predecessor company of Teck-Cominco) 60%, Consolidated Canadian Faraday (a predecessor company of Alberta Energy Corporation) 20%, and Canadian Nickel Company Limited (a wholly owned subsidiary of Inco Limited) 20%. The mine operated from 1966-1972 producing 6 million pounds of molybdenum sulphide concentrate from a series of 9 open pits on the west slope of Red Mountain. At the end of 1971, the mine was closed and the property sold to the shareholders. Inco held the permit and the mining property in trust for the owners.
The Technical and Research Committee on Reclamation

Figure 1. Location Map
and acted as a manager. Red Mountain Mines Limited was wound up on February 23, 1979 and no further work was done on the property which was sold to Helix Industries Limited in 1980. The ownership of the property has since changed a number of times. At this time Premanco Industries Ltd. owns the surface rights, while the sub-surface rights belong to the Crown.

Attention was focused on the site in 1997 when the Mines Branch of the BC Ministry of Energy and Mines (MEM) became aware of a prior, uncontrolled release of pond water over the Good Friday dam. In 1998, under the authority of the Mines Branch and acting as an agent for Mines Branch, Inco, with technical assistance from Klohn Crippen, made some temporary repairs to the Good Friday dam. Both tailings impoundments were inspected daily during the 1999 and 2000 freshet. Problems developed suddenly on June 4/5, 1999 when the old creek diversion culvert beneath the Jumbo dam failed, resulting in a series of emergency repairs, culminating on June 29, 1999 with the successful diversion of the creek around the tailings facility and the grouting of the culvert.

Site Conditions
At Red Mountain, folded Carboniferous and Jurassic sedimentary and volcanic rocks are intruded by a variety of younger igneous rocks; molybdenum, gold-silver-copper, and other mineralization is apparently centred on the mountain and related to local faciès of the Eocene Trail granodiorite batholith.

The average annual total precipitation, as rainfall equivalent at the nearby Rossland Maclean station, at an elevation of 1085 m, is 908 mm for the period of record (1964 -1988). Rainfall values were adjusted for elevation since the tailings facilities are located at an elevation of about 1300 m.

Water samples taken in Little Sheep Creek indicates that it seems to be relatively unaffected despite the historic mining activity. Variations in water quality are strongly influenced by dilution along the length of the stream. At the US border, the molybdenum concentration in Little Sheep Creek has consistently met the BC guideline for livestock water, since the in-stream work at Jumbo was completed in 1999, and the copper concentration similarly meets the aquatic life guideline. These are the most restrictive limits, respectively, for these parameters.

Good Friday Impoundment
The Good Friday impoundment covers an area of about 6 ha at an elevation of 1285 m as shown in Figure 2. The slope of the Red Mountain ski hill bounds the impoundment to the east and north while an earthfill dam, comprised of two limbs, bounds the impoundment to the south and west. The disused facility had a beach that sloped from north to south into a pond located against the southern arm of the perimeter dyke.
The only design or “as-built” drawings available were photocopies of B-size hand drawings from 1965, obtained from the mine design consulting company. The design drawings indicated the south limb to be a downstream constructed till-cored dam with an ultimate crest elevation of 1283 m, well below the current dam height, with an original ground elevation of 1268 m for a maximum design dam height of about 15 m. It appears that the south limb of the dam has been raised upstream, or at least the crest widened to about 15 m, using rockfill dressed with road base material, with tailings sand (likely hydraulically separated) upstream of the centreline of the crest. This south limb is generally in good condition.

The characteristics of the dam appear to change where the main dam (or south limb) joins the west limb. Observations suggest that this west limb is likely an upstream raised dam, as there is insufficient space to have constructed a downstream dam without impacting the main mine access road. The west limb of the impoundment is characterized by a significant amount of tailings sand with a downstream rockfill face, presumably for erosion protection. The thickness of the rockfill zone decreases northward as the dam height decreases. The northern half of the west limb is primarily a sand (tailings) dyke. The 1997 overtopping incident, at the south end of the west limb, has significantly altered the dam profile and may even have washed away most of the till starter dam in that area.

Design drawings also identify the presence of decant towers and associated structures located in the southeastern portion of the impoundment. At present only two, wooden, decant towers exit to the surface of the tailings.

**Jumbo Impoundment**

The Jumbo dam is a valley fill dam about 28 m high. It appears that the dam was built essentially to full height with rockfill, with upstream coarse and fine filter zones and a foundational blanket drain. The main structure appears stable. The dam impounds a 340 m long by 120 m wide tailings beach, which was normally dry except during the freshet. The beach is at about 1295 m elevation and the Little Sheep Creek valley at the dam toe is at about elevation 1270 m, as seen in Figure 2.

Until 1999, Jumbo Creek, now known as Little Sheep Creek, was intercepted upstream of the tailings beach and directed into a 600 mm diameter, asphalt coated, corrugated metal (CMP) diversion culvert. The culvert ran beneath the impoundment and discharged in mid-valley, into the water reclaim pond. By the time the culvert failed in 1999, the intake was about half filled with alluvial gravel and was surrounded by heavy second growth. The failure of this culvert caused the development of large sinkholes and release of tailings from the impoundment during early June, 1999.
The main operating decant for the impoundment was located at the south end of the impoundment. The decant was a wood structure.

ESTABLISH DESIGN CRITERIA AND RISK ASSESSMENT

Both the Mining Association of Canada (MAC) guidelines on Management of Tailings Facilities and the Canadian Dam Safety guidelines (CDA 1999) were followed to establish appropriate practice and criteria for the stabilization of the tailings facilities.

The initial step in the process is to define the classification of the facilities in terms of the "consequences of failure". A qualitative risk assessment using Failure Modes and Effects Analysis (FMEA) was undertaken in 1999. This is an engineering reliability technique used to systematically identify, characterize, and screen risks that derive from the failure of an engineered system to operate or perform as intended. For FMEA to characterize risk, both the relative likelihood of a failure event and its consequences must be accounted for. As a qualitative technique, likelihood and consequences are evaluated in FMEA using professional judgement and opinion. The FMEA allows perceived risks to be prioritized in order of importance, cost, and consequence.

The two facilities are fairly small in size but are situated within a watercourse and thus it seems appropriate to assign a low risk category. In the case of failure, no fatalities are anticipated, and only moderate environmental and hence, economic, damage would arise. To support this assessment, it should be noted that in June 1999, approximately 3,000 tonnes of tailings were released from the Jumbo tailings impoundment, mostly within a 24 hour period. These tailings were found to have a minor impact on water quality and benthic invertebrate at the US border, in the days subsequent to the failure.

The Table I presents the design criteria that are proposed for this low risk facility, based on the CDA (1999) guidelines. It should be noted the upper end of the recommended range was selected, primarily because of the potential political issues relating to the proximity to the US border.
The design work has proceeded as required over the past 3 years to maintain the short-term integrity of the structures. Proceeding with construction on the essential items demonstrated to MEM, Inco's desire to ensure adequate protection of the environment.

**Water Management**

A key feature of the long-term physical stabilization for both facilities was proper control of surface flows. The following sections describe the water management systems implemented for both Jumbo and Good Friday.

A sediment control weir was installed in Little Sheep Creek, about 600 m downstream from the toe of Jumbo dam. Immediately downstream of the weir, a water quality sampling station was established. Other sediment controls including widespread use of hay bales, non-woven geotextile filter cloth, and silt fences, throughout the system.

Any areas on the tailings where there is no vegetation following construction, will be reclaimed by mechanically tilling, fertilizing and seeding with a grass seed mix. The grass cover will provide protection against water and wind erosion. Any constructed swales will be re-enforced initially by mulch...
or coconut matting in areas where erosion is most severe. Steep and more difficult-to-access areas will be hydroseeded with a mix of seed, mulch and fertilizer.

Good Friday
A riprap lined drainage channel has been installed to provide the Good Friday impoundment with a long-term, low to no-maintenance surface water discharge system. This includes the channel that conveys surface flows across the tailings facility, the spillway through the east abutment of the Good Friday dam, and a swale that directs surface water from the tailings into the drainage channel. Downstream of the dam, a small guide berm and channel direct the flows safely away from the dam and into the woods, returning the flow to the original stream bed.

The channel design included a buried rock drain along the eastside of the channel. The purpose of the rock drain is to intercept seepage from the valley side, helping to minimize the amount of groundwater entering the tailings.

A seepage collection system has been designed to convey the seepage safely away from the west limb dam to help reduce the potential for liquefaction or piping failure of the dam. A rock drain will be excavated along the toe of the west berm to collect any seepage emanating from the tailings pile and convey it northward and then across the Jumbo access road and down into Little Sheep Creek. While the quality of some of the seepage water is poor (low pH, elevated Cu and Mo), the flow rate is sufficiently low that no significant impact has been observed through the monitoring of Little Sheep Creek.

Also along the west limb, where tailings are exposed on the dam face, an erosion protection blanket of sand and gravel will be placed down the slope. This is intended to prevent local erosion of the tailings surface by direct precipitation and snow melt. The west limb dam face will also be revegetated.

On the Good Friday dam, the decants and other pipes will be plugged with a flowable grout. It is possible that other, presently unidentified, conduits exist and potential problems may arise with the unknown conduits in the future. However, no other conduits are shown on the engineering drawings nor have been identified through the site work over the past 3 years.

Jumbo
As the Jumbo impoundment is a cross-valley dam, there is a substantial flow of water that needs to be directed in a controlled fashion from upstream of the tailings until well downstream of the dam toe. The original diversion culvert was plugged at the upstream end by filling the pipe with concrete, welding a steel plate over the end and backfilling the area with local till borrow. A grout plug was injected from the
downstream end to fill an estimated 40 m section that lies through the upstream filter zones. Flow rates are still less than 4 L/s, over 2 years after successful completion of the grouting work, with no evidence of fines in the water.

The decants and other surface water drain lines passing through the dam were grouted using a flowable grout mixture, and the decant towers backfilled with tailings.

Before the decant was plugged, a riprap lined surface water diversion channel with spillway was installed along the length of the west side of the impoundment, and passing through the west abutment of the dam. The spillway itself was blasted into bedrock.

The spillway chute is located at least 10m downstream of the dam contact with the west abutment. The upper 15m portion of the chute is in bedrock. Elsewhere, a thick layer of boulders was placed to safely carry the design flow down the chute into the valley bottom. At the bottom of the spillway chute, a riprap lined stilling basin, was installed to dissipate energy. Flow from the stilling basin then reports to Little Sheep Creek via a riprap lined swale running through the centre of the former water reclaim pond.

Along the toe of the Jumbo dam, a rock drain was installed to direct, primarily seasonal, seeps away from the dam and into the stilling basin.

Geotechnical Stabilization
A series of site investigation programs have been undertaken to reduce uncertainty identified in the risk assessment and provide a sound basis for the remedial design.

Good Friday
Stability analyses indicate that some remedial work was needed along the west limb, particularly in the area of the overtopping incident identified in 1997, to achieve factors of safety against slope instability as required by the design criteria. Construction of a major toe berm, extending from Little Sheep Creek up, across the Jumbo access road, to about mid-way up the dam section at El. 1280 m, was selected as the preferred option.

Jumbo
Stability analyses of the Jumbo dam, based on the 1971 "as-built" drawings, existing topography and geotechnical data obtained from two holes drilled in 2001, concluded that no physical stabilization work was required at Jumbo, other than the water management systems described previously.
MONITORING

Daily monitoring during the freshet season has occurred annually beginning in 1999, following the initial remedial work in 1998. Water levels in piezometers installed in 1999 have been recorded weekly through the snow free period of the year. On various occasions, water samples have been taken from select piezometers, to try and assess tailings water chemistry. Tailings samples were submitted for geochemical testing including ABAs, metals analyses, and short duration leach tests. To complement the chemical test work a number of tailings and ore samples were submitted for optical, electron microscope and XRF studies.

Surface water quality monitoring at least 3 sites has occurred monthly during the open water season since June 1999. During periods of construction activity and particularly during the remedial works in-stream at Jumbo, a higher frequency of sampling has been undertaken (as frequent as daily samples during key periods) at up to 5 sites. Monitoring will continue through 2003 on a monthly basis. In 2004, monitoring will be reduced to a seasonal basis and the Crown will assume the monitoring responsibilities following permit surrender.

SUSTAINING FUND AND PERMIT SURRENDER

Inco met with MEM representatives in the summer of 2000 to explore the alternatives for the surrender of the old Reclamation Permit dating back to the early 1970's. Inco held the permit and the mining assets in trust for the owners when Red Mountain Mine was closed in 1971. At that time Inco acted as the manager of the trust property.

As a result of the meeting MEM and Inco came to an understanding that the permit could be surrendered once a physical stabilization program acceptable to MEM had been completed to their satisfaction. Consequently, Inco directed Klohn Crippen to assess the site conditions and design a stabilization program that would upgrade the tailings structures and water management to meet current acceptable standards for the agreed level of risk. Klohn Crippen developed a final stabilization program that was presented to MEM at a meeting in April, 2001.

An important and integral part of the permit surrender was a sustaining fund negotiated with MEM. The fund provides for a certain level of physical (dam safety reviews every 10 years) and chemical (seasonal water quality sampling) monitoring of the site and for expected maintenance of the water management structures. Upon delivery of the final construction report and 2004 monitoring report, and the sustaining fund in November 2004, MEM will assume all future physical risks associated with the property's tailings.
impoundments without recourse to the previous owners. The total cost incurred by Inco over the 6 year period leading up to permit surrender is expected to approach $3 million including the sustaining fund of $262,000.

CONCLUSIONS

The events at Red Mountain Mine during the last few years highlight the importance of regular monitoring of abandoned facilities. They also reiterate the need to incorporate eventual closure designs in the original tailings dam plans. The final water management system should be part of the original tailings impoundment design.

The differences in the historic and current regulations and mine reclamation practices may lead to hard-to-resolve differences in the points of view between the miners and the regulatory authorities. It is important that everyone maintains certain degree of flexibility to allow room for 'out-of-box' thinking for satisfactory solutions to be reached.

REFERENCES
