WATER MANAGEMENT AND MOLYBDENUM TREATMENT AT THE CLOSED NORANDA INC. – BRENDA MINES SITE, PEACHLAND BC.

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ABSTRACT

Brenda Mines, an open pit copper-molybdenum producer, operated from 1970 until 1990. Located in the southern interior of British Columbia, approximately 200 million tonnes of ore were processed at the site. During the operating period the site water balance was such that discharge of effluent was not required. However, the long-term legacy of the site is that on average 3.1 million cubic meters of water per year, containing 3 mg/L molybdenum, will have to be treated prior to discharge. Water treatment is expected to be required for an estimated 50-200 years. This paper will discuss the water management strategy implemented at the site, and the unique water treatment facility, which reduces molybdenum levels to an average of 0.03 mg/L.

INTRODUCTION

The Noranda Inc. Brenda Mine site is located in the Okanagan Valley of South-central British Columbia, approximately 22 km. Northwest of the town of Peachland. It is located at an elevation of approximately 1500m. above sea level and is in the headwaters of both MacDonald Creek and Peachland Creek. These two creeks are the start of two separate drainage systems, which both eventually report to Okanagan Lake. The former copper-molybdenum open pit mine operated from 1970 until 1990, when it ceased production due to depletion of the ore reserves. While in operation, the mine processed approximately 200 million tonnes of ore and 109 million tonnes of waste rock. From the ore came 278,000 tonnes of copper, 66,000 tonnes of molybdenum and 125 tonnes of silver. Almost 200 million tonnes of tailings were also produced. While in production, the operation did not discharge an effluent from the tailings impoundment, and was thus considered a "zero discharge" system. The site required fresh water for potable water, and to augment the water reclaimed from the tailings pond, for mineral processing. Fresh water was drawn from the nearby Peachland Lake, which was also part of the water supply for the town of Peachland.

Upon closure in 1990, the site consisted of the following seven main water management units:

- The fresh water system, including the Peachland Lake dam, pumphouse and pipeline.
- A series of small dams and diversion ditches which captured clean water on the site and rerouted it to either Peachland Creek or MacDonald Creek.
- Contaminated water collection ponds and ditches which directed metal contaminated water to either the tailings pond or open pit for storage.
- Tailings facility, including the tailings pond, Main Dam, Saddle dam and two reclaim water facilities.
- Open Pit.
- Plant and mill site.
- Waste rock dumps.

The water management system was re-evaluated after the cessation of operations, and a proposed new system recommended with the development of a detailed decommissioning plan for the site. This plan received input from a Technical Committee of government representative, and a Public Surveillance Committee of community stakeholders. The plan was completed in 1993 by Steffen Robertson and Kirsten (Canada) Inc., Rescan Environmental Services Ltd., C.E. Jones and Associates Ltd., and H.M. Larratt Aquatic Consulting Ltd. Water quality in the receiving environment, (MacDonald/Trepanier Creek and Peachland Creek), were evaluated for all significant parameters, however it was clear that the main element of concern would be molybdenum.

Three main options for water management were evaluated:

- Direct discharge of site drainage to MacDonald Creek, with the provision of an alternative water supply to users on Trepanier Creek.
- Discharge of site drainage into a pipeline, which discharged directly into the deeper portions of Okanagan Lake.
- Treatment of site runoff by biological and/or chemical means, with season discharge to either MacDonald/Trepanier Creek or Peachland Creek.

The study determined that all three options were viable, but each had strengths and weaknesses. Each plan would have to meet the Provisional Water Quality Objectives for Peachland and Trepanier Creeks. These specified a maximum molybdenum content of 0.05 mg/L, with a long-term objective of 0.01 mg/L during the May to September irrigation season. For reference, the water quality standard in 1969, when the original operating permit was issued, was 10 mg/L.

Further testing and evaluations, led to the conclusion that molybdenum treatment by co-precipitation with iron was the preferred option, with season discharge to MacDonald/Trepanier Creek. The BC Ministry of the Environment amended the 1969 discharge permit in 1997 to allow treatment and discharge. This permit was further amended in 1998, 1999, 2000 and 2003. The Water Treatment Plant (WTP) was constructed in 1998, with the first discharge of treated effluent on November 17, 1998.

Between 1990 and 1998 there was no discharge of effluent, with all contaminated waters being transferred to the open pit for storage.

Description of the Water Management Units

Fresh Water Supply

During production, fresh water was required at the mine for both potable water and mineral processing. The water was drawn from Peachland Lake, which was located approximately 5 miles from the mill site. In addition to supplying water to the mine, the lake also supplied domestic water to downstream farms and the town of Peachland. The storage capacity of the lake increased in 1969, when the mine constructed a dam at the outlet of the lake. Pumping facilities and a 5 km. long 480 mm. steel pipeline to the minesite were also established. During mine operations, an average of 1.43 million m3 of water were pumped to the minesite annually. An additional 7.65 million m3 of water were released annually for downstream users.

After production ended, these facilities were no longer required by the mine, and the infrastructure and associated water licenses for this system were transferred to the town of Peachland.

Clean Water Diversion System

While the mine was in production, it was important to minimize inflows of uncontaminated water to the open pit and tailings pond, and to augment the flow to Peachland Lake. In order to achieve this, a series of small dams, diversion ditches and pipelines were constructed. These structures diverted clean water around the rock piles and open pit, and directed it to either Peachland Creek or MacDonald Creek.

As part of the reclamation activities, these ditches were upgraded to handle a design runoff event with a 1 in 200 year return interval. In 2000, the MacDonald Creek Emergency Diversion was constructed below the fresh water MacDonald Creek Diversion. The emergency diversion was to ensure that during any runoff events, up to the Probable Maximum Flood (PMF), that the flows from the upgraded MacDonald Diversion would be directed to MacDonald Creek, and not to the tailings pond.

Contaminated Water Collection System

During mine operations, contaminated site drainage was collected by a series of ditches and pumping stations, and directed to the tailings pond. From here, the contaminated water was used as part of the reclaim water supply used for ore processing.

The closure plan for the site redesigned these structures, so that the pumping stations were removed and the flows were transferred by gravity to either the open pit or tailings pond for storage.

Tailings Facility

The tailings facility is made up of: the main tailings pond, the Main Dam, the Saddle Dam, the Upper Reclaim System and the Lower Reclaim System. The tailings facility occupies 370 ha., of which about 87 hectares are currently flooded and form the tailings pond. This pond is 3-4 meters deep, and collects most of the contaminated runoff from the site. It is the main feed source for the WTP and is expected to receive 2.1 million m3 of runoff during an average year.

The main dam was constructed as a cross valley embankment in the former MacDonald Creek. It is 2048 meters long, and rises 137 m. in height above the downstream toe. It is constructed of hydraulically placed tailings sand, deposited between two starter dams. The crest of the dam is at an elevation of 1392.9m. Construction of the dam was completed in 1988, at which time seeding and fertilizing of the dam, and upstream tailings was initiated.

Downstream of the Main Dam, is the Lower Reclaim Facility, which consists of a clay core dam forming a collection pond, a pumphouse and a pipeline to the tailings pond. The facility is designed to collect contaminated seepage and toe drainage from the main dam, and to return it to the tailings pond. The system has 3 pumps which operate automatically by level control. Two of the pumps operate of the main power system, while the third is run by an emergency generator system in the event of a power outage. This system returns an average of 1.2 million m3 of contaminated water back to the tailings pond each year.

The upstream end of the tailings pond is formed by the Saddle Dam. This dam is an earthfill structure, with an impervious till core and outer shells of sand, gravel and rockfill. It has a crest elevation of 1392.9m. The emergency overflow for the tailings pond was constructed in this dam in 1999, and has an invert elevation of 1387.1 m.

Below the Saddle Dam is the Upper Reclaim System. This facility collects seepage from the Saddle Dam and returns it to the tailings pond. As it is located on the upstream side of the tailings pond, and below a dam with an impervious core, it handles much lower flows than the Lower Reclaim facility.

Open Pit

The Open Pit was created by the removal of 200 million tonnes of ore, 27 million tonnes of overburden, and 109 million tonnes of waste rock. It is 1050 m. long, 980 m. wide and covers an area of 95 ha. At the west end of the pit, it has a depth of 335 meters.

The pit serves as a buffer storage for contaminated site water. During the period 1990 till 1998, when the WTP started, all excess water from the tailings pond was pumped to the pit for storage. It also collects contaminated runoff from within it's drainage area. As of December 31, 2002 the pit contained 33, 890,000 million m3 of water.

Plant and Mill Site

The Plant and Mill Site area of the mine is the location of the former concentrator, shops, administration office and warehouse. It occupies an area of approximately 34 hectares.

All unused buildings have been demolished, and removed from the site, and the area regraded. During 2003 the area was seeded and fertilized. Contaminated drainage from this area reports to the tailings pond.

Waste Rock Piles

Four main waste rock piles were created during the mining operation, with all piles located around the periphery of the open pit. They contain approximately 109 million tonnes of rock, and occupy an area of 160 ha. They range in height from 63 m. to 117 m.

Drainage from the rock piles is contaminated, and reports either directly to the open pit, or is collected in the surface ditches which report to the tailings pond.

Long Term Runoff Management System

In 1998, AGRA Earth & Environmental, (now AMEC Earth & Environmental) was retained to develop updated hydrologic designs for the runoff management system. The detailed design criteria for the work was based on the specifications outlined in the amended Ministry of the Environment, Lands and Parks (MOELP) Permit PE-00263 issued on July 15, 1997. As such, Agra was to review the site hydrology, specify the water treatment and pumping rates, and model the expected water quality in Trepanier Creek.

Design Objectives

The primary design objectives of the Runoff Management System were:

- Prevent the release of untreated, molybdenum bearing site runoff for at least a hydrologic event with a return period equal to, or less than 200 years.
- Provide for adequate treatment of the runoff prior to its eventual release to Trepanier Creek.
- Develop a treated water discharge schedule adequate to meet the receiving water criteria specified in Permit PE-00263.
- Ensure that the operating procedures in the Runoff Management System were consistent with the tailings dam safety requirements.

Hydrology

Precipitation data was collected at the Brenda Mine site by the Atmospheric Environment Service between 1968 and 1993. Based on this data, the site receives mean annual precipitation of 633 mm, with 245 mm as rainfall, and 388 mm of water equivalent snowfall. The maximum recorded single-day rainfall was 45.0 mm and the maximum single-day snowfall was 44.7 cm.

The site was divided into 20 catchments, having a total area of 1044 ha. Each catchment was evaluated to determine if it reported to the tailings pond, open pit, MacDonald Creek or Peachland Creek.

Based on these analysis, it was determined that the 1:2 year annual runoff volume for the Brenda site was 3.1 million m3. Of this, 2.1 million m3 reported to the tailings pond, and 1 million reported to the open pit.

Water Treatment Plant Capacity and Schedule

Based on the hydrology analysis, the WTP design called for the facility to be able to treat 3.1 Mm3 a year, with a maximum of 5.0 Mm3 in a year as specified in Permit PE-00263. The plant would have to be able to treat water from the tailings pond and the open pit.

The Permit specified a maximum molybdenum concentration in the final effluent of 0.25 mg/L. It also required that the water quality at the receiving environment station (the Peachland Irrigation Intake on Trepanier Creek), not exceed 0.03 mg/L molybdenum between June 1 and September 30. It was not to exceed 0.06 mg/L for the remainder of the year. These restrictions, in addition to the low volumes of water available for dilution during the irrigation season meant that the WTP would operate from the fall to the spring of each year, with a summer shutdown.

The WTP would require a nominal treatment rate of 250 L/s (4000 gpm) with a minimum treatment rate of 125 L/s (2000 gpm).

Water Treatment Plant

The WTP was designed by the Kilborn Division of SNC-Lavalin. The plant is unique, and is the only known plant that treats these concentrations and volumes. The process flowsheet was based on an iron co-precipitation process originally developed for the removal of molybdenum and antimony at the Battle Mountain Golden Giant gold mine in the early eighties.

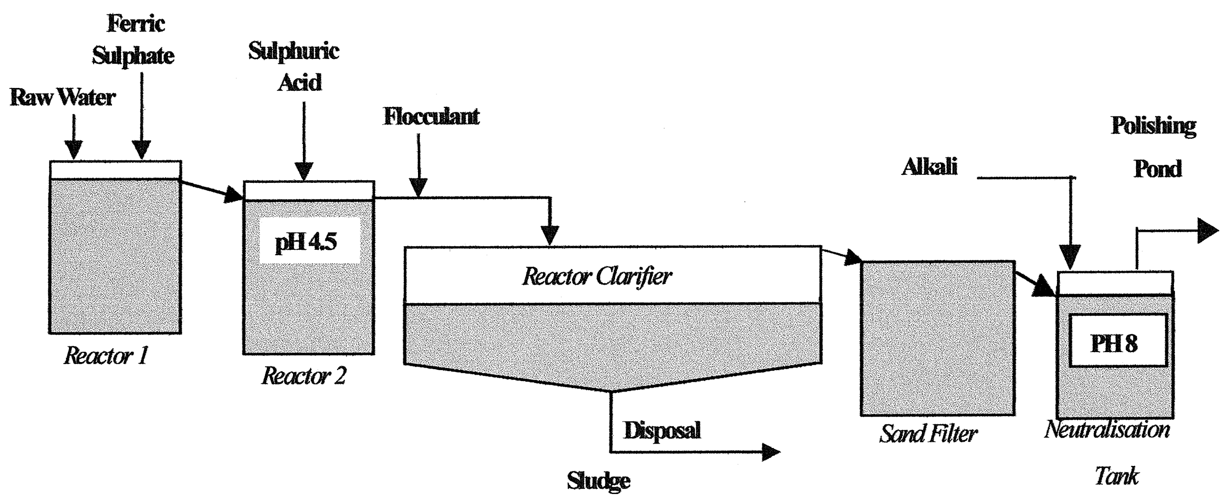
Built in 1998, at a cost of $10.5 million, the plant has a design capacity of 313 L/s (5000 gpm). The long-term Sludge Storage System was constructed in 2000, at a cost of $540,000.

Treatment Process Description

The Brenda WTP uses the best available technology to remove molybdenum from contaminated water. The process utilizes ferric sulphate to co-precipitate the molybdenum and the iron. As shown on Figure 1, the process involves the addition of ferric sulphate in the first reactor, followed by sulphuric acid in reactor 2. This reduces the pH to 4.5 pH, for optimum molybdenum co-precipitation with iron. Flocculent to aid in settling is added to the solution as it flows by gravity to a 39m. diameter clarifier-reactor. In this vessel, the sludge settles to the bottom of the tank, while a clear effluent is decanted at the top. Rakes in the clarifier keep the sludge moving towards the centre of the tank, where it can be drawn out of the tank. The remaining solids in the are removed by a sand-anthracite filtration system. Following filtration, the process water is still has a pH of about 4.5 pH and a small amount of soluble iron. A combination of hydrated milk of lime and caustic soda is added to the process water to raise the pH to approximately 8 pH and to help settle the remaining iron. This settling occurs in a Polishing Pond, which has a residence time of 6 days. After the Polishing Pond, the treated water is discharged to MacDonald Creek.

Figure 1

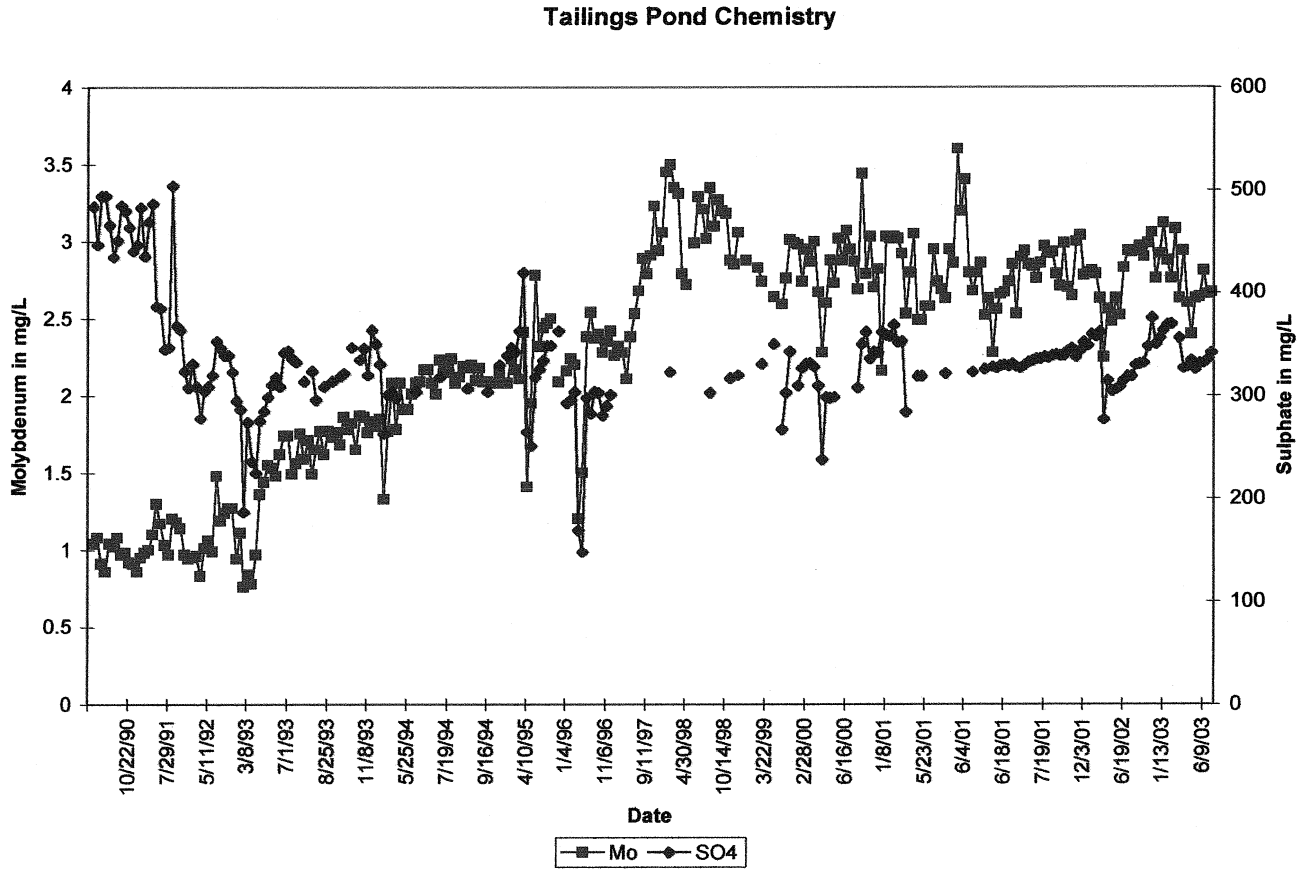
Brenda Water Treatment Process Flowsheet



Influent and Effluent Characteristics

When production ceased in 1990, the tailings pond water averaged about 1 mg/L molybdenum and 460 mg/L sulphate. From 1991 till 1997 the molybdenum levels in tailings was rising steadily, with peak values exceeding 3 mg/L. Since 1997 the molybdenum levels have stabilized, and currently average 2.9 mg/L. Sulphate levels declined from 1990 until 1992, and have remained fairly stable, averaging 340 mg/L. These trends are shown in Figure 2. One of the main sources of contaminated water reporting to the tailings pond, are the waste rock piles. As shown on Figure 3, the molybdenum concentrations coming from the waste rock piles increased during the period 1993 –1996, but have remained stable since then. During the period 1990 to 1997, the sulphate levels also appear to have been increasing. The trend since 1997 is stable, but highly variable.

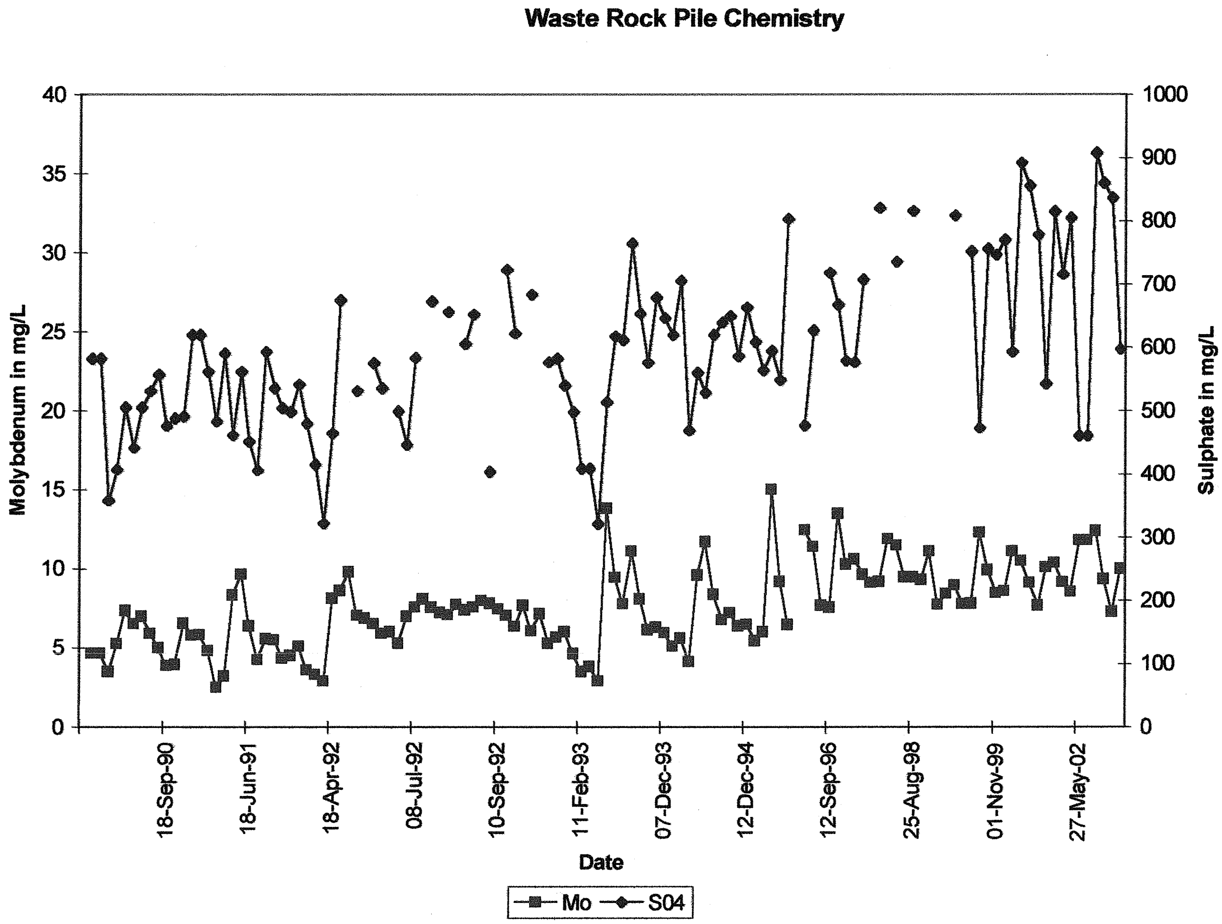
Figure 2



The performance of the treatment plant in respect to molybdenum removal has been significantly better than the design criteria required. Since start-up in 1998, the final effluent concentrations have ranged from 0.03 to 0.04 mg/L molybdenum. This has resulted in near background molybdenum concentrations at the downstream receiving water monitoring station. These results are presented in Figure 4.

The excellent molybdenum removal has enabled us to amend our operating schedule so that we operate the plant from mid-May until mid-October. This allows us to discharge effluent when there is maximum dilution available in Trepanier Creek, which minimizes the impact the effluent has on the receiving environment and the domestic water supply utilized by the residents of Peachland.

Figure 3



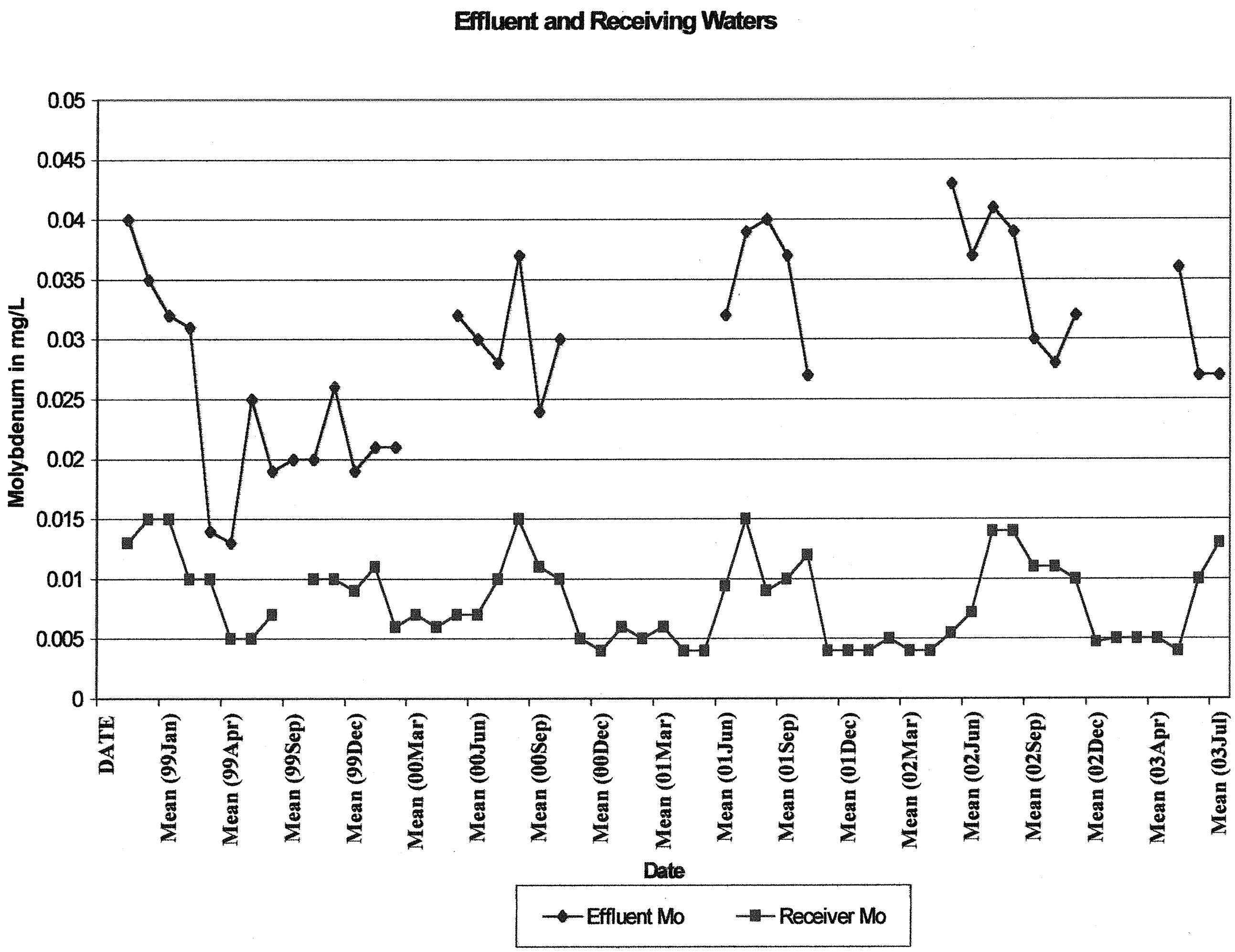
Sludge Management

The WTP creates as a waste product, a low density, iron-molybdenum sludge. The plant produces about 1000 tonnes per year of sludge, which is composed of 44% iron and 4% molybdenum. This sludge contains a significant amount of water within the sludge matrix, and even after draining, and freeze-thaw action, the sludge only reaches 9% solids.

The long-term sludge management plan involves the storage of the sludge within a sludge storage pond. The pond is designed to drain, and is constructed with a permeable waste rock dam that contains sand and gravel filters. The pond is divided into two cells, with each cell used in alternate treatment years. This will allow the sludge to reach its maximum density, and thus reduce the cost of expanding the sludge pond.

The pond design will allow for expansion of the sludge storage area, so that 200 years of sludge can be safely stored on the site.

Figure 4



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