WESTMIN RESOURCES LIMITED
MYRA FALLS OPERATIONS

DECOMMISSIONING PLAN

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1.0 INTRODUCTION

A decommissioning program has been developed for Westmin Resources Limited, Myra Falls Operations which is based on the current knowledge of acid generation control and land use objectives. The mine is believed to have a life of at least 10 to 20 years and it is expected that changes in control technologies will occur which may modify activities outlined in this plan. For example, the potential for controlled leaching of waste rock and recovery of leached metals resulting in a depletion of the acid generating potential of these waste materials is presently being considered. The expenditures proposed in this decommissioning plan are adequate to meet expected costs and future technological developments should reduce these costs, not increase them.

The closure options selected for the acid generating portions of the mine site are based on detailed hydrogeological investigations of each major component. Monitoring of these systems will continue for some years to ensure that the hydrogeologic conditions observed during the study period are typical.

The land use plan is based upon the current objective of the B.C. Ministry of Environment Lands and Parks, to return the land to a natural condition. It is recognized that this objective could change during the period of time prior to the closure of the mine and that the land use plan could be modified, except where a proposed use could have a negative impact on the acid generation controls. Acid generation control is viewed as the primary goal of the decommissioning plan.

Westmin Resources Limited has undertaken to implement and monitor the effectiveness of many of the acid generation controls over the next five to seven years. Portions of the decommissioning program cannot begin until closure of the mine operations, however those activities which can proceed during the life of the mine will be completed. Further research activities to field test the shotcreted cementitious mixtures, and to define the hydrogeological conditions of the Myra Creek floodplain and Myra:Price:H-W mining complex are proposed.

2.0 MINING PROGRAM

Westmin Resources Limited, Myra Falls Operations is a 3650 tonnes per day copper-zinc-gold-silver mine located near Buttle Lake, 85 km from Campbell River on Vancouver Island. Mining began in 1966 with the development of the Lynx Open Pit, producing about 950 tonnes per day of copper-lead-zinc ore with gold and silver values as well. This pit operated until 1973, since then all mining has been underground. A second underground mine, the Myra Mine, was developed in 1970 and produced until 1985.

An extensive zone of copper-zinc mineralization was discovered in 1980 which resulted in the opening of the H-W Mine in 1985. This development required the establishment of new facilities including a 2700 tonnes per day mill, which has since been expanded to 4000 tonnes per day, and a 1.4 km conveyor to transport ore from the H-W shaft to the mill. The new mining complex also required an enhanced hydro-electric power development, an improved water control and treatment system, a new backfill plant and a new tailings disposal facility. Prior to 1984, tailings had been deposited subaqueously in Buttle Lake.

A small exploration development in the lower Thelwood drainage, the Price Mine, is composed of 4 adits, one of which connects with the underground development in the Myra Valley. This operation has not been active since the early 1980's.

The present reserves of ore indicate at least a 10 year mine life for the Myra Falls Operations, however, only 40 percent of the claims have been explored and it is anticipated that mining will continue for approximately 20 years. A series of new ore deposits in both Lynx and H-W ore zones have recently been discovered and have not yet been fully defined. The development of these new ore bodies may impact upon some aspects of the present decommissioning plan.

2.1 Milling Process

The mill employs tertiary crushing and two-stage grinding, producing copper and zinc concentrates through differential flotation. Tailings from the milling process are cycloned and the coarse fraction, approximately 50 percent by volume, are used as backfill underground.

2.2 Tailings Deposit

Prior to 1984, tailings materials were discharged to the south basin of Buttle Lake. The floculated fine tailings were discharged below the thermocline via a submerged outfall. Studies indicate that the tailings on the lake floor were not releasing dissolved metals into the overlying water column during the time when this tailings deposition was occurring (Pedersen 1983). Pedersen (1982), suggested that oxidative diagenesis of the tailings might be expected to occur for a period immediately after the cessation of discharge, prior to the deposits being covered with a veneer of organic-rich natural sediments. Studies carried out in 1989, indicate that the tailings on the lake bottom are now being covered with a veneer of organic-rich sediments at a rate on the order of 4 mm/yr, and that the deposits are anoxic below depths of 2 or 3 cm. Based on high-resolution (parts per trillion) interstitial water data it was concluded that the now-buried tailings in the south basin of Buttle Lake are having a negligible impact on water quality in the lake (Rescan, 1990).

Begining in July 1984, tailings were deposited on land into the tailings storage facility. Using a sub-aerial technique, the fine portion of the cycloned tailings material is deposited through spray bars along the outer tailings embankment. Under the spray bars the slurry segregates over a gently sloping beach. Water drains off the beach and collects in a pond beyond the beach where it is drawn off through decant pipes to the water treatment facilities. After the deposition of a thin layer of tailings, 3 to 5 cm, on a portion of the beach the deposit is allowed to drain and air-dry before the next layer is deposited. The process results in a fully drained and partially saturated deposit with permeabilities ranging from 5×10^{-8} to 7×10^{-10} m/s (Knight and Piesold, 1986). As increased storage capacity is required, additional confining berms are constructed above the elevation of the starter embankments. These berms are constructed directly on the tailings adjacent to the embankment, in successive lifts to form an engineered structure using the tailings as a principal structural material (Westmin Resources, 1988).

A sloping sand filter was constructed against the waste rock dump and valley side to an elevation of 320 m on the north side of the tailings disposal facility. The primary purpose of the filter is to decant supernatant run-off from the surface of the tailings and to intercept contaminated seepage from the waste rock dump. Additional raises of the sloping filter will be added as required when the level of the tailings approaches the top of the filter.

Piesometers installed into the tailings indicate that all structural zones of the tailings mass are fully drained and consolidated. If excess pore pressures are indicated by the piezometers, vertical drains could be installed along the confining embankments to dissipate excess pore pressures in the tailings and increase the factor of safety against liquefaction failure. To date vertical drains have not been required (Westmin Resources, 1988).

2.3 Waste Dumps

The majority of waste rock and overburden at the mine site was generated between 1966 and 1975 during the development and mining of the Lynx open pit. This waste has been stockpiled adjacent to and within the open pit. Much smaller volumes of waste rock are generated by underground mining and most of the H-W waste is used underground as backfill. Non-acid generating waste rock is used in the construction of tailings pond berms.

The waste rock dumps contain three categories of materials:

- andesites and basalts with a significant carbonate component. Acid generation potential of these materials is low, and some materials have a limited acid consuming potential.

- mixed volcanics with a minor carbonate component. Acid generation potential will be variable depending on the proportion of sulfide constituents.

- pyritic, sericitic schists (pyritic stringer mineralization). This phase has high potential for acid generation.

These materials are segregated to some degree within the waste dumps although considerable intermixing is apparent. In general, the upper dumps are composed mainly of andesites and basalts, whereas the main # 1 Dump contains both mixed volcanics and pyritic stringer material.

2.4 Stockpiling of Soil and Overburden

The construction of the tailings facility involved the removal of approximately 200,000 m^3 of fluvial soil materials. These materials were stockpiled to the east of the tailings area for use in the reclamation of the mine site (see Map #1 located in map pocket). The surface of this stockpile has been seeded with a grass and legume mix to control erosion of these materials during storage.

2.5 Drainage Control

To minimize the amount of water entering the mine area from the slopes to the north of the mine site, an interceptor ditch was constructed up slope of the former Lynx surface operations to convey surface flows away from the area of disturbance. The portion of the ditch which flows adjacent to the # 1 Waste Dump is lined with shotcrete to inhibit leakage. Water is discharged from the diversion ditch to Myra Creek downstream of the tailings facility.

Subsurface water flowing through Waste Dump # 1 charges the alluvial gravel underlying the tailings area. To prevent this water from reaching Myra Creek, interceptor drains have been placed in the gravel under the tailings area. One drain is located at the toe of the waste dump and collects much of the contaminated groundwater as it enters the subsurface gravel. The other drain, located under the tailings embankment adjacent to the creek, collects excess groundwater during periods of high runoff. This outer drain is located slightly below the level of the creek bed, therefore it also collects some creek water to ensure an inflow into the drain rather than to the creek. Water is pumped from these drains to the water treatment system.

2.6 Water Treatment Systems

The water treatment system employed at the mine site consists of two components: a primary treatment and settling pond, the Lynx Pond, and six polishing ponds, the Myra Ponds. The Lynx Pond receives water from a mix tank which collects effluent from the milling process, decant water from the tailings thickener, Lynx mine water, decant water from the tailings disposal area, contaminated groundwater from an interceptor drainage sysem, discharge from a sewage treatment plant and surface runoff from the mill yard and Lynx mine areas. The purpose of the mix tank is to combine high pH discharges from the milling process with low pH mine water and ground water. Lime and/or CO^2 can be added to the mix tank for pH control. Accumulated solids are removed from the Lynx Pond by a floating, automatically controlled pump which discharges sludges to the tailings area. Lynx Pond effluent flows by gravity pipeline to Myra Pond #1 where further settling of solids occurs. In addition, Myra Pond #1 receives water from the Myra and H-W mines, discharge from a second sewage treatment plant, and effluent from the Surge Basin which drains the Lynx Open Pit and recieves decant water from Tailings Disposal Area #1. Accumulated solids are removed from Myra Pond #1 on a continuous basis by a submersible pump. Effluent from pond #1 is decanted into two ponds which in turn decant into three additional ponds. These ponds discharge into a common channel. A pumphouse recycles water from this channel back to the mill. Excess water is discharged to Myra Creek through a Parshall Flume equipped with a flow measurement device and a continuous pH recorder. The quality of water discharged to the creek is governed by an effluent permit, PE-6858.

3.0 OBJECTIVES FOR DECOMMISSIONING PROGRAM

The intent of this plan is to provide environmentally secure decommissioning to ensure that acid drainage is minimized and long-term water treatment is not required. Research and monitoring programs have been undertaken to develop a thorough understanding of the hydrogeological systems on the mine site.

Innovative methods of controlling acid generation, particularly in waste rock, have been developed specifically for the mine site conditions. A primary objective of the research program has been to ensure that methods used to control acid generation are compatable with revegetation activities.

The location of the mine within a Provincial Park requires the decommissioning program to return the land to a natural condition, re-establishing native vegetation communities and providing wildlife habitat.

The design objectives for the decommissioning program at Myra Falls Operations are:

- to provide long term, maintenance free water management measures to protect water quality in the area;
- to integrate the disturbed lands into the surrounding landscape; and
- to return the land to native vegetation.

4.0 ENVIRONMENTAL SETTING

4.1 Climate

4.1.1 Introduction

The climate of the Myra Creek Valley area is described as Marine West Coast, as based on the Koppen classification system. Frequent frontal passages from the Pacific Ocean and Gulf of Alaska combine with orographic influences to produce abundant precipitation. Prevailing westerlies and the moderating influence of the Pacific Ocean result in relatively mild winters, warm but not hot summers, and a small annual temperature range. Strong winds are frequent, particularly during the fall and winter periods.

4.1.2 Wind

The local topography of the mine area plays a significant role in determining wind flow and air dispersion characteristics over the mine site area. Winds are predominantly along the axis of the Myra Creek Valley, and at night, drain down the mountainsides to continue along the valley floor and over Buttle Lake. During the day, particularly in the summer, winds flow up the mountainsides and also up the valley to the west of the mine.

4.1.3 Temperature

Although there are no major weather reporting stations in the immediate vicinity of the Myra Falls site, basic temperature and precipitation data have been collected at the Myra Falls Station since the late 1960's. Table 4.1-1 provides the average monthly maximum and minimum values at Myra Creek over a 10-year period (1970-1980). This information has not been revised to include 1980-1990 as updated 10-year temperature and precipitation normals will not be available from Environment Canada until late 1992.

The frost-free period, or the greatest number of consecutive days free of temperatures of 0°C or less in an average calendar year is 160 days (British Columbia Ministry of Environment).

Above 500 m asl, the freeze-free period would be reduced. The average minimum temperature data available from Myra Falls indicates freezing temperatures can occur from October through May.

TABLE 4.1-2

Average Monthly Temperatures
For Myra Falls Weather Station
(1970-1980)

Month	Average Maximum Temperature (°C)	Average Minimum Temperature (°C)
January	2.8	-12.0
February	4.2	-7.4
March	8.9	-8.3
April	15.2	-3.9
May	23.5	-1.5
June	27.5	2.5
July	31.5	4.2
August	30.8	4.9
September	24.7	2.6
October	16.6	-2.0
November	9.0	-7.1
December	5.1	-8.7

Source: Environment Canada, Atmospheric Environment Service, 1982.

Effective growing degree days (E.G.D.D.) range from 900 to 800 in the valley bottom, from 800 to 700 on the lower slopes, and from 700 to 600 on the upper slopes (British Columbia Ministry of Environment). The period over which E.G.D.D. are accumulated extends from the first day when the mean temperature is equal to or greater than 5°C, to the last day of the last 5 consecutive days in the same year with a mean daily temperature greater than or equal to 5°C. This figure provides another measure of the growing season.

The highest temperatures in the Myra Creek area are generally recorded in July, when monthly extreme values average 31.5°C. Average maximum temperatures greater than 20°C occur from May through September.

4.1.4 Precipitation

Table 4.1-3 shows the mean monthly total precipitation for Myra Falls, Strathcona Dam, Campbell River and Comox. The Myra Falls area received more precipitation than the other regional locations. The difference is explained primarily by topographic influences resulting in orographic lifting - thus the discharge of considerably higher precipitation over the Myra Creek airshed. The Myra Creek Valley also has a shorter summer 'drought' period than occurs in Campbell River, Comox, or at the Strathcona Dam.

These other regional locations have mean monthly precipitation values of less than 10 cm from April through September, while at Myra Falls this period extends from May through August. The precipitation which falls from May to September is an important factor in the climatic control of plant growth. The May to September precipitation on the valley floor and slopes below 500 m ranges from 200 to 250 mm (British Columbia Ministry of Environment). This precipitation, in combination with high summer temperatures, results in a climatic moisture deficit of -200 mm on the valley floor and -150 mm on the lower slopes. This factor represents the average difference between the total precipitation and the total evapotranspiration during the period extending from May 1st to September 30th.

The average accumulation of snowfall at the closest recording snow course, Upper Thelwood Lake, is 3.8 m. The heaviest snows fall at the mine site from December through February, with little or no accumulation from May through October. The difference in aspect

TABLE 4.1-3

Mean Annual and Monthly Total Precipitation
For Campbell River Area (cm)

Month	Myra Falls	Strathcona Dam	Campbell River	Comox
January	34.9	21.4	22.3	19.3
February	31.6	18.4	17.3	12.5
March	33.1	10.0	15.5	11.1
April	19.7	6.5	7.7	5.7
May	9.8	5.0	5.3	3.7
June	7.8	5.2	4.9	3.5
July	5.2	4.2	4.0	2.8
August	7.9	6.1	5.5	4.4
September	17.7	7.0	7.7	5.2
October	32.7	14.3	16.3	12.8
November	47.9	19.1	24.0	19.2
December	43.8	20.9	27.7	21.3
Annual	292.1	138.1	158.1	121.5

Source: Environment Canada, Atmospheric Environment Service, 1982.

between the valley sides results in a difference in the time of snow melt in the spring. The timing of snow melt can be important to the reclamation program because it can delay planting until May or June, months which can have high temperatures and low rainfall.

4.2 Hydrology

4.2.1 Drainages

With the exception of a small, partially developed ore zone in the Thelwood Valley, the Myra Falls operation is confined to the Myra Creek catchment. The headwaters of Myra Creek, a tributary of the Campbell River System, are at the east/west divide of the Vancouver Island Ranges. The stream flows east from the divide for approximately 16 km to the south end of Buttle Lake. Its catchment area of 72 km^2 ranges in elevation from 1814 m asl on Mount Myra to 221 m asl at Buttle Lake.

The upper 10 km of Myra Creek flows through a narrow, steep-walled valley with an irregular profile. Gradients in this portion of the stream vary between 1 in 5 and 1 in 35. Downstream of the mouth of Tennent Creek, a tributary of Myra Creek, the next 5 km flow through a U-shaped valley where the average gradient is less than 1 in 100. It is within this portion of the drainage that the Westmin mining operations are located. The lower 0.5 km of Myra Creek is a series of rapids and falls up to 20 m in height.

4.2.2 Surface Water Hydrology

Flow data for Myra Creek and its tributaries has been collected since 1981. However, since mine facilities were designed and constructed in the early 1980's, it was necessary to estimate flood flows for Myra Creek in the absence of long-term hydrometric records for Myra Creek. There were also no records of this type for other Buttle Lake tributaries or similar basins in the region.

Various analytical methods were used and compared in calculating an acceptable flood estimate for Myra Creek (Westmin, 1982). The figures selected for the purposes of facility design were 400 m^3/s for the 1 in 200-year flood, and 500 m^3/s for the Probable Maximum Flood.

4.3 Fisheries

The Myra Falls obstruction, located at the outlet of the creeks, precludes the usefulness of Myra Creek as spawning habitat for fish stocks from Buttle Lake. However, the stream does provide habitat for a small introduced cutthroat trout population.

In general, the Myra Creek watershed drains a mature forest area where natural physical features produce a diversity of excellent but somewhat unstable aquatic habitat. Fish sampling results of the 1982 study confirmed that the Myra Creek fish population was comprised of a small number of slow-growing, cutthroat trout restricted to the natural habitat upstream of the power plant bridge.

Modifications to the water management system in 1981 and 1982 resulted in improvements in the water quality of Myra Creek downstream of the power plant bridge. Subsequent to the improvements, fish were observed to use more of Myra Creek than they had previously. Further improvements to fish habitat occurred with construction of the stream diversion in 1984 . The diversion replaced a section of stream habitat which had been unstable and characterized by a meandering channel, eroded banks, gravel bars and fallen timber. The diversion incorporated fisheries enhancement facilities such as spawning, rearing, food production and overwintering areas much in excess of those present in the creek prior to the diversion.

As part of Westmin's expansion of their mine and mill operations in 1983, a small hydroelectric generating facility was installed on the Thelwood Creek system to satisfy the increased energy demands associated with the new mill (Hatfield, 1983). Dams were constructed at the downstream ends of both Thelwood and Jim Mitchell lakes, and water levels in both lakes were raised.

The baseline aquatic study completed by Hatfield (1983) prior to dam construction indicated that "both Thelwood and Jim Mitchell Lakes ...were... typical oligotrophic subalpine lakes with a low biological standing crop during the study period". Concentrations of zooplankton in both lakes were low, and no fish were captured or observed in either lake. A variety of fish capture techniques were employed (including electro-shocking) and searches for fish sign were used, however no fish or sign of fish were observed. Hatfield (1983) inferred that no fish were present within the lake system.

Subsequent to construction of dams on both lakes and construction of road access to Jim Mitchell Lake, the British Columbia Ministry of Environment began stocking Jim Mitchell lake with trout fry. Stocking efforts have been ongoing, and the lake appears to receive considerable use by local anglers.

4.4 Terrain and Soils

The rugged terrain of the Myra Falls operation was shaped during the last glacial advance of the Wisconsin glaciation. During this advance, glacial erosion sharpened the highest peaks and rounded lower-lying area, but did not change the underlying topography. Alpine glaciers sculpted high serrate peaks, while the continental ice sheet modified surfaces below 1220 m asl and valley glaciers deepened and modified lower valleys.

The lowest elevation in the vicinity of the mine is approximately 221 m and occurs along the water's edge at Buttle Lake. The low-lying delta area at the south end of Buttle Lake, formed by the convergence of Thelwood and Price Creeks, falls within the 240 m contour. With the exception of this delta, however, land surrounding Buttle Lake rises steeply. Mount Phillips, which rises more than 1700 m asl, is located within 2.5 km of the lake shore north of the minesite, and Mount Myra (1813 m asl) is located less than 4.5 km south of the lake shore. Myra Creek has a relatively broad valley bottom at the 400 m contour, extending upstream over 6 km. The Myra Creek drainage basin is ringed by peaks rising to elevations of 1520 m to the north, 1732 m to the northwest, 1805 m to the west, 1730 m to the southwest, and 1813 m to the south.

The soils in the Myra Creek Valley have developed on relatively coarse parent materials under mild temperature and high precipitation conditions. This resulted in the formation of Podzolic soils. The vegetative cover of a moderately dense Douglas-fir and western hemlock forest, in combination with climate and landform features, contributed to the development of Humo-Ferric Podzols. An indurated pan, a duric horizon, is found where stable conditions exist. These pans are massive and can restrict rooting depth and water movement through the soil.

Soils developed on colluvial slopes in association with the steep rock slopes at the northeast end of the Myra Creek Valley near Buttle Lake are rapidly drained Orthic Humo-Ferric Podzols of the Rossiter Soil Association. These soils have a gravelly sandy loam texture and are generally very shallow. They also occur directly north of the mine area, where they are found in combination with well drained Duric Humo-Ferric Podzols of the Quimper Soil Association, developed in morainal materials. The latter soils also have a gravelly sandy loam texture. On the south side of the valley shallow well drained Orthic Humo-Ferric Podzols of the Rossiter, Cullite and Nitnat Soil Associations occur on coarse colluvial materials. These soils are gravelly sandy loam in texture.

Soil development on the valley floor in the gravelly sandy fluvial materials is very weakly expressed due to irregular inundation and the deposition of fresh materials. In areas which are not subject to flooding, Duric Humo-Ferric Podzols of the Honeymoon Soil Association develop. These soils have a very gravelly loamy sand texture and are rapidly drained. In 20 to 50 percent of the valley floor area, the soils are affected by imperfect drainage, resulting in the development of gleyed soil conditions (Jungen, 1985).

4.5 Vegetation

Most of the Myra Creek Valley lies within the Coastal Western Hemlock biogeoclimatic zone, Wetter subzone, Leeward Montane Maritime variant (CWHb4) (Nuszdorfer et al., 1985). The lower portion of the Myra Valley, near the falls, is drier and warmer than the area near the mine site and is classified in the Drier Maritime subzone, Vancouver Island variant (CWHa1). Upper elevation portions of the drainage (typically above 1100 to 1350 m asl) lie within the Mountain Hemlock biogeoclimatic zone, Maritime Forested subzone (MHa).

The zonal ecosystem association for the CWHa subzone is western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), *Rhytidiadelphus loreus*, and step moss (*Hylocomium splendens*). Other major species include vanilla leaf (*Achlys triphylla*), salal (*Gaultheria shallon*), *Kindbergia oregana*, dull Oregon-grape (*Mahonia nervosa*), sword fern (*Polystichum munitum*), and red huckleberry (*Vaccinium parvifolium*) (Klinka et al., 1984).

The zonal ecosystem association for the CWHb subzone is western hemlock, amabilis fir (*Abies amabilis*), Alaskan blueberry (*Vaccinium alaskaense*), and *Rhytidiadelphus loreus*. Other major species include western redcedar (*Thuja plicata*), step moss, *Rhytidiopsis robusta*, and red huckleberry. The CWHb4 is differentiated from other CWHb variants by the presence of yellow-cedar (*Chamaecyparis nootkatensis*), western tea-berry (*Gaultheria ovatifolia*), twinflower (*Linnaea borealis*), and dull Oregon-grape (Klinka et al., 1984).

The zonal ecosystem association for the Mha subzone is mountain hemlock (*Tsuga mertensiana*), amabilis fir, black huckleberry (*Vaccinium membranaceum*), Alaskan blueberry, and *Rhytidiopsis robusta*. Other major species include western hemlock, yellow-cedar, *Dicranum fuscescens*, *D. scoparium*, false azalea (*Menziesia ferruginea*), *Rhytidiadelphus loreus*, and five-leaved bramble (*Rubus pedatus*) (Klinka et al., 1984).

4.6 Wildlife

4.6.1 Ungulates

The Columbian black-tailed deer (*Odocoileus hemionus columbianus*) is the most common ungulate in the area. The results of a field study conducted in the early 1980's found deer use of the Myra Creek area to be concentrated in the burned area east of the minesite, however, it is expected that use of this site will likely decline over time as forest cover again becomes dominant and the amount of available forage is reduced. The study also found that the steep, south-facing slopes with exposed rock bluffs located on the north side of the valley, downstream of the minesite, were used more heavily than the slopes on the southern side of the valley.

In general, exposed, south-facing slopes are recognized as valuable deer winter habitats on Vancouver Island. Most of the Myra Creek valley would not support wintering deer due to the excessive snow depths. This is reflected in the Canada Land Inventory (CLI) Capability for Wildlife rating of Class 4 to 6 (moderate to severe limitations to ungulate productivity). The exposed south-facing slopes downstream of the mine provide the only likely winter habitat in the area, and have a CLI rating of 3W (significant winter range).

During the field studies in the early 1980's, only one elk pellet group was found in the area.

Based on this single observation, it is possible that a small number of Roosevelt elk (*Cervus elaphus roosvelti*) may migrate through or make sporadic use of the Myra Creek Valley.

The upper portion of the Myra Creek drainage has a CLI rating for ungulates of Class 4 to 7. Field surveys of this area in the early 1980's indicated that ungulate use of this area was likely insignificant due to extended periods of snow cover and limited availability of food.

4.6.2 Carnivores

The black bear (*Ursus americanus*), Vancouver Island wolf (*Canis lupus crassodon*) and cougar (*Felis concolor vancouverensis*) are the large carnivores most likely to occur in the mine site area. Bear sign was widespread throughout the area during the early 1980's studies, and individuals are frequently observed near the mine site.

Based on the presence of what appears to be suitable habitat and abundant prey populations, it is probable that cougar and wolf populations also occur in the area. However, no evidence of cougar or wolf activity was observed during the course of the field studies.

4.6.3 Furbearers

Based on observations of available habitat in the Myra Creek valley, the furbearers most likely to be present include the Vancouver Island wolverine (*Gufa luscus vancouverensis*), marten (*Martes americana caurina*), mink (*Mustela vison evagor*), short-tailed weasel (*Mustela erminea anguinae*), red squirrel (*Tamiascuirius hudsonicus*), and raccoon (*Procyon lotor vancouverensis*).

4.6.4 Rare and Endangered Species

The Vancouver Island marmot (*Marmota vancouverensis*) has been designated as an endangered species by the Committee on the Status of Endangered Wildlife in Canada, and is recognized as endangered by the British Columbia Ministry of Environment, Lands and Parks. Sightings of Vancouver Island marmots have been reported at Flower Ridge (8 km southeast of the mine) and Marble Meadows (14 km north of the mine). The alpine areas adjacent to Mount Myra have been identified as potential locations of marmot colonies.

5.0 LAND USE

The location of the mine within Strathcona Provincial Park determines the potential uses of the land after mining. At the present time, the objective of the B.C. Ministry of Environment Lands and Parks, is for the land to be returned to a natural condition. This will entail the establishment of plant species which will initiate the natural successional patterns of local ecosystems.

The covering of sealed acid generating wastes with soil and the establishment of natural vegetation is the best use of these areas. This type of revegetation effort will protect the integrity of the seal which is necessary to ensure the control of acid generation in wastes. Intensive use of these areas for other recreational activities should be discouraged.

The development of early successional vegetation communities will provide wildlife habitat, particularly for deer, elk and bear. Small mammals and birds will also utilize the habitats provided by the revegetation program.

The control of all acid generation at the mine site will improve the water quality of the groundwater and Myra Creek. This will be reflected in an improved aquatic habitat in Myra Creek.

All mine related structures will be removed and the sites reclaimed to meet these land use requirements. The only exceptions will be the main road into the mine site which will be left open for park access, and the road and dams at Jim Mitchell and Thelwood Lakes which will be retained to provide use of the improved fishery provided by this development.

6.0 REVEGETATION PROGRAM

6.1 Soil Materials

Soil materials were salvaged during the construction of the tailings facility and were stockpiled for use in reclamation programs. It is estimated that 200,000 m^3 of fluvial soil materials were salvaged from the floodplain of Myra Creek were stockpiled. These soil materials have a very gravelly loamy sand texture.

Table 6.1-1 indicates the areas to be covered with soil materials and the prescribed depth of cover. Soil depth is greater on areas with a cementitious seal since the seal must be protected to ensure control of the acid generation in contained materials. A depth of 0.7 m will provide adequate rooting for most species. Many naturally occurring soils in this area have root restricting duric horizons at 0.7 to 1.0 m.

TABLE 6.1-1

Soil Materials Required for Reclamation Program

Site	Area (ha)	Depth (m)	Volume (m^3)
Lynx Pit	6	0.7	42,000
Waste Dump #1	6.5	0.7	45,000
Tailings surface	18	0.7	126,000
Tailings berm	28	0.3	84,000
Mill & Mine Site	20	0.5	100,000
Water Treatment Ponds	9	0.5	45,000
		TOTAL	442,000

The stockpiled soil materials will not be adequate for all the reclamation requirements. Approximately 240,000 m^3 will be required from other sources.

6.2 Vegetation Establishment

The objectives of the revegetation program are to:

- Establish erosion controlling plant cover.
- Initiate nutrient cycling in revegetated systems.
- Plant selected native species which will initiate the natural succession to mature forests.
- Develop suitable habitat for wildlife.

Experience in revegetation of various disturbances in the mine site area has led to the design of appropriate species mixes, fertilizer applications, and timing of seeding and planting of woody species (Reid, Collins Nurseries 1984a, 1984b; Jones and Associates 1991). Table 6.2-1 provides the agronomic species mix which has shown to be most successful in establishment of an initial erosion controlling grass and legume cover.

TABLE 6.2.1

Agronomic Seed Mix

Scientific Name	Common Name	Percent Composition
Festuca rubra	Creeping red fescue	20
Poa compressa	Canada bluegrass	20
Phleum pratense	Climax timothy	20
Trifolium hybridum	Alsike clover	20
Trifolium repens	White clover	20

The most suitable times for seeding of the agronomic mixes are in early spring, as soon as the snow melts, or in mid-August, to take advantage of the fall rains. The summer, from May through August, is characterized by a climatic moisture deficit (see Section 4.1.4).

The grass and legume cover is important in controlling surface soil erosion and initiating nutrient cycling. These species also provide valuable forage for ungulates and bear.

To initiate the return to natural forest communities on the revegetated sites, native tree and shrub species will be planted with the grass and legume cover. Early successional species such as Sitka alder (*Alnus viridis spp. sinuata*) are very valuable in providing a fast developing shrub cover and improving the nitrogen levels in the soils. Other shrubs will be planted for their value as deer and elk forage, species such as: red huckleberry (*Vaccinium parvifolium*), oval-leaved blueberry (*Vaccinium ovalifolium*), salal (*Gaultheria shallon*), salmonberry (*Rubus spectabilis*), bunchberry (*Cornus canadensis*), dull Oregon-grape (*Mahonia nervosa*), Pacific ninebark (*Physocarpus capitatus*), and red elderberry (*Sambucus racemosa*) (Nyberg, J.B., 1990). Many of these species, particularly the berries and the hardwood trees will also provide valuable black bear forage. Tree species such as Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) will provide some forage for wildlife species but will also develop important cover.

Various native tree and shrub species which will be used in the revegetation program are provided in Table 6.2-2. Planting of native shrubs at this site has been most successful in the fall. Conifers may be more successful in spring plantings, if the sites are free of snow by March or early April.

6.3 Vegetation Maintenance

Fertilizer will be applied at time of seeding, the rate to be determined by soil analysis prior to planting. Typically, revegetation sites at the mine site receive an initial application of 400 kg/ha of a 20:20:20 (N:P:K) fertilizer, which is supplemented for three years at an application rate of 200 kg/ha. Trees and shrubs are not fertilized at time of planting due to an observed increase in competition from the grasses and legume cover.

TABLE 6.2-2

Native Tree and Shrub Species for Reclamation of Myra Falls Operations

Scientific Name	Common Name
Acer glabrum	Douglas maple
Alnus viridis ssp. sinuata	Sitka alder
Ceanothus sanguineus	Redstem ceanothus
Cornus sericea	Red-osier dogwood
Cornus canadensis	Bunchberry
Gaultheria ovatifolia	Western tea-berry
Gaultheria shallon	Salal
Mahonia nervosa	Dull Oregon-grape
Physocarpus capitatus	Pacific ninebark
Pinus contorta	Lodgepole pine
Pseudotsuga menziesii	Douglas fir
Rosa nutkana	Nootka rose
Rubus spectabilis	Salmonberry
Sambucus racemosa	Red elderberry
Thuja plicata	Western red cedar
Tsuga heterophylla	Western hemlock
Vaccinium ovalifolium	Oval-leaved blueberry
Vaccinium parvifolium	Red Huckleberry

7.0 ACID DRAINAGE CONTROL

7.1 Introduction

There are various options for decommissioning acid-generating mine components (e.g., B.C. AMD Task Force, Draft Acid Rock Drainage Technical Guide, 1989). Selection among the options is dependent on numerous site-specific and component-specific conditions and processes. For example, a mine located in a high-rainfall area might require options differing from a mine in a low-rainfall area. Also, a mine with a large volume of acid-generating rock may require different options from a mine with little acid-generating rock. In order to understand, and to develop closure options for each acid-generating component, detailed hydrogeological investigations were conducted on each major component at the Myra Falls operations (Northwest Geochem, 1992).

The primary acid-generating components at Myra Falls are (as shown in Figure 7.1-1):

- Lynx Pit, containing Waste-Rock Dumps #2, #3, and #4
- Lynx Underground
- Waste-Rock Dump #1, and
- Myra Falls Tailings Impoundment

The first two were investigated by Northwest Geochem for a period of one year, Dump #1 was studied for three years, and the tailings were studied by others (Environment Canada, 1990). The results of all these studies are presented in the aforementioned hydrogeological report (Northwest Geochem, 1992).

Other potentially acid-generating mine components include the Myra mine and the H-W mine. These areas will be assessed in a proposed hydrogeologic study to be initiated in 1992.

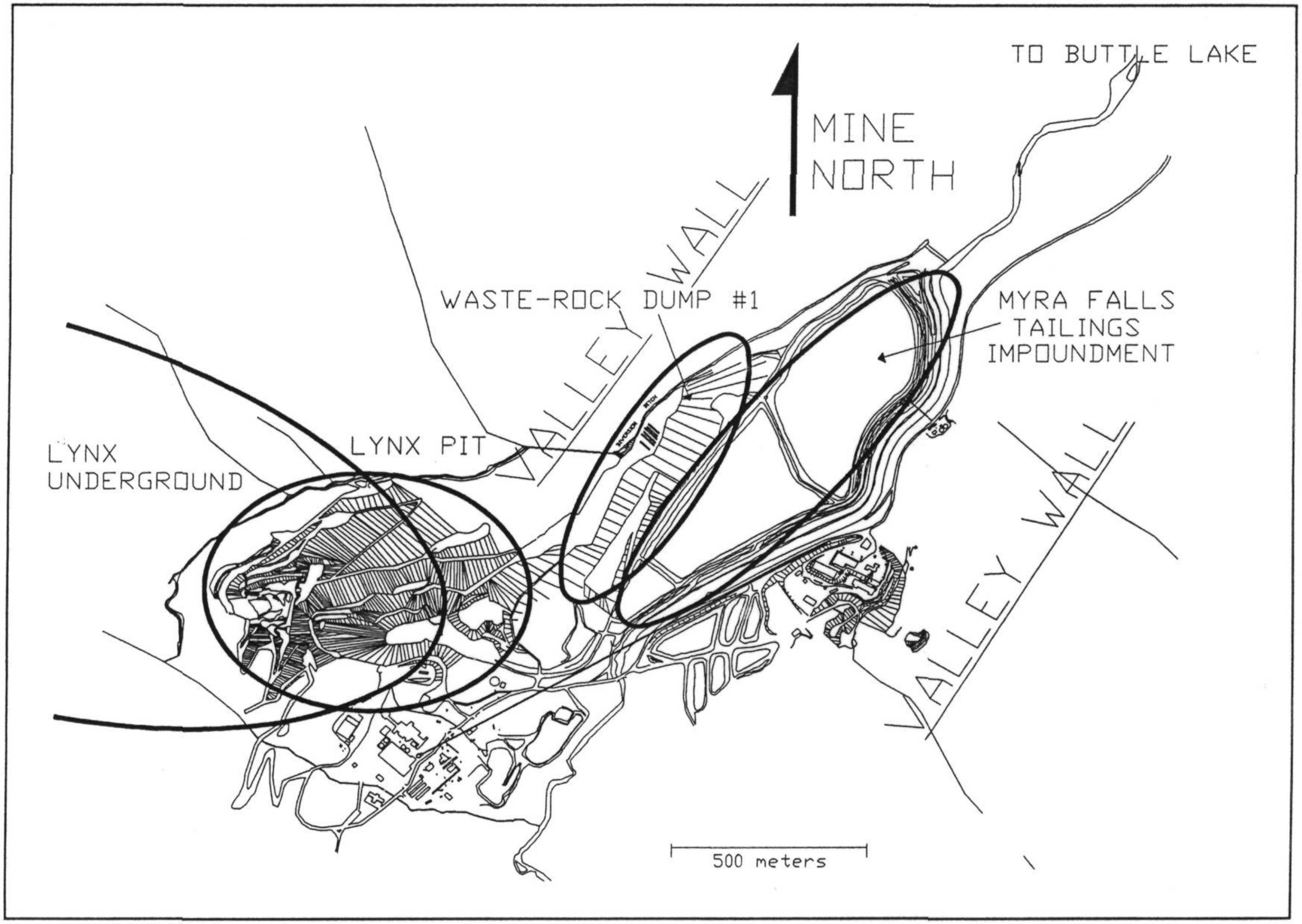

FIGURE 7.1-1. Location of Primary Acid-Generating Mine Components at Myra Falls Operation.

The specific objectives of the hydrogeologic study for each component were:

- to delineate variations in water movement and water quality in and around the Lynx Pit and Lynx Underground,
- to define the water balance and the evolution of water chemistry in and around Waste-Rock Dump #1, and
- to assess the hydrogeological impacts of the Myra Falls Tailings Impoundment.

Each component was found to have unique physical and geochemical characteristics, which were used to select the most appropriate closure option to minimize acid drainage (Table 7.1-1). The following sections summarize the findings and describe the selected closure option for each component, whereas the remainder of this section discusses the interactions and aqueous pathways among the Myra Creek mine components.

From the perspective of water balance and water transport, the existing pathways from the components and the interactions among components can be summarized as a flowchart (Figure 7.1-2). At the present time, a number of flowpaths from the mine components are apparently bypassing the Westmin collection-and-treatment system (shaded area on Figure 7.1-2) and thus are entering the floodplain which is not entirely controlled by the collection system. The objectives of the closure options are to:

- stop all water inputs into the components that can be reasonably controlled,
- stop most flowpaths of acidic water leaving the components,
- remediate water quality in the remaining flowpaths, and
- partially redirect the flowpath from the Lynx Underground into Myra Creek when water quality is acceptable (Figure 7.1-3).

This approach also leads to fewer pathways for monitoring of closure efficiency.

TABLE 7-1

Summary of Closure Options
for the Myra Falls Operations

LYNX PIT		
Criteria To Be Met	**Selected Options**	**Environmental Liabilities/Risks**
Minimize water reaching Lynx pit surfaces	Fill pit with acid-generating rock with internal underdrains and cover pit surfaces as fill rises	Failure (e.g. clogging) of underdrains
Minimize flow through fill in Lynx Pit	Cover rockfill and remaining exposed walls for water control	Failure of cover leading to flushing of accumulated acidity and leached metals; significant condensation and drippage in rockfill and on pit surfaces

LYNX UNDERGROUND		
Criteria To Be Met	**Selected Options**	**Environmental Liabilities/Risks**
Isolate primary zones of acid-generating rock	Within the acid-generating zones, seal walls, stopes, raises, etc. with minor water diversion	Failure to seal entire zones; failure of seals
Minimize oxygen contact on deeper levels	Submerge deeper levels using plugs and bulkheads and accelerate flooding with alkaline water	Failure of plugs and bulkheads; potential long time to remove and neutralize accumulated acidity
Minimize stagnant water on higher levels and ensure sufficient flow to prevent degradation of water quality upon mixing with underdrain water	Divert water from Diversion Ditch into Underground where needed	Insufficient flow for maintenance of water quality; flash flooding degrading seals and remedial work

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TABLE 7-1 (continued)

Summary of Closure Options
for the Myra Falls Operations

DUMP #1		
Criteria To Be Met	**Selected Options**	**Environmental Liabilities/Risks**
Minimize downward movement of water through waste rock	Cover the dump with an impermeable cover for water control with tailings acting as cover in places	Degree of failure of cover determines degree of water-quality degradation in Myra Creek Floodplain.
Minimize water-table fluctuations within dump	If justified by further monitoring, excavate drifts behind valley wall for drainage and control of water table	Failure of drifts to intercept primary groundwater pathways; exposure of acid-generating rock during excavation

MYRA CREEK TAILINGS		
Criteria To Be Met	**Selected Options**	**Environmental Liabilities/Risks**
Minimize acid water flushing through or from tailings	Impermeable cover for water control	Degree of failure will determine the extent and severity of water-quality degradation caused by flushing of accumulated acidity

MYRA CREEK FLOODPLAIN		
Criteria To Be Met	**Selected Options**	**Environmental Liabilities/Risks**
Remove acid drainage and improve water quality in groundwater	Pumping Wells	Insufficient wells and pumpage to capture all significant contaminant pathways

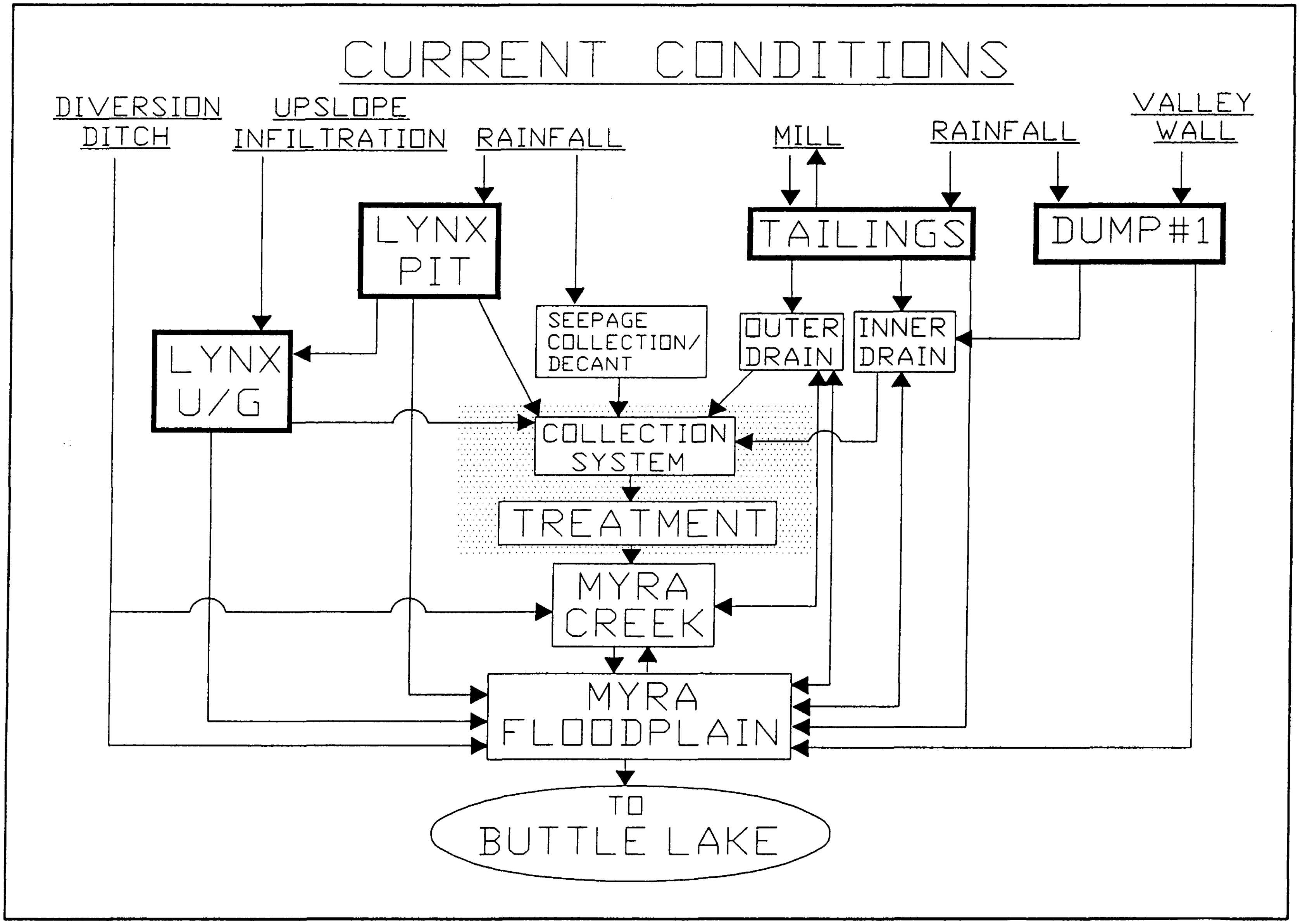

FIGURE 7.1-2. Flowchart of Current Water Pathways.

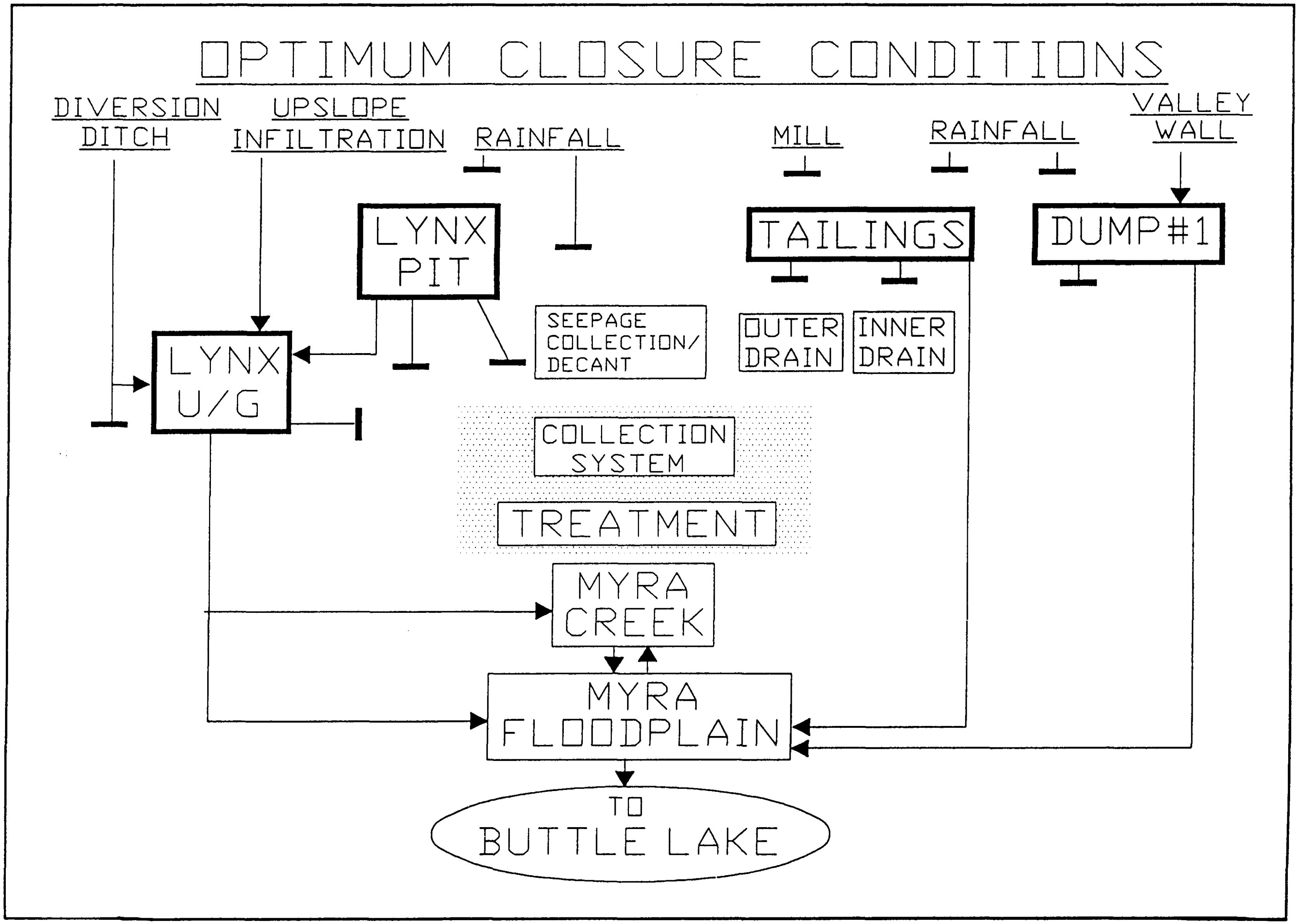

FIGURE 7.1-3. Flowchart of Future Water Pathways After Closure Options Become Effective.

7.1.1 Lynx Pit

The Lynx Pit was excavated laterally into the northwest valley wall (Figure 7.1-1) and is thus not entirely surrounded by rock walls. Precipitation into the Lynx Pit area (Figure 7.1.1-1) was found to be a primary source of water to the Lynx Underground (Section 7.1.2 and Northwest Geochem, 1992). Water passing through the pit area might also be a source of water to the Myra Creek floodplain beneath the tailings (Section 7.1.5).

Visual examination and mapping of the pit surfaces indicated about one-half of the pit in plan view was covered with loose waste rock that appeared to be non-acid-generating, corresponding to Waste-rock Dumps #2, #3, and #4. The intact wall rock beneath the waste rock could not be seen, but is assumed to be acid generating based on wall rock at similar elevations exposed elsewhere in the pit. This rock is capable of degrading the quality of water flowing over and through it into the Lynx Underground. Furthermore, Westmin is currently filling the lower portions of the pit with waste rock which is assumed to be acid generating.

Based on visual mapping and the observations in the Lynx Underground, acid-generating rock is predominately located in the lower two-thirds of the pit (below Level 6 of the Underground). The upper one-third (Levels 5 and 6) of the pit walls appear predominately non-acid-generating, except for approximately 10% located in various discrete pockets.

The closure option for the Lynx Pit must address the following specific criteria:

- minimize water reaching pit walls, and

- minimize water flow through the fill.

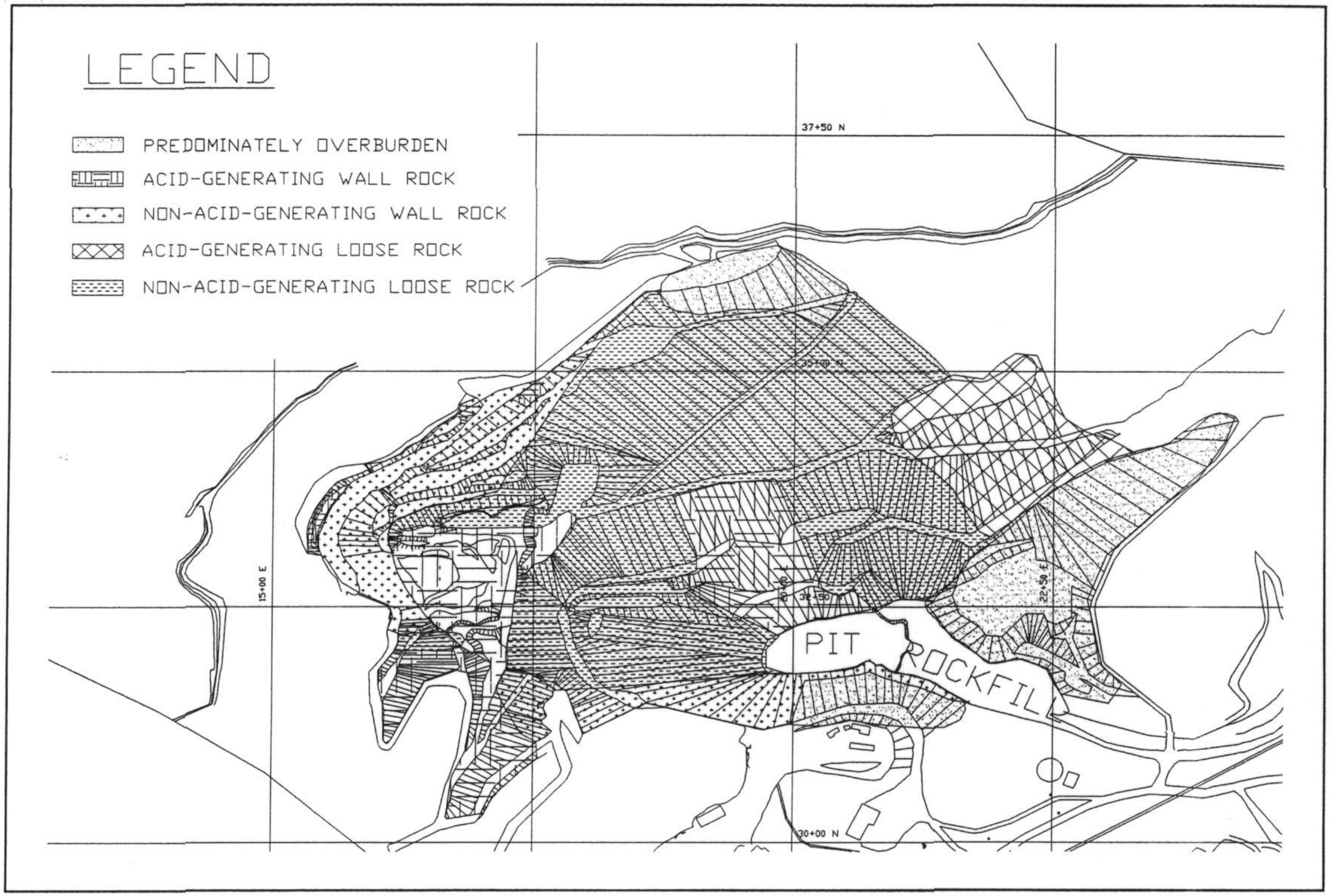

FIGURE 7.1.1-1 Surficial Map of Potentially Acid-Generating Rock in the Lynx Pit Area Based on Visual Iron Staining.

The selected closure option to meet these criteria (Table 7.1-1) involves:

- moving Waste-rock Dumps #2, #3, and #4 in the pit down into the rockfill,(see Map #1, located in map pocket).

- isolating pit walls by covering with sealant and rockfill and controlling water movement with internal drains, and

- isolating the top of the rockfill and any acid-generating pit walls above the rockfill with a sealing cover.

Westmin has been sponsoring research-and-development activity in cementitious sealing covers in association with the MDA program for several years. This research is continuing in order to develop an optimum cover for the environmental conditions at Myra Falls. Nevertheless, an obvious conclusion is that the "impermeable" cover will permit some leakage to occur. Therefore, the internal drains must remain capable, in the long term, of intercepting this leakage and delivering it to the Lynx Underground for neutralization and control. Solidification of the rockfill with cement is also being considered.

7.1.2 Lynx Underground

The Lynx Underground consists of numerous levels at or above the base of the Lynx Pit (Levels 5, 6, 8, 9, 10, and 11) and additional levels below the base (Levels 12 and higher). Some of these levels extend for more than 2 kilometers west of the pit walls (Figure 7.1.2-1).

The one-year hydrogeologic study by Northwest Geochem indicated that most of the water moving through the monitored levels originated within approximately 200 meters of the pit walls and portals. This likely reflects the enhanced fracturing in the rock in the pit area, permitting rapid infiltration of precipitation into the Underground. Verbal reports of flow decreasing by a factor of two after a rainstorm support this conclusion.

Monitoring of flows on various inactive levels shows that flow is often linear in direction, that is, flow originating deep in the mine is augmented by flows from drillholes, fractures, and intersecting cross-cuts and drifts as the flow moves towards the portal or shaft. In places,

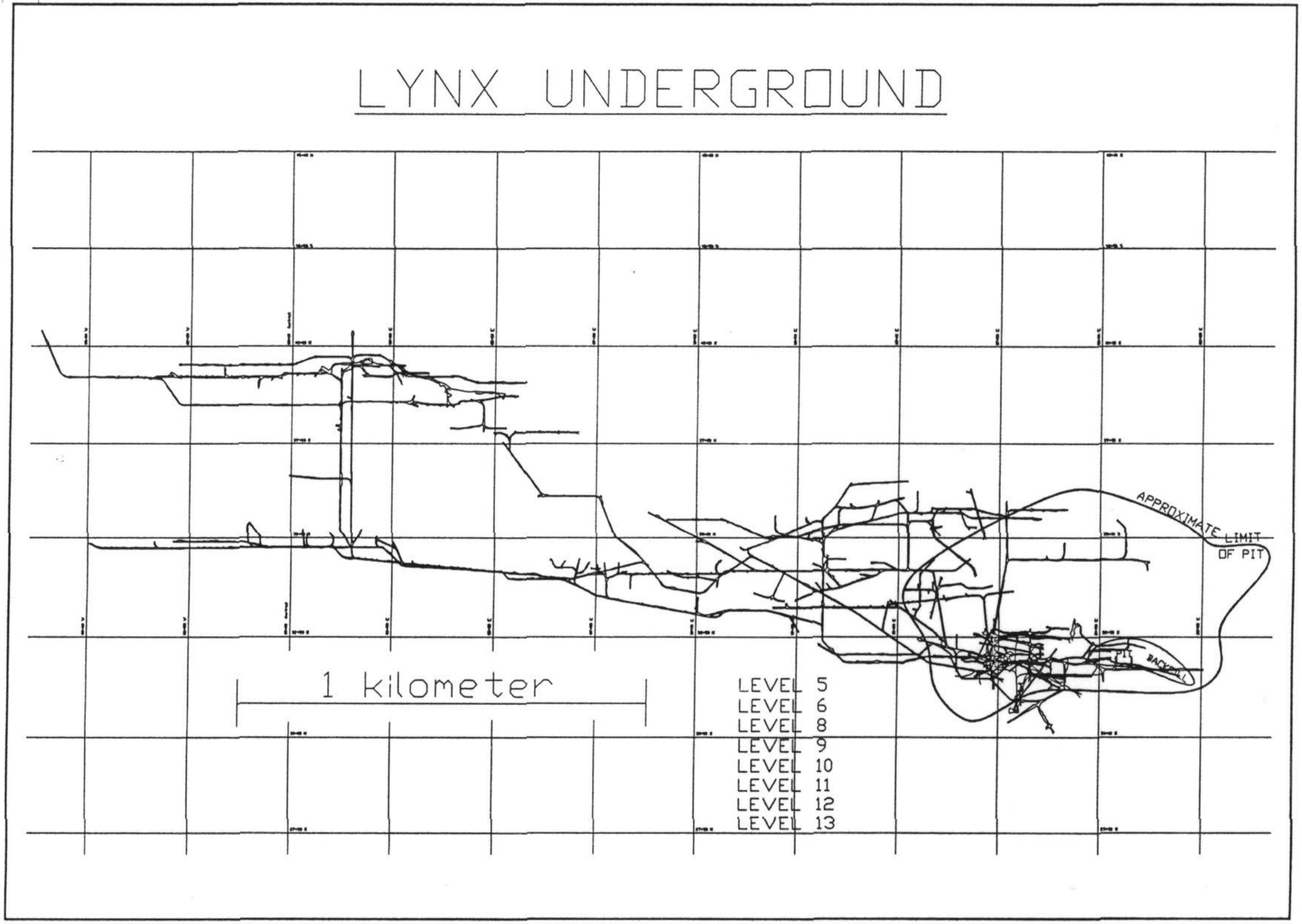

FIGURE 7.1.2-1. Composite of Lynx Underground Levels 5, 6, 8, 9, 10, 11, 12, and 13.

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flow is reduced by loss to underlying levels through raises and fractures. Level 8 has been found to be more complicated, with reversals of flow directions in some drifts as the volume of flow changes. These reversals significantly affect the quality of water appearing at the portal. On active levels, water movement from precipitation is masked by pumping of impounded mine water to the zones of active mining where it then flows over the mine floors to the portal or shaft.

Water-chemistry monitoring on various levels showed that there are two basic sources of acidity. Firstly, on inactive levels, stagnant water provided the lowest values of pH whereas moving water was often pH-neutral or alkaline. This indicates long-term contact of water with exposed underground walls could lead to significant degradation of water quality. Because the pit area will be sealed against water infiltration (Section 7.1.1), water could become stagnant and acidic after closure. Secondly, there were discrete areas on all levels where moving water with acidic pH was identified. This water was usually neutralized upon joining the main flow. Nevertheless, the acidic areas appeared to cluster around a rock mass with lateral dimensions of roughly 100 meters by 100 meters. On Levels 6 through 8, the center of this rock mass is approximately 16+00 meters East/33+00 meters North. Stope "Y" on Level 8, which delivered 1500 L/minute at pH 2.33 in late Autumn of 1990, is located within this rock mass and Westmin has targeted this stope for remediation in 1992. On Levels 10 through 13, the center of the block has shifted to approximately 18+50 meters East/32+00 meters North. There is insufficient information to determine if the rock mass is acid-generating throughout or is composed of randomly distributed acid-generating zones.

The closure option for the Lynx Underground must address the following criteria:

- isolate primary zones of acid-generating rock
- minimize oxygen contact on deeper levels to minimize oxidation, and
- minimize stagnant water on upper levels where flooding may not be feasible due to the extent of fracturing within the pit area.

The selected option to meet these criteria (Table 7.1-1) involves:

- sealing walls, stopes, raises, etc. with cementitious sealant and/or cemented backfill, and use water diversion to other levels where necessary,
- submerge deeper levels with alkaline water, and
- divert water from the upper Diversion Ditch as necessary to minimize stagnant water on upper levels which cannot be easily flooded.

Because the pit area will be sealed against significant water infiltration, the amount of water entering the Underground will decrease upon closure of the pit area (Section 7.1.1). This could lead to two potential concerns. Firstly, the time to flood the deeper levels below the base of the pit will increase, resulting in extended exposure of deeper mine walls to oxygen as well as initial degradation of water quality due to accumulated acidity in the mine walls. These problems can be alleviated by pumping alkaline water into the deeper levels. Secondly, the movement of water in the unflooded higher levels may be insufficient to eliminate stagnant ponds and to neutralize any water entering from the pit rockfill. Augmentation of water flow such as from the Diversion Ditch above the pit may be necessary, under the condition that the primary zones of acid-generating rock in the Underground can be isolated from water movement. Based on data in the hydrogeology study (Northwest Geochem, 1992), the rates of acid generation and metal leaching appear to be relatively slow on some levels and, as a result, only stagnant or slow-moving water is degraded with respect to quality. The purpose of diverting water into these levels of the underground is to minimize stagnation of water and thereby prevent the degradation of water quality, not to provide dilution of contaminated water. Where the diverted alkaline water would come into contact with acid-generating mine walls, the water may also provide acid neutralization. The flows, directions, controls, and alkalinity of the required diverted water are not yet known in detail. Studies are proposed for more intensive delineations of the Lynx levels with respect to such parameters as iron staining, acidity levels and water tracking. Based on these studies, a detailed evaluation of of the water diversion and the acceptability of water from the Diversion Ditch can be made.

7.1.3 Waste-Rock Dump #1

The primary waste-rock dump at the minesite, Dump #1 (Figure 7.1.3-1), was constructed against the northwest valley wall and rises up to 42 meters above original land surface. It contains more than 10,000,000 tonnes of mine rock from all of the mine workings and consists of an upper lift, a partial middle lift, and a lower lift directly adjacent to the tailings impoundment. This dump is still active, currently receiving rock from the H-W Underground.

Due to rapid infiltration of water through this dump, water levels in selected monitor wells were measured twice daily for nearly a year in order to define groundwater movement in and around the dump. Water levels in all other wells were measured during occasional water-quality campaigns. The data show that groundwater moves laterally from the adjacent valley wall, through the base of the dump, and into Myra Creek Floodplain. During peak precipitation events, a significant portion of the water infiltrating into the surface of the dump moves downward within several hours to a few days, causing the water table in the dump to rise by up to 4 meters for a few days. As the groundwater moves towards the Floodplain, it is partially intercepted by the Inner Drain, located near the toe of the dump which is now covered by tailings, and is pumped to the treatment ponds.

Because most of the waste rock is capable of generating net acidity, significant amounts of acid water are flushed downward through the dump during heavy rainfalls and snowmelt. This water then mixes with, and overwhelms, the pH-neutral groundwater at the water table producing a greater volume of acidic water.

Monitoring of ambient temperatures within the dump shows that the dump remains above freezing throughout the winter at depths of 2 meters and deeper. The heat is produced by the acid-generating process of sulfide oxidation at various locations and depths within the dump, generating maximum temperatures of nearly 50°C at depths of approximately 10 meters. This heat generation can be expected to continue for at least several decades.

Monitoring within the dump of concentrations of oxygen, which is required for acid generation to proceed, and carbon dioxide, which indicates the general extent of neutralization reactions, has revealed complex seasonal trends where oxygen can vary from

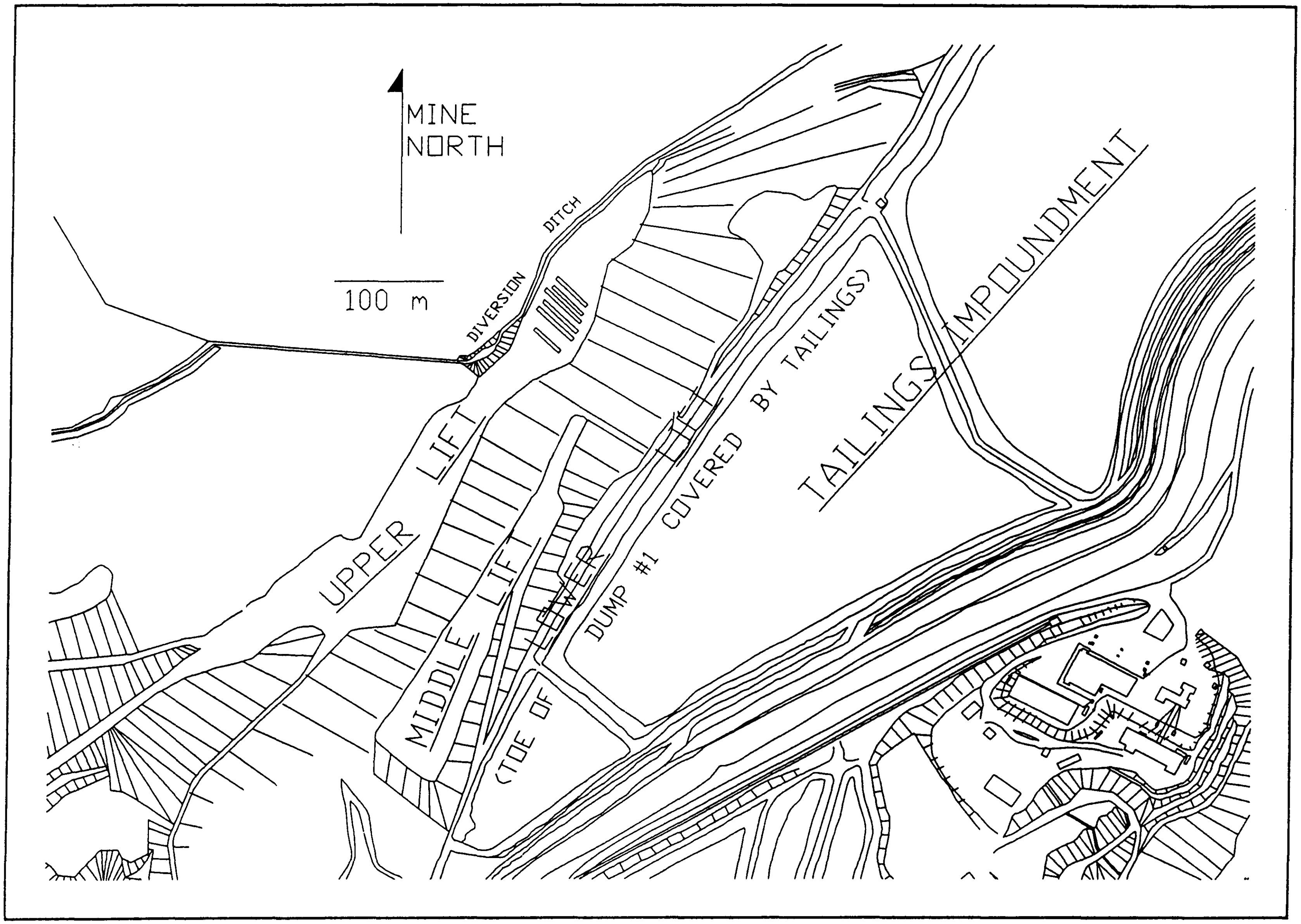

FIGURE 7.1.3-1. Locations of Waste-Rock Dump #1 and Myra Falls Tailings Impoundment.

atmospheric levels to nearly zero down to depths of at least 30 meters. These results suggest rapid migration of oxygen through alternating vertical and horizontal pathways, rendering the prediction and control of gas migration complex and difficult.

This dump contains acid-generating waste rock which releases acid drainage to the underlying and downgradient groundwater systems, particularly the Myra Creek Floodplain. The waste rock requires oxygen and moisture for continued acid generation and requires water movement to flush the acidity from the dump. Because the limitation of oxygen from waste-rock dumps is not currently reliable, and because gas monitoring in Dump #1 suggests the presence of rapid, alternating vertical and lateral pathways for gas migration, closure of the dump must focus on control of water movement. The two primary aspects of water movement that permit flushing of acidity from Dump #1 are: downward migration of acidity to the water table and, to a lesser extent, seasonal fluctuations of the water table upwards into acid-generating rock.

In light of the preceding observations, the specific criteria to be met by the closure options are:

- minimize downward movement of water through the dump, and

- if required by further monitoring, minimize water-table fluctuations within the dump.

The selected closure option to accomplish this involves (Table 7-1):

- covering the dump with a cementitious or other sealant, and

- if required by further monitoring, control of water-table fluctuations could be necessary, for example, excavating free-draining drifts behind the valley wall for drainage and water-table control could be considered.

The sealing cover over the dump will not completely eliminate infiltration and some degree of failure is expected. Further studies are required to define the acceptable level of failure and to design a cover with the resulting degree of integrity.

7.1.4 Tailings Impoundment

Northwest Geochem has not studied the tailings impoundment (Figure 7.1.3-1) as part of the hydrogeologic study. However, a detailed hydrogeologic investigation of the surficial tailings was conducted by Environment Canada (Environment Canada, 1990). The final 1990 report explained that significant portions of the surficial tailings were capable of generating net acidity. Based on geochemical and permeability data, there was evidence of lateral and vertical migration of acidic porewater in the tailings impoundment.

Based on this and other available information (Northwest Geochem, 1992), the criterion to be met by the closure option is:

- minimize migration of acidic water through or from the tailings.

Based on the environmental liabilities and risks involved for all options, a cementitious cover has been selected as the closure option (Table 7.1-1). Establishment of stable soil and vegetation on the cover would enhance the ability of the cover to limit the penetration of water and oxygen. A drainage system will be established on the surface of the tailings prior to the application of the sealant. The tailings deposition pattern results in a sloping surface as indicated in Figure 7.1.4-1. The final deposition of tailings will be carefully monitored to ensure the required drainage is achieved. The water from the tailings surface area will drain into a collection system which will release the water into the main diversion ditch and ultimately into Myra Creek. Two spillways have been constructed in the tailings berm to provide emergency discharge to Myra Creek during the operation of the tailings facility. These structures will be retained at mine closure and will continue to provide emergency discharge and protect the integrity of the tailings berm.

The emergency tailings impoundment, adjacent to the Lynx settling ponds, will be removed and the tailings placed in the main tailings impoundment. The berm materials from this impoundment will be placed into the rockfill in the Lynx pit. The site will then be revegetated. Since this emergency facility is no longer necessary for the operation of the mine, the decommissioning of this facility is proposed to be completed by 1995.

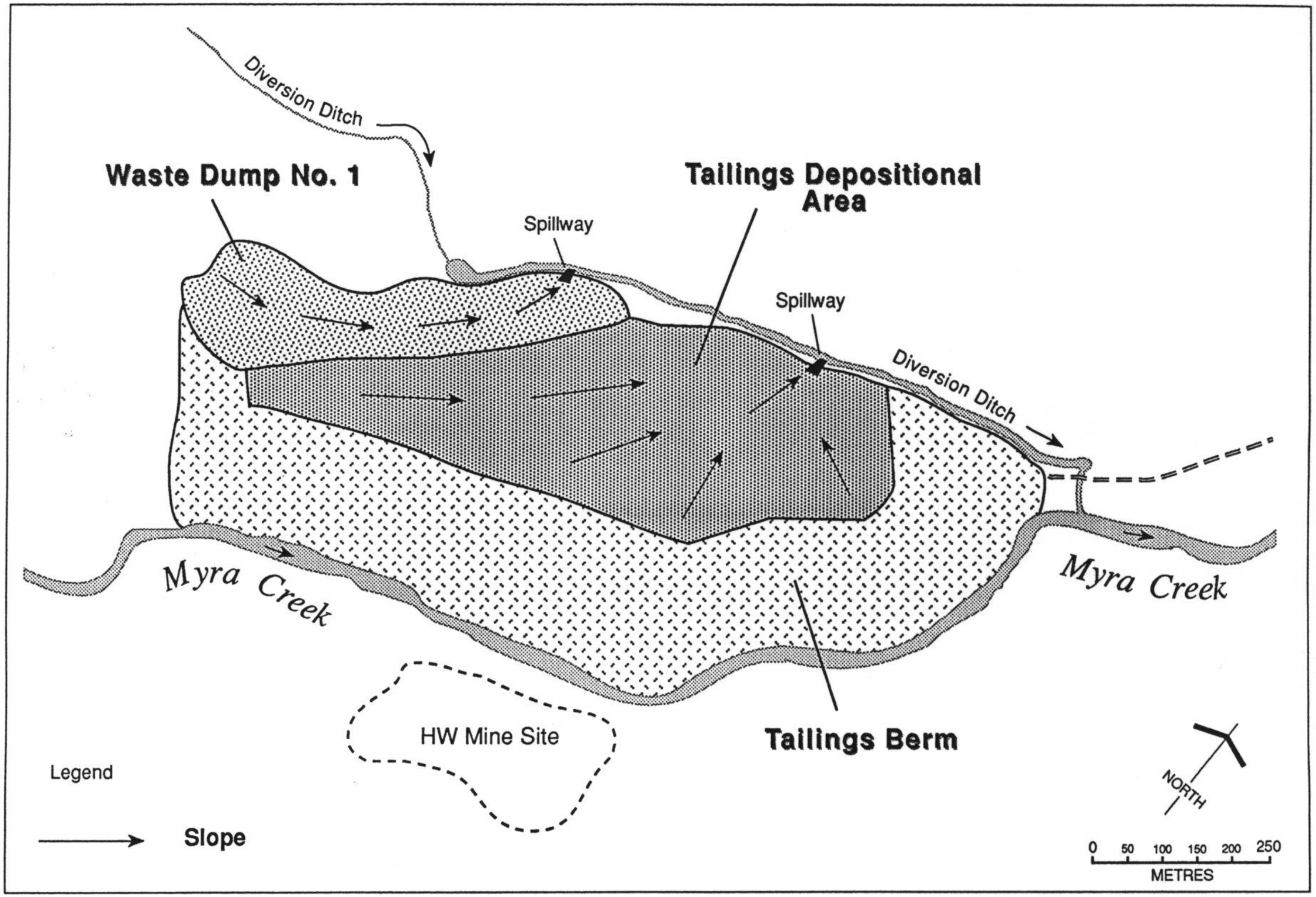

FIGURE 7.1.4 -1 Conceptual Plan of Surface Drainage From Waste Dump and Tailings Area

7.1.5 Myra Creek Floodplain

The Myra Creek Floodplain lies hydrogeologically downgradient of the Lynx Pit, Lynx Underground, Dump #1, and the Tailings Impoundment. As a result, the floodplain has been receiving acidic groundwater for more than 10 years (Northwest Geochem, 1992). It is not known at this time the degree to which the floodplain has been affected, and a hydrogeology study is proposed to assess the present groundwater conditions. When the acid-generating mine components are securely decommissioned and closed, the quality of groundwater in the floodplain will begin to improve. If necessary, pump wells will be installed in various locations in order to intercept and extract most of the acidic water. Additionally, the measured trend in water quality during pumping will provide the necessary downgradient monitoring of subsurface water to establish the success of all implemented closure options.

7.2 Sealant Technology

A variety of materials have been proposed for use as covers or seals for reactive waste rock and tailings; including soils, synthetic membranes, compacted clay and till, asphalt and concrete. The Draft ARD Technical Guide (1989) discusses the relative advantages and disadvantages of the various types of covers. Solidification technology employing cement-based products has been in use for at least three decades. These materials have primarily been developed for the purpose of encapsulating radioactive materials and heavy metal wastes to render them inert or non-leachable during burial. The technology is also gaining acceptance as a method for capping of waste rock and tailings to restrict the acid generation process and the formation of acid drainage.

Design objectives for a dry cover capping system for control of acid rock drainage would require that the material:

- is easily applied
- is durable
- has good ductility

- has reasonable compressive strength
- is chemically resistant
- has low permeability to air and water
- is economical
- is compatible with revegetation programs.

Cementitious sealants have the potential to be designed to meet these criteria.

Westmin Resources Limited, in association with the MDA program, has been researching, developing and testing a cementitious cover which incorporates mine waste materials, specifically; mine tailings and wastewater sludge from the water treatment system. The primary objective for the incorporation of these waste materials was to reduce the overall cost of the solidified cover material. In addition, chemically stabilizing the waste materials into an inert matrix would provide a safe means for disposal. The stabilization of wastewater sludges is discussed in Section 7.3.

The research program has led to the design of a shotcrete mix which can be applied to vertical or sloped rock faces. The concrete has to have a relatively dry consistency so that the material can support itself on a slope; at the same time the mix has to be wet enough to obtain compaction and adhere to the surface. This study has shown that solidification of mine tailings in a cementitious matrix can be a viable option for sealing waste rock dumps to control acid mine drainage. The concrete mixes tested showed good compressive strengths, good ductility, and low permeability. Shotcreting was found to be an ideal method to apply the fibre-reinforced solidified cementitious cover to sloping waste rock surfaces (Northwest Geochem, 1991; Gerencher *et al.* 1991). A large scale test of this shotcrete technique is proposed for the 1992 field season. This study will evaluate the effectiveness of the cementitious cover to restrict acid generation and to evaluate material properties such as durability, weatherability and permeability.

7.3 Stabilization of Wastewater Sludge

The water treatment facilities at Myra Falls produce sludges which, during mine operations, are deposited into the tailings facility. Upon closure of the mine, water treatment may be required for an indeterminate length of time, and an alternative method of sludge disposal will be necessary. Research conducted by Northwest Geochem (1991) tested methods of chemically stabilizing the sludge into an inert matrix to provide a safe means of disposal. Solidification of sludges was found to be limited by retarded setting times and batching problems due to the inconsistent water contents. However, further work showed that the sludge could be stabilized in a weak cement mixture which could be disposed in a landfill or utilized as a grout material to seal voids when dumped concurrently with waste rock. A weak cement mixture is adequate for these uses because the material does not require strength. Leachate testing showed that the solidified mixture was chemically inert. The material met requirements for shrinkage, freeze/thaw resistance, and acid neutralization capacity. This study suggests that the sludge stabilization mixture should be composed of 6-8 per cent cement, a maximum of 20-22 percent decanted sludge, and aggregate in the form of coarse tailings and/or sand in weight proportions exceeding 70 percent (Northwest Geochem, 1991).

8.0 WATERCOURSES

All watercourses, natural and constructed, will be left in a condition where they will sustain themselves without maintenance. The water quality of these watercourses will be ensured through control of acid generating materials. Some watercourses will be returned to original drainages, while others will remain diverted in secure channels. Closure details for each watercourse are provided in the following sections.

8.1 Myra Creek

A portion of Myra Creek was diverted in 1985 to provide for the construction of the tailings facility. This diversion was designed to meet maximum flood criteria of the 1 in 200 year flood. Rip rap was placed along the berm of the tailings facility to a height of the probable maximum flood level. This diversion is permanent. The water quality of Myra Creek will be ensured through the acid generation controls discussed in Section 7.0.

8.2 Tennent Lake and Creek

A small dam was constructed on Tennent Lake in the 1960's to provide water storage for a small hydro-electric facility located near the confluence of Tennent and Myra Creeks. This facility will be required to provide power to the mine area after closure as long as the water treatment facility is operating. When water treatment is no longer required, the dam, above ground portions of the penstock, and the power plant will be removed and the site reclaimed. The outflow from the Lake will be returned to Tennent Creek.

8.3 Lynx Diversion Ditch

A diversion ditch was constructed upslope from the Lynx pit, waste dumps and tailings facility to reduce the water entering the mine operations area. At the time of mine decommissioning the acid generation control for the Lynx underground may require a portion of the flow from this ditch to eliminate stagnant water and to neutralize any water entering from the pit rockfill. It will not be possible to return the flow in the diversion ditch to previous channels since these areas have been modified by the construction of mine components. The sealed surfaces in the pit, dump and tailings facility must be protected from the erosive force of streams, therefore the diversion ditch must be retained and upgraded where required to meet probable flood levels.

8.4 Myra-Lynx Water Treatment Ponds

A series of ponds for chemical water treatment has been constructed on both sides of Myra Creek. It is proposed to maintain the use of these ponds until acid generation control techniques have eliminated the requirement for chemical water treatment. The ponds will be redesigned to act as a passive, biological acid generation control facility through the establishment of wetlands. Wetland have been shown to provide "polishing" of acidic seeps at abandoned mines (Acid Rock Drainage Technical Guide, 1990). This type of control facility is suitable for treatment of low levels of acidity and will provide a buffer zone between the mine facilities and Myra Creek.

8.5 Jim Mitchell Lake

Jim Mitchell Lake was raised by approximately 20 m through the construction of a dam in 1984. The access to this lake through the construction of a road to the lower end and the decision by the British Columbia Ministry of Environment Lands and Parks to stock the lake, has led to use by local anglers. Westmin proposes to leave the dam in place to protect the unique fisheries values in this lake. The intake structures at the lake will be removed and the penstock sealed.

8.6 Thelwood Lake

The water level in Thelwood Lake, upstream from Jim Mitchell Lake was raised approximately 3.5 m to provide storage for the hydro-electric facility. The British Columbia Ministry of Environment Lands and Parks has also stocked this lake with fry and therefore the small dam on Thelwood Lake will not be removed.

8.7 Thelwood Creek

The closure of the intake to the penstock at Jim Mitchell Lake will return all of the natural flow to Thelwood Creek.

9.0 STABILITY OF ENGINEERED STRUCTURES

The engineered structures which will remain after decommissioning of the mine site are the tailings impoundment and the rockfill in the Lynx pit.

The tailings embankment was designed for long-term safety against seismic activity, with a final slope of 1 vertical to 4 horizontal, and a starter embankment crest width of 8 meters (Knight and Piesold Ltd, 1982). The tailings facility was designed to resist deformation in a magnitude 7.5 earthquake. Subsequent testing of the tailings (Knight and Piesold, 1986) concluded that the tailings as deposited meet or exceed all design assumptions.

An engineering design study will be undertaken on the proposed rockfill of the Lynx Open Pit with waste rock. This study will design the underdrains, and appropriate slopes for the surface sealed rock.

10.0 ROADS

Two access roads will be left after decommissioning the mine; the main access road to Myra Creek and the access road to Jim Mitchell Lake. British Columbia Ministry of Environment Lands and Parks will assume responsibility for these roads. All other small access roads will be reclaimed to meet the land use objective of the land unit in which they occur. Culverts will be removed and water courses reestablished, erosion controlling water bars will be constructed as required to ensure the physical stability of slopes. All power poles, road edge barriers, etc. will be removed. Roads will be recontoured to blend into the surrounding topography and the road bed will be scarified or ripped to reduce compaction. Road cuts and small borrow pits will be backfilled. Steep cut and fill slopes will require stabilization through bioengineering techniques, and all areas will be seeded and planted with native trees and shrubs.

11.0 MINE STRUCTURES AND EQUIPMENT

All of the equipment will be removed from the site and the buildings dismantled. Acid generating material has been identified in the fill used in the Lynx operations area, the H-W service yard and the H-W warehouse compound area. These materials will be excavated and transported to the Lynx Open Pit or # 1 Waste Dump where they will be sealed with the other materials in those sites. The foundations of all the structures will be removed or buried with non acid-generating soil materials. Where acid generating wastes have been removed, soil materials will be placed to a depth of 0.5 m to provide a suitable rooting environment for plants. Soils which have not been impacted with acid-generating materials will be scarified to reduce compaction and revegetated directly.

The surface openings of the H-W Mine will be permanently sealed for public safety. All access to the Lynx Mine will be sealed as part of the acid generation control for this area.

12.0 SCHEDULE OF DECOMMISSIONING

The proposed schedule for the decommissioning of the mine site is provided in Table 12-1. The date of closure of the mine is unknown at this time, therefore the schedule is not accurate beyond 1995. The time required to decommission the mine site after closure will be influenced by various factors and is not predicted. It is the intent of Westmin Resources to carry out all decommissioning activities in a timely fashion upon closure of the mine.

All areas which can be decommissioned prior to mine closure are shown in Table 12-1. The control of the acid generation in these areas will reduce the amount of water which requires chemical treatment. This work schedule will also allow the evaluation of the performance of the acid generation control methods prior to the closure of the mine.

TABLE 12-1

Decommissioning Schedule 1992-1998

AREA	BEGIN	COMPLETE
Lynx Underground - Sealing of Acid Generating Areas	1992	1995
Rockfill Lynx Pit and Seal	1993	1998
Price Mine Revegetation	1993	1995
Remove Emergency Tailings Pond	1993	1995

13.0 DECOMMISSIONING COSTS

Costs have been estimated for the various components of the mine closure based on the techniques believed to be the best options at this time. Developments in acid-generation control technology may vary these costs significantly. However, the approach proposed is considered to be an expensive solution and new technological developments should reduce these costs, not increase them. Table 13-1 provides the total decommissioning costs by mine component, in 1992 dollars. Details of the costs are presented in the following sections.

TABLE 13-1

Total Estimated Closure Costs

Lynx Pit	$4,608,000
Lynx Underground	$6,450,000
Waste Dump # 1	$1,514,500
Tailings (surface & berm)	$4,535,600
Myra Creek Floodplain	$1,000,000
Mill and Mine Site	$1,602,000
Roads	$153,000
Water Treatment Ponds	$611,500
Price Mine	$366,800
Tennent Lake & Penstock	$327,900
TOTAL COST	**$21,169,300**

In addition to the closure costs, it may be necessary to operate the chemical water treatment facility for an unknown period of time. The operating costs for this facility are approximately $750,000 per year. A decrease in the water volumes requiring treatment would result in a reduction in lime costs, however a minimum cost to operate the facility is approximately $500,000 per year.

13.1 Lynx Pit

As described in Section 7.1.1, the closure option selected for this area is to move waste rock from the upper dumps, # 2, 3, and 4, into a constructed rockfill with internal drains and a cementitious seal over the surface. This sealed rockfill area would then be covered with soil material and revegetated. Areas of acid generating pit walls above the sealed rockfill would be sealed with a shotcrete cover. The costs to complete these tasks are provided in Table 13.1-1.

TABLE 13.1-1

Estimated Closure Costs for Lynx Pit

Task	Costs	Total
Develop rockfill in pit with acid-generating waste from dumps #2, #3 & #4, adjacent to the pit.	1,000,000 m^3 of waste, loaded, hauled and placed @ \$3.00/m^3	\$3,000,000
Seal rockfilled area and remaining exposed acid generating walls.	6 ha rockfill and 1 ha of wall, @ \$210/m^3	\$1,470,000
Cover sealed rockfill area with overburden material	6 ha @ 0.7m depth =42,000 m^3 @ \$2.70/m^3	\$113,400
Revegetate overburden area	6 ha @ \$4100/ha	\$24,600
	TOTAL FOR LYNX PIT	**\$4,608,000**

13.2 Lynx Underground

The closure option selected for the Lynx Underground involves sealing acid-generating walls, with a shotcrete cover, filling stopes with a cemented backfill, and blocking off all portals with concrete bulkheads, and instituting various water diversions. The costs for implementing these control measures are presented in Table 13.2-1.

TABLE 13.2-1

Estimated Closure Costs for Lynx Underground

Task	Costs	Total
Seal acid generating walls and fill stopes with cemented backfill	areas and volumes to be determined.	range from $3,000,000 to $6,300,000
Plugs for portals and bulkheads	estimate 20 @ $7,500	$150,000
	TOTAL FOR LYNX UNDERGROUND	**$6,450,000**

13.3 Waste Rock Dump # 1

The tailings will encapsulate most of the surfaces of the Waste Rock Dump # 1. To control water infiltration on the remaining surface of Waste Dump # 1, a shotcrete capping will be applied, to be covered with soil material to a depth of 0.7 m and revegetated. The estimated costs to complete this program are given in Table 13.3-1.

TABLE 13.3-1

Estimated Closure Costs for Waste Dump # 1

Task	Costs	Total
Seal exposed dump surface for water control with shotcrete	area not covered with tailings estimated @ 6.5 ha @ depth of 0.1 m 6,500 m^3 @ \$210/m^3	\$1,365,000
Cover sealed area with overburden material	6.5 ha @ 0.7m depth =45,500 m^3 @ \$2.70/m^3	\$122,850
Revegetate overburden area	6.5 ha @ \$4100/ha	\$26,650
	Total Cost for Waste Rock Dump # 1	**\$1,514,500**

13.4 Tailings Deposit

The surface of the tailings deposit will be sealed with shotcrete to control water migration through or from the tailings. The shotcrete seal will require protection to ensure its integrity, therefore the level surface area will be covered with soil material to a depth of 0.7 m. The berm slopes will not be sealed with shotcrete and will therefore not require the same depth of soil material. It is proposed to apply 0.3 m depth of soil to the berm slopes. All of the tailings area will be revegetated with appropriate plant species. The costs associated with this program are presented in Table 13.4-1.

TABLE 13.4-1

Estimated Closure Costs for Tailings Deposit

Task	Costs	Total
Seal exposed tailings surface for water control with shotcrete	area of level tailings estimated @ 18 ha shotcrete @ 0.1 m depth 18,000 m^3 @ $210/$m^3$	$3,780,000
Cover sealed area with overburden material	18 ha @ 0.7m depth =126,000 m^3 @ $2.70/$m^3$	$340,200
Revegetate level overburden area	18 ha @ $4100/ha	$73,800
Cover berm area with overburden material	28 ha @ 0.3 m depth =84,000 m^3 @ $2.70	$226,800
Revegetate sloping overburden area	28 ha @ $4100/ha	$114,800
	Total Cost for Tailings Deposit	**$4,535,600**

13.5 Myra Creek Floodplain

The floodplain has been impacted by acidic groundwater for over a decade and will continue to be impacted until all the acid-generating mine areas are securely decommissioned. To improve water quality, pump wells may be required in various locations to intercept and extract most of the acidic groundwater. The number of wells required and the duration of operation is not known at this time, however an allowance for costs associated with this program has been made. This cost estimate is presented in Table 13.5-1.

TABLE 13.5-1

Estimated Closure Costs for Myra Creek Floodplain

Task	Costs	Total
Drilling and pumping of wells	costs to be determined by wells required.	Estimate $1,000,000
	TOTAL FOR MYRA CREEK FLOODPLAIN	**$1,000,000**

13.6 Mill and Mine Site

The buildings and equipment will be sold and removed from the mine site. It is estimated that the revenue generated from the sale of these assets will cover all of the costs of removal. The primary cost involved in the reclamation of these areas is the removal of contaminated fill material. After removal of these acid generating materials to safe disposal in the Lynx Open Pit or # 1 Waste Dump, clean soil material will be placed over these sites at a depth of 0.5 m. These areas will then be revegetated with appropriate species. The cost estimate for this program is shown in Table 13.6-1.

TABLE 13.6-1

Estimated Closure Costs for Mill and Mine Site

Task	Costs	Total
Removal to Lynx pit of acid generating waste material	estimate 500,000 m^3 to move @ $2.50/$m^3$	$1,250,000
Cover areas with overburden material	20 ha @ 0.5 m depth =100,000 m^3 @ $2.70/$m^3$	$270,000
Revegetate overburden area	20 ha @ $4100/ha	$82,000
	Total for Mine and Mill Site	**$1,602,000**

13.7 Roads

Roads associated with the mine site, but not included in any of the other areas, are calculated to be approximately 5 ha in area. Many of these roads are associated with the Lynx Open Pit and are very steep, with long cut and fill slopes. Techniques to revegetate similar roads have been implemented along the Jim Mitchell Lake road, and have been used to determine the cost estimates presented in Table 13.7-1. Bioengineering techniques of wattle fencing, and hedge brush layering, in association with dense planting of rooted native plant seedlings have been very sucessful in stabilizing very steep road disturbances. Additionally, water control structures will be installed, all culverts removed, and drainages redirected into original channels.

TABLE 13.7-1

Estimated Closure Costs for Roads

Task	Costs	Total
Site preparation	5 ha ripping, contouring	$72,000
Slope stabilization	bioengineering	$54,000
Revegetation	5 ha @ $5400/ha	$27,000
	Total Cost for Roads	**$153,000**

13.8 Water Treatment Ponds

When the water treatment ponds are no longer required for the chemical treatment of acid waters, it is proposed to reclaim these areas as wetlands to provide a biological treatment for low levels of acidity. This will involve removal of all accumulated sediments, reconstruction of the water flow and depths of ponds, and revegetation with wetland species. The costs estimated for the reclamation of these ponds is presented in Table 13.8-1.

TABLE 13.8-1

Estimated Closure Costs for Water Treatment Ponds

Task	Costs	Total
Removal of sediments, replacement with soil materials	sediment removal $20,000; soil material 45000 m^3 @ $2.70/$m^3$	$141,500
Establish desired drainage pattern	$20,000	$20,000
Revegetate with wetland species	9 ha @ $50,000/ha	$450,000
	Total Costs for Water Treatment Ponds	**$611,500**

13.9 Price Mine

The land disturbance associated with the Price Mine exploration area includes roads, adits, and waste dumps. The Price ore reserves are not presently scheduled for development, and the final reclamation of this site cannot be completed until these reserves are mined. However, a detailed assessment of these areas has recently been completed and the costs for final closure are based on experience in revegetation of similar sites along the Jim Mitchell road. The adits will be secured with concrete seals at the portals. Structures and equipment associated with the previous mining activities will be removed, and the areas recontoured as much as possible. Bioengineering will be required on many of the steep slopes to stabilize these areas for plant establishment. The cost estimate for this program is shown in Table 13.9-1. A portion of this program is scheduled to begin in 1993.

TABLE 13.9-1

Estimated Closure Costs for Price Mine

Task	Costs	Total
Roads, approximately 2.5 ha	ripping, contouring $60,000 planting $22,500 bioengineering $45,000	$127,500
Closure of portals	4 @ $7,500	$30,000
Revegetation & Bioengineering of Dumps	planting 2.5 ha @ $9000/ha; bioengineering $42,000	$64,500
	Total Cost for Price Mine	**$366,800**

13.10 Tennent Lake and Penstock

The power generation from the Tennent system will be required until all of the decommissioning is complete and water treatment is discontinued. At that time, the power generation facility and the dam at Tennent Lake will be removed. The penstock will be removed in steep areas to allow the right-of-way to be reclaimed. In more level areas near the lake, the buried penstock will be sealed and left in place. The steep portions of the right-of-way will require considerable bioengineering and water control to ensure vegetation establishment. The estimated costs for this program are given in Table 13.10-1.

TABLE 13.10-1

Estimated Closure Costs for Tennent Lake and Penstock

Task	Costs	Total
Removal of dam and inlet structure, re-establish channel of creek	$30,000	$30,000
Sealing portions of penstock pipe, removal of portions of pipe, regrading right of way	$130,000	$130,000
Revegetate level areas	5 ha @ $4100/ha	$20,500
Revegetate steep areas	2.3 ha @ $5400/ha planting; 4500 m bioengineering @ $30/m	$147,420
	Total Cost for Tennent Lake and Penstock	**$327,920**

14.0 MONITORING REQUIREMENTS

Surface water quality monitoring will continue throughout the life of the mine, at the time of mine closure an appropriate sampling program will be determined in conjunction with the Ministry of Environment, Lands and Parks. Quarterly water quality sampling will continue in Waste Dump #1 and the Lynx Underground to confirm the results obtained in the hydrogeology studies to date. The sampling programs will be modified, particularly in the Lynx Underground to test the success of the remediation measures to be undertaken in 1992 through 1995.

Hydrogeologic monitoring of the Myra Creek Floodplain will be initiated to determine the degree to which the floodplain has been affected by mine operations. Wells established in this study will provide downgradient monitoring of subsurface water to establish the success of all implemented closure options.

Revegetation success on all reclaimed sites will be monitored, during the initial establishment phase, to determine species survival and productivity. Additionally, at that time, vegetation tissue samples will be monitored for metal uptake.

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TRUE
MINE
WASTE DUMP No. 2
WASTE DUMP No. 1
WASTE DUMP No. 4
WASTE DUMP No. 3
LYNX PIT BACKWALL
LYNX PIT
BACKFILL AREA
TAILINGS DEPOSITION AREA
OVERBURDEN STOCKPILE
DIVERSION DITCH
MILL SITE
TAILINGS BERM
EMERGENCY TAILINGS POND
HW MINE SITE
TAILINGS BERM
MYRA CREEK
MYRA PIT
FORMER TAILINGS LINE AND ROAD
TO MYRA FALLS
TO CAMPBELL RIVER
TO POWER HOUSE
BUTTLE LAKE
KEY PLAN
SCALE N.T.S.
THIS DRAWING
LEGEND
Reclamation Treatment
• Revegetated
• Surface Seal and Till Cover
• Revegetated
• Waste Removed
• Revegetated
• Building and Waste Removal
• Revegetated
• Waste Removed
• Wetland Constructed
inches
centimetres
This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.
BRITISH COLUMBIA GEOLOGICAL SURVEY
0 200 400 600 800 FEET
0 50 100 150 200 250 METERS
WESTMIN RESOURCES LTD.
MYRA FALLS OPERATIONS
Map 1
Conceptual
Final Reclamation
February 1992
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