2.6 Ore Processing

2.6.1 Summary

The processing facilities have been designed to process 584,000 t/y of Wolverine deposit ore and recover the contained copper, lead, zinc, gold, and silver. The process will utilize conventional techniques in progressive particle size reductions, physical separation and concentration of the minerals of interest from gangue into concentrates at marketable grades. Particle size reductions will be achieved with crushing and grinding, while mineral separations will be achieved by dense media separation and flotation techniques. Processing will not involve chemical processes or alterations to the products. The low concentrations of reagents added during processing will largely be adsorbed on particle surfaces to facilitate the physical separation and will not generate chemical reactions.

The process facilities will operate 24 hours per day, 365 days per year with scheduled downtime for maintenance of equipment. The facilities will have the following unit operations:

- two-stage crushing
- dense media separation
- two-stage grinding
- differential flotation
- rougher concentrate regrinding
- concentrate thickening
- concentrate filtration
- concentrate storage
- paste backfill preparation and delivery
- tailings disposal and process water reclaim
- water treatment

The facilities are grouped as the crushing plant, dense media separation (DMS) plant, the concentrator, paste backfill plant, tailings management and water reclaim facility, and water treatment plant. The crushing and DMS plants will operate on the same schedule while the concentrator, tailings management facility, and water reclaim operations will operate on a different and more continuous schedule. A fine ore storage bin for the DMS product will be installed to ensure proper integration of the two operating schedules. The paste backfill plant will operate as required to provide backfill to the underground mine.

An average of 1,600 t/d of run-of-mine ore will be processed through the crushing and DMS plants. The products from the DMS plant will include 350 t/d of non-sulphide “float” (waste), which will be trucked to underground as backfill or the tailings facility, and 1250 t/d of ore, which will feed the concentrator. The process will produce an average of 46 t/d of copper concentrate, 26 t/d of lead concentrate, 239 t/d of zinc concentrates, and 939 t/d of tailings. Gold and silver will be recovered in the copper and lead concentrates.

Selected process streams will be sampled and analyzed in an on-stream analytical system for operations monitoring and control purposes. Any process spillages will be contained and collected in sumps within their respective areas then pumped back into the process streams. The process will not directly generate air emissions.

Tailings will be used for paste production when required to backfill the underground mine, or impounded in the tailings facility when backfilling is not required. The paste backfill operation will reduce surface environmental impact from the mining and ore processing operations.

A water management system has been incorporated in the process to maximize water recycle and re-use (refer to Section 2.9: Site Water Management for details). All water from the process facilities will be collected in the tailings facility. A small portion of the water will be trapped with the consolidated tailings in the facility and paste backfill. The balance of the water will be reclaimed to the process water distribution system in the facilities. The reclaimed water will fulfill virtually all the water requirements in the plant. Small amounts of fresh water will be required for reagent make-up, lube systems cooling and as gland seals of slurry pumps.

The underground mine water and any excess process water will be treated prior to discharge. A portion of the treated water may be used as fresh water for some equipment and processes.

2.6.2 Crushing Operations

The flowsheet for the crushing operations is provided in Figure 2.6-1. Run-of-mine ore will be hauled by 40 t trucks from the Wolverine underground mine to the dry crushing plant on surface. The crushing plant has been designed for direct dump of the ore from the trucks. There is provision for a temporary emergency stockpile on surface for the ore during unscheduled crushing plant shutdowns. The run-of-mine ore will be crushed in two stages, with inter-stage screening, from a top size of 450 mm to the 19 mm size required for the first bulk separation of gangue from ore in the DMS plant.

Figure 2.6-1 Crushing and Reclaim Flowsheet (Vol. 2)

The crushing plant equipment will consist of:

- fixed grizzly
- rock breaker
- 300 t dump pocket
- apron feeder
- primary jaw crusher
- secondary cone crusher
- secondary screen
- collection conveyors
- fine ore bin
- dust pick ups and collector

A fixed grizzly screen will be installed on the dump pocket to ensure that large ore pieces do not feed the jaw crusher and plug the crusher. A rock breaker will be installed above the fixed grizzly to break any oversize ore through the grizzly. The dump pocket will have a capacity of 300 t to provide the surge capacity for transitioning the batch truck dumping to a steady feed rate to the crusher. An apron feeder will withdraw the ore from the dump pocket at a nominal rate of 95 t/h to feed the jaw crusher in the primary crushing stage. The ore will be crushed to 80% passing 75 mm size then dropped on to a conveyor for conveyance to the secondary crushing stage, consisting of a cone crusher operating in closed circuit with a vibrating screen with an opening of 19 mm.

The crushed ore will be conveyed from the jaw crusher to the vibrating screen. The screen oversize will feed the cone crusher. The cone crusher product, at 80% passing 19 mm, will be recycled to the vibrating screen via a conveyor. The screen undersize will be the crushing plant product and will drop on to a conveyor and be conveyed to the 300 t fine ore storage bin. The storage bin will provide the capacity necessary to keep the DMS plant running during short, unscheduled maintenance shutdowns of the crushing plant.

One belt feeder will be installed to reclaim ore from the fine ore storage bin to feed the DMS plant at a controlled rate of 95 t/h.

A dust collector will collect the fugitive dusts generated during ore crushing and handling and ensure a clean workplace environment. Dust pick-ups will be installed at the crushers, screen and ore transfer points. The collected dust will be bagged and introduced into the grinding circuit via the DMS fines surge tank. The process will not produce any other air emissions.

2.6.3 Dense Media Separation Operations

The flowsheet for the dense media separation operations is provided in Figure 2.6-2. The Wolverine mineralization lies between a hanging wall and footwall and is comprised mainly of argillite and rhyollite which on an average, dilute the ore by approximately 28% during mining. These dilution materials have a lower density than the ore and, consequently, can be separated by differential gravity separation technique. This initial bulk removal of dilution materials from the ore will be achieved in the DMS plant using a dense slurry of fine ferro-silicon and a series of washing screens and cyclones. The operation of the washing screens and cyclones will be controlled to recover and re-use the ferro-silicon within the plant. The major equipment in the DMS plant will consist of three vibrating screens, two cyclones and two magnetic separators.

Ore will be reclaimed from the fine ore storage bin by a belt feeder and conveyed to a vibrating de-slime screen with 1 mm opening and washing sprays. The screen undersize of minus 1 mm will be pumped to a surge tank in the grinding circuit. The screen oversize will be mixed with the dense media slurry then pumped to a 650 mm heavy-media cyclone to separate the ore from the dilution materials.

The lighter dilution materials will report to the cyclone overflow to the vibrating "floats" screen with 1 mm opening and washing sprays. The screen oversize, containing the non-sulphide dilution materials at approximately 10% moisture, will be trucked to underground as backfill or to the tailings facility for disposal. The ferro-silicon media in the screen undersize will be recovered for re-use via two double-drum magnetic separators. The non-magnetics (fine ore particles) will flow through the magnetic separators and join the de-slime screen undersize stream that will be pumped to the grinding circuit in the concentrator.

The ore will report to the heavy-media cyclone underflow to the vibrating "sinks" screen with a 1 mm opening and washing sprays. The ore will be recovered as the screen oversize at approximately 10% moisture and conveyed to a 1,200 tonne mill feed storage bin. The storage bin will be heated to prevent the moist ore from freezing. The screen undersize will largely be ferro-silicon, which will be recovered to the circulating media system via either a bank of cyclones or the magnetic separators.

The products of the DMS plant will be 1,250 t/d of sulphide ore to the concentrator that consists of "sink" from the storage bin and fines from the de-slime screen, and 350 t/d of the dilution materials ("float") to be disposed of either underground or to the tailings facility.

Figure 2.6-2 Dense Media Separation Flowsheet (Vol.2)

2.6.4 Concentrator Operations

Following the DMS operation, further multiple stages of particle size reduction and physical upgrading are necessary to recover copper, lead and zinc minerals as high grade concentrates. Particle size reductions will be achieved in wet grinding mills while mineral separations and upgrading will be achieved in a series of froth flotation cells.

2.6.4.1 Grinding

The flowsheet for the grinding operations is provided in Figure 2.6-3. The ore will be ground in a two-stage grinding circuit to produce the particle size required for effective separation and recovery of copper, lead and zinc minerals. The primary grinding circuit will consist of one open circuit rod mill (single pass grinding) while the secondary grinding circuit will comprise one ball mill operating in closed circuit with cyclones (multiple-pass grinding).

Figure 2.6-3 Grinding Flowsheet (Vol.2)

The grinding circuit equipment will consist of:

- one 300 kW, 3.0 m by 4.27 m rod mill with trommel screen
- one 450 kW, 3.0 m by 4.27 m ball mill with trommel screen
- pack of cyclones

From the storage bin, ore ("sink") will be withdrawn at a nominal rate of 48.5 t/h via a belt feeder and conveyed to the primary rod mill. The slurry density in the rod mill will be maintained at 70% solids by controlling the addition of process water to the mill feed. The high mill slurry density will enhance grinding efficiency so that the rod mill discharge particle size will be 80% passing 800 microns, which is an appropriate feed size for the secondary grinding circuit.

The rod mill discharge will be piped to the common rod and ball mill discharge sump. The secondary ball mill discharge and the ore fines from the DMS plant will also feed the sump. The total slurry will then be pumped to a bank of cyclones to remove the fine particles to the cyclone overflow prior to ball milling and to avoid overgrinding and adversely affecting the flotation process. The cyclone underflow, at a density of 70% solids, will be the feed to the ball mill. The ball mill will not require additional water. The cyclone overflow, at a density of approximately 32% solids, will feed the flotation circuit at a solids rate of 56.6 t/h (equivalent to 1250 t/d). The particle size of flotation feed will be 80% passing 70 microns for optimum mineral recovery in the flotation cells.

Steel rods and balls will be the grinding media in the rod mill and ball mill, respectively. The steel grinding media will be added to the respective mills periodically to replace the worn out grinding media and to maintain grinding efficiencies in the mills.

Process water will be used for diluting the rod mill feed and for washing the trommel screens on the mill discharge ends. The ore fines slurry from the DMS plant will provide the bulk of the water required for cyclone feed density control to achieve the particle size separation in the cyclones. Process water will be added as make-up to the cyclone feed, if required. Relatively small amounts of fresh water will be used for cooling the rod and ball mill lube systems, gland seals of slurry pumps, and in the addition of sodium sulphite reagent to the mill. All the water additions will end up diluting the cyclone overflow to flotation.

2.6.4.2 Flotation and Regrind

The flowsheets for the flotation and regrind operations for copper, lead and zinc are provided in Figures 2.6-4 through 2.6-6, respectively. Conventional flotation cells will be used for all the flotation stages. This process will selectively float and concentrate copper, lead, then zinc minerals in sequence into their respective high grade concentrates for sale. A regrinding step in between flotation stages will be used to liberate the fine minerals from gangue and achieve optimum product recovery and grade.

Figure 2.6-4 Copper Flotation and Regrind Flowsheet (Vol. 2)

Figure 2.6-5 Lead Flotation and Regrind Flowsheet (Vol. 2)

Figure 2.6-6 Zinc Flotation and Regrind Flowsheet (Vol. 2)

Cyclone overflow from the grinding circuit will first feed the pre-flotation circuit to remove the gangue slimes component of the ore so as to eliminate its interference on mineral flotation. A frother, methyl-isobutyl carbinol (MIBC), will be added to produce the froth for carrying the slimes. Approximately 0.8 t/h or 18 t/d of the slimes will be removed as concentrate and pumped together with other plant tailings streams to the tailings facility.

The pre-flotation tailings will be processed through sequential flotation to produce separate copper, lead and zinc concentrates. Reagents will be added to selectively float each mineral species (refer to Section 2.6.8 for additional reagent information).

The pre-flotation tailings will be pumped to an agitated copper flotation conditioning tank where the slurry will be conditioned with lime and reagent Aero 5100 to enhance copper flotation. The conditioned slurry will overflow the conditioning tank to the copper rougher flotation circuit. Rougher concentrate, together with first cleaner scavenger concentrate, will be pumped to the copper regrind circuit while the copper rougher tailings will be pumped to the lead flotation circuit.

The copper rougher concentrate and first cleaner-scavenger concentrate will be reground in a 93 kW vertical regrind mill operating in closed circuit with a bank of cyclones. Target regrind product size will be 80% passing 25 microns for optimum concentrate upgrading in three stages of cleaner flotation. Cleaner flotation tailings from each stage will be recycled to the preceding stage, except the first cleaner scavenger tailings, which will be pumped to the lead flotation circuit together with the rougher tailings. The final concentrate from the third cleaner will be pumped to the copper concentrate thickener.

The reagents required for selective copper flotation will consist of lime, sodium sulphite, Aero 5100 (dialkyl thionocarbamate), and MIBC. Copper flotation tailings will be pumped to the lead flotation conditioning tank. Lead flotation reagents will include sodium sulphite, potassium ethyl xanthate (KEX) and zinc cyanide, a complex that will be made on-site by mixing zinc sulphate with sodium cyanide solution. The lead flotation circuit will comprise rougher flotation, rougher concentrate regrind and then two stages of cleaner flotation.

It is noted that there will be no free cyanide in solution. The zinc cyanide complex added is not expected to break down in the alkaline conditions in the flotation circuit. The actual cyanide added will be equivalent to approximately 8 ppm in the flotation solution. Any cyanide complex remaining in the final tailings is expected to be insignificant.

Rougher concentrate and first cleaner scavenger concentrate will be reground in a 30 kW vertical regrind mill operating in closed circuit with a bank of cyclones then upgraded in two-stages of cleaner flotation. The target regrind product size will be 80% passing 25 microns for optimum concentrate upgrading. The zinc cyanide complex will be added to depress pyrite and facilitate the upgrading of lead concentrate. The second cleaner tailings will be recycled to the first cleaner stage, while the first cleaner scavenger tailings will be pumped to the zinc flotation circuit together with the lead rougher tailings. The final concentrate from the second cleaner will be pumped to the lead concentrate thickener. Lead flotation tailings will be pumped to the first of three zinc conditioning tanks in series prior to flotation.

Zinc flotation reagents will include lime, Aero 5100, KEX and MIBC. The zinc flotation circuit will consist of rougher flotation, rougher concentrate regrind followed by four stages of cleaner flotation. Zinc rougher concentrate and first cleaner scavenger concentrate will be reground in a 186 kW vertical regrind mill operating in closed circuit with a bank of cyclones to a product size of 80% passing 25 microns. The tailings from each cleaner stage will be recycled to the preceding stage, except the first cleaner scavenger tailings, which will be combined with the zinc rougher tailings as final plant tailings. The final concentrate from the fourth zinc cleaner will be pumped to the zinc concentrate thickener while the tailings will be pumped to the paste backfill plant.

The products of the concentrator will be 0.8 t/h of pre-flotation concentrate, 2.1 t/h of copper concentrate, 1.2 t/h of lead concentrate, 10.8 t/h of zinc concentrate, and 41.7 t/h of tailings.

The entire final flotation tailings stream will be pumped either to the paste backfill plant when it is operating, or to the tailings facility when paste backfill is not required by underground.

2.6.4.3 Concentrate Dewatering

The flowsheet for the concentrate dewatering operations is provided in Figure 2.6-7. Each flotation concentrate will be dewatered in its respective circuit consisting of a concentrate thickener, a concentrate stock tank and a filter press. The objective will be to produce concentrates with minimal moisture contents for manageable and economical long distance transportation without liquefaction or pyrophoric properties.

Figure 2.6-7 Concentrate Dewatering Flowsheet (Vol. 2)

The equipment for concentrate thickening and filtration will include:

- 9.5 m copper thickener, 3.0 m lead thickener, 4.5 m zinc thickener
- concentrate stock tank (filter feed) for each concentrate
- one 12-chamber filter press each for copper and lead concentrate
- one 40-chamber filter press for zinc concentrate

Each thickener underflow will be pumped to an agitated concentrate stock tank with 8 hours of operating capacity then filtered in the respective filter press. Filter presses have been selected over vacuum filters because they will achieve lower cake moisture, minimize potential for liquefaction during transportation, and reduce transportation costs.

The overflows from the three concentrate thickeners and the filtrates from all the pressure filters will be pumped to the tailings facility via the final tailings pump box in the paste backfill plant. This will allow for blending and time for natural degradation of reagents in the tailings facility prior to reclaim as process water and distribution throughout the process facilities.

2.6.5 Paste Backfill Operations

The flowsheet for the paste backfill operations is provided in Figure 2.6-8. Yukon Zinc will utilize paste backfill as a strategy to manage tailings and reduce surface environmental impact from the operations. Paste backfill is an engineered mixture of tailings solids, binder (cement) and water with the required strength for backfilling the underground mine. The main unit operations are tailings dewatering in a thickener and filters, paste components mixing and paste pumping to the mine.

Figure 2.6-8 Paste Backfill Flowsheet (Vol. 2)

Zinc rougher and first cleaner scavenger tailings will be pumped to the paste backfill plant when backfill is required for underground. The major equipment of this plant will include:

- one 9.0 m tailings thickener
- cyclopac with ten 150 mm cyclones
- two 1.82 m diameter disc filters with 6 discs each
- 250 t cement silo with dust collector
- twin screen paste mixer
- colloidal mixer
- vacuum system including pumps and receivers
- flocculant make-up system

The total zinc tailings will be flocculated and thickened in the thickener to 60% solids then stored in a filter feed tank. The thickener overflow will be directed to the final tailings pumpbox then pumped to the tailings facility together with the pre-flotation concentrate, overflows from the three concentrate thickeners and filtrates from the concentrate filters.

From the filter feed tank, the tailings will be filtered in two vacuum disc filters to approximately 77% solids then mixed with cement in a twin screen paste mixer to produce the paste. Dry cement will be withdrawn from the cement storage silo with a screw feeder and fed to the colloidal mixer where water will be added. The cement slurry will then be pumped to the twin screen paste mixer. The paste will then be pumped underground using a variable speed positive displacement pump. The filtrate from the tailings filters will be pumped to the tailings thickener and sent to tailings via the thickener overflow.

A dust collector will be installed to remove fugitive dusts from the cement handling system and maintain an acceptable work environment. The collected dust will be recycled to the silo.

A pack of cyclones will be installed as an option to scalp off the fines from the flotation tailings prior to thickening and paste production. The cyclone underflow will be thickened in the tailings thickener while the overflow will be piped to the final tailings pump box.

Approximately 70% of the tailings will be processed to paste for the backfill and the remainder will be disposed in the tailings facility.

2.6.6 Tailings and Reclaim Water

All water streams from the process facilities including the flotation concentrate, concentrate thickener water, and filtrates, will be pumped to the tailings facility to allow for blending and time for natural degradation of reagents prior to reclaim and re-use as process water.

When the paste backfill plant is operating, the tailings thickener overflow will be combined with the other water streams and pumped to the tailings facility. The total stream to the tailings facility, then, will contain only the pre-flotation concentrate of approximately 0.8 t/h in a flow of approximately 220 m^3/h.

When the paste plant is bypassed, the total tailings stream to the tailings facility will contain all the zinc flotation tailings solids. After combining with the other water streams, the total flow will be approximately 240 m^3/h at 15.7% solids.

In a steady state operation, solids from both of the paste backfill operating modes will consolidate to approximately 80% solids. Water will be reclaimed from the tailings facility and pumped to the process water distribution system. Excess reclaimed water will be treated together with the underground mine water to remove heavy metals prior to discharge to the environment.

2.6.7 Reagents

The flowsheet for reagents addition to the flotation circuit are provided in Figures 2.6-9 and 2.6-10. Reagents will be added to the flotation circuit to modify the mineral particle surfaces and enhance their floatability. The reagents added are selectively adsorbed on each of the copper, lead and zinc minerals to produce their separation and recovery. Their as-delivered form and packaging, approximate consumption and solution make-up concentration have been tabulated in Table 2.6-1.

Table 2.6-1 Flotation Reagents

Reagent	As Delivered		Consumption kg/day	Solution Concentration %
	Form	Packaging		
Lime	Pebble	Truck load	3656	20
Sodium metabisulphite	Powder	1 tonne bag	2906	10
Aero 5100	Liquid	200 kg drum	150	100
Zinc sulphate	Powder	1 tonne bag	280	10
Sodium cyanide	Powder	200 kg drum	94	10
Sodium sulphite	Powder	1 tonne bag	1875	10
Potassium ethyl xanthate (KEX)	Flakes	1 tonne bag	80	10
Methyl isobutyl carbinol (MIBC)	Liquid	166 kg drum	25	100
Copper sulphate	Powder	1 tonne bag	875	10

Figure 2.6-9 Reagent Systems Flowsheet – 1 of 2 (Vol. 2)

Figure 2.6-10 Reagent Systems Flowsheet – 2 of 2 (Vol. 2)

Powder reagents will be made into dilute solutions using fresh water to facilitate their addition and control using metering pumps. The volume of fresh water required for reagent use is summarized in the process plant water balance (Figure 2.6-11). Liquid reagents will be metered to process as-is. All reagents will be prepared in a separate, self-contained area within the concentrator building then delivered by individual metering pumps to the addition points.

Figure 2.6-11 Process Plant Water Balance Flowsheet (Vol. 2)

Lime will be delivered to site in powder form in 40 t trucks and pneumatically off-loaded into the lime silo. It will be mixed in fresh water to produce a 20% milk of lime slurry to enhance its utilization as a pH modifier. The slurry will be pumped continuously in a return loop around the flotation area. It will be pulse-added via valves controlled by pH controllers to maintain pre-set pHs in the flotation cells.

Sodium metabisulphite, sodium sulphite, zinc sulphate, and copper sulphate will be delivered in 1 t bags and stored in a dry area near the make-up systems. Each reagent make-up system will comprise a bag handling system, agitated mix tank, holding tank and metering pumps. Each reagent will be dissolved batch-wise in fresh water in the mix tank to approximately 10% concentration then transferred to the holding tank based on a level controller in the holding tank. Metering pumps will deliver the reagents from the holding tanks to the addition points. Each mixing tank will be vented to atmosphere outside the plant to remove the minor amounts of dust generated during bag dumping.

Methyl isobutyl carbinol (MIBC), potassium ethyl xanthate (KEX) and Aero 5100 will be delivered as a liquid in approximately 200 kg drums and transferred into storage tanks. Metering pumps will deliver the as-received reagents to their addition points in the flotation circuit.

Zinc cyanide for the process will be prepared at site by mixing zinc sulphate powder and sodium cyanide powder in fresh water in a prescribed ratio to a 10% concentration. The solution will then be transferred from the mix tank to the holding tank and metered to the addition points.

Spillages of each reagent will be contained within its own area to an in-ground sump then pumped back into the holding or storage tank.

2.6.8 Water Treatment

A water treatment plant will be installed to treat the excess reclaimed water from the tailings facility and underground mine water, as detailed in Section 2.9. It will consist of three agitator tanks and a clarifier to remove the precipitated metals (Figure 2.6-12). The overflow from the clarifier will be recycled as fresh water back to the process plant or discharged to Go Creek (Figure 2.6-13). The clarifier underflow (sludge) will be pumped to the tailings pump box for disposal in the tailings facility. The process plant water balance showing flow volumes, pathways and end products is summarized in Figure 2.6-11.

Figure 2.6-12 Water Treatment Plant General Arrangement Flowsheet (Vol. 2)

Figure 2.6-13 Water Treatment Plant Flowsheet (Vol. 2)