Facility Mercury Mass Balance Analysis (RS66)

PolyMet Mining Inc.

March 2007

Attachment A

POLYMET NORTHMET PROJECT, TOTAL FACILITY
MERCURY MASS BALANCE FLOW DIAGRAM
ZERO SURFACE-DISCHARGE YEAR-10 SCENARIO

Based on 32,000 st/day Ore Processed and 21.6 Hours per Day Operation for Process Plant

Product 0.05 **MSTPY** (million short tons per year)

Solids Throughput

Crushing/Milling:	11.7	**MSTPY**
Concentrating (output):	0.4	**MSTPY**
Flotation Tailings:	11.3	**MSTPY**
Hydrometalurgical Residue:	0.8	**MSTPY**
Process Consumables (at Concentrating):	1.414	**STPY**
Process Consumables (at Hydromet):	42.71	**STPY**

Liquids Throughput

Process Water (From Mine):	1,336	**GPM**
Makeup Water (Tailings Basin):	8,661	**GPM**
Makeup Water (Hydrometalurgical Residue Cell):	330	**GPM**
Flotation Tailings (liquid):	19.2	**MSTPY**
Hydrometalurgical Residue (liquid):	1.4	**MSTPY**

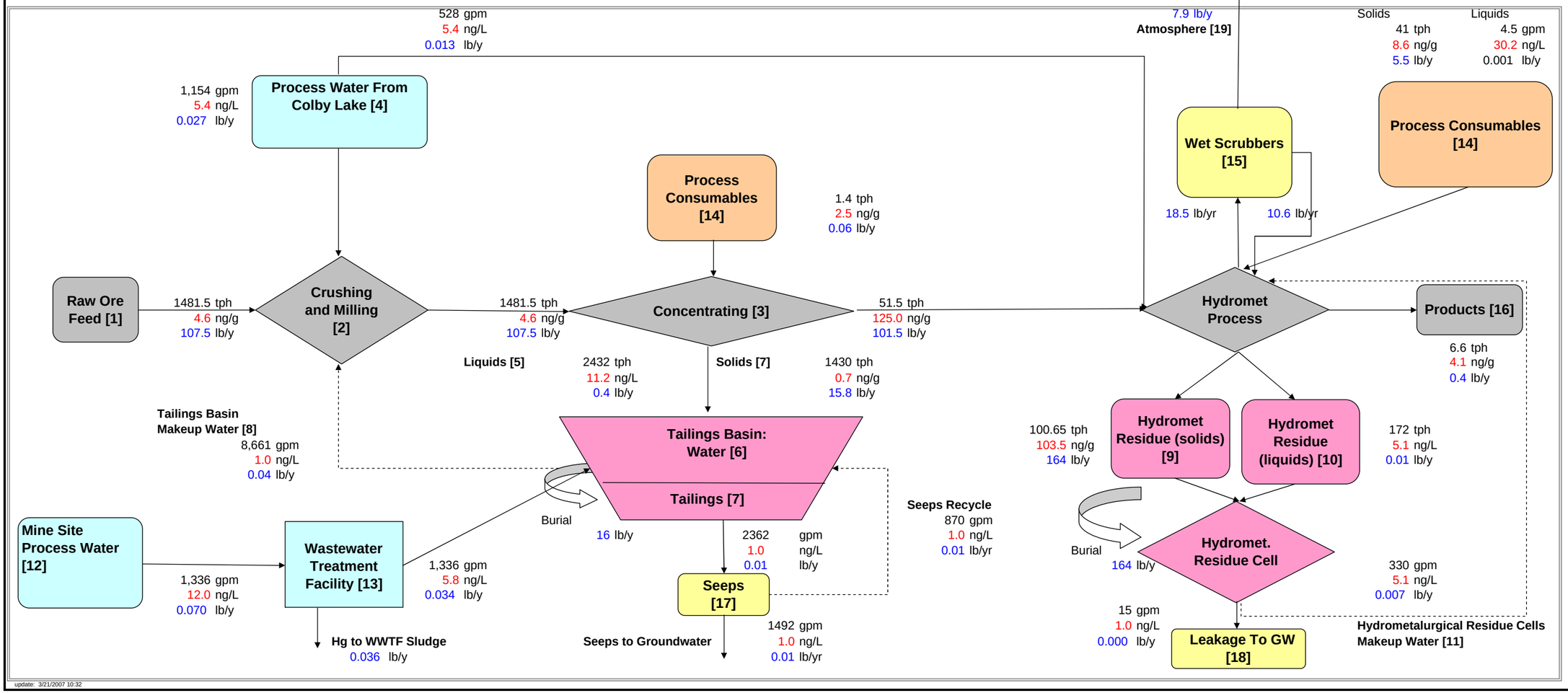
Units

Throughput (tph)
Hg Concentration (ng Hg/g) or (ng/L)
Hg Annual Mass Load (lb Hg/y)
------- Recycle

	Hg Mass Balance Summary (lb Hg/y)					
	Total Input	Total Output	Output Constituents			
			Air	TB	HR	Product
Total Facility **[20]**	113	189	8.3	16.2	164.3	0.4

TOTAL AIR EMISSIONS: **8.3 lb/y**
NATURAL GAS, CRUSHING, MINING, TAILINGS AIR EMISSIONS **0.4 lb/y**

TOTAL GROUNDWATER DISCHARGE: **0.01 lb/y**



Appendix C Footnotes:
Unless noted otherwise, Bateman Metals Throughput Data Based on MetSim Revision U3

[1] Raw Ore Feed
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: SGS Lakefield Research Limited, *Flotation pilot Plant Products Environmental Investigation and Air Testing* , LR10054-003 Progress Report No. 6, 2004 -- collected 10/4/2000
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x raw ore (st/y) x 2000 lb/st
2004 SGS Lakefield Progress Report used EPA Appendix to Method 1631. Ore samples from the 2005 Pilot Plant Study were analyzed using EPA 7641A. All 2005 ore samples were below the 20 ng/g detection limit (See RS 32 Pilot Plant Environmental Results -- Part 1, Liquids and Solids Sampling Flotation Report, Table 4, Ore Samples.) Thus, the composite sample from the 2004 Progress Report was used because low-level method is more accurate than an estimated concentration based on the 2005 Pilot Study non-detects.

[2] Crushing and Milling
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: Same as [1] above
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x crushed/milled ore (st/y) x 2000 lb/st
Less than .005 lbs per year Hg air emissions estimated from crushing and grinding operations; See RS57A for detailed emission calculations

[3] Concentrating
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: SGS Lakefield Research Limited, *Flotation pilot Plant Products Environmental Investigation and Air Testing* , LR10054-003 Progress Report No. 6, 2004 -- collected 10/4/2000
Concentrate samples from the 2005 Pilot Plant Study were analyzed using EPA 7641A. Although these 2005 concentrate samples were above the 20 ng/g detection limit (See RS 32 Pilot Plant Environmental Results - - Part 1, Liquids and Solids Sampling Flotation Report), Method 1631 data from ealier SGS pilot study used in order to be consistent with method 1631 data used for ore and flotation tailings [see note 7].
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x concentrate produced (st/y) x 2000 lb/st

[4] Process Water from Colby Lake
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: Polymet Mining, Inc., Polymet's Northmet Project, NTS Dunka Pit Sampling Data Report, 2005 (Includes sample from Colby Lake)
Mass Loading (lb/y) = water flow rate (gal/min) x 3.8 L/gal x 60 min/h x 8760 h/y x Hg concentration (ng/L) x 10^-9 g/ng / 453.6 g/lb

[5] Process Liquids to Tailings Basin (liquids)
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: RS 32 Pilot Plant Environmental Results -- Part 1, Liquids and Solids Sampling Flotation Report, Table 6, Process Water Samples; average of all parcels. Results below the detection limit included in average as half the detection limit.
Samples were taken from the process water tank. This water should be generally representative of water in the tailings basin.
Mass Loading (lb/y) = concentration (ng/L) x 10^-9 g/ng x tailing liquids (st/y) x 2000 lb/st x 3.8 L/gal / 8.34 lb/gal / 453.6 g/lb

[6] Tailings Basin Water
Existing Concentration Source: RS64 Existing Tailings Basin Water [Hg] is 1.0ng/g, Average of Cell 1E and 2E for 2002/2003.
Predicted concentration expected to also be less than or equal to 1.0 ng/L based on tests confirming tailings would adsorb mercury similar to taconite tailings, Bench-Scale Mercury Testing Report, May 2006 prepared by Northeast Technical Services, Inc.
Polymet is proposing a seeps collection system.
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x products produced (st/y) x 2000 lb/st

[7] Tailings (solids)
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: SGS Lakefield Research Limited, *Flotation pilot Plant Products Environmental Investigation and Air Testing* , LR10054-003 Progress Report No. 6, 2004 -- collected 10/4/2000
The 2004 SGS Lakefield Progress Report study used EPA low-level method (Appendix to Method 1631) for solids.
Flotation tailing samples from the 2005 Pilot Plant Study were analyzed using EPA 7641A. Most of these 2005 tailings samples were below the 20 ng/g detection limit, with some high data points (See RS 32 Pilot Plant Environmental Results -- Part 1, Liquids and Solids Sampling Flotation Report). The result is a 47 ng/g average concentration as a Windsorized mean of log transformed data, accounting for a suspected outlier value.
However, using 47 ng/g would result in about eight times more mercury being sequestered in tailings basin than input with the ore. Therefore, data from the earlier SGS Report (2004) composite sample based on Appendix to Method 1631 was used in the mercury balance (0.7 ng/g).
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x tailings (st/y) x 2000 lb/st
Approximately 0.1 lbs/year Hg air emissions estimated due to wind erosion not shown in diagram.

[8] Makeup Water from Tailings Basin
Throughput Source: Polymet (via Bateman Metals) with adjustments made by Barr Engineering to reflect project water balance.
Concentration Source: Assumed concentration in makeup water is same as concentration in tailings basin water
Mass Loading (lb/y) = water flow rate (gal/min) x 3.8 L/gal x 60 min/h x 7884 h/y x Hg concentration (ng/L) x 10^-9 g/ng / 453.6 g/lb

[9] Hydrometalurgical Residue (solids)
Solids include filter cakes. Hydromet Residue Cells are lined treatment cells, separate from the Flotation Tailings Basin
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: Pilot Plant Envrionmental Sampling and Analysis, Hydrometallurgical Process Liquids and Solids Sampling Results; RS32 Part 3.
Weighted average concentration calculated from data for Mg Residue, Raffinate Neutralization Gypsum, Neutralization Gypsum, and leach residue. Values below the detection limit were assigned a value of 1/2 the detection limit.
Note: Fe/Al removal residue was also collected during the pilot plant. This step has been eliminated from the process and the Fe/Al and presumably any trace mercury would be preciptitated in the raffinate neutralization gypsum per Bateman.
The weighted average Hg concentration in the raffinate neutralization/Al-Fe removal residue was calculated based on relative residue generation rate data in Table 4.1 of RS33/RS65.
Mass Loading (lb/y) = concentration (ng/g) x 10^-9 g/ng x hydromet residue (st/y) x 2000 lb/st

[10] Hydrometalurgical Residue (liquids)
Liquids include entrained filter wash water and liquid in Mg precipitation slurry. Hydrometalurgical Residue Cells are lined treatment cells, separate from the Flotation Tailings Basin
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: Envrionmental Sampling and Analysis, Hydrometallurgical Process Liquids and Solids Sampling Results; RS32 Part 3, Table 6 Magnesium Overflow Analytical Data Summary.
The water from the magnesium thickener overflow is respresentative of the major source of water in the residues. The current plant design has the magnesium slurry being blended with the other residues and sent to the lines cells without the use of a thickener. However, the end result is the same.
Mass Loading (lb/y) = concentration (ng/L) x 3.785 L/gal / 8.34 lb H20/gal * 2000 lb/ton x 10-9 ng/g / 453.6 g/lb * water to hydrometallurgical residue celss (st/hr) x 7884 hours/yr

[11] Makeup Water from Hydrometalurgical Residue Cells
Throughput Source: Polymet (via Bateman Metals) with adjustments made by Barr Engineering to reflect project water balance
Concentration Source: Makeup water assumed to have same mercury concentration as Magnesium Thickener overflow described in Note [10] .
Mass Loading (lb/y) = water flow rate (gal/min) x 3.8 L/gal x 60 min/h x 8760 h/y x Hg concentration (ng/L) x 10^-9 g/ng / 453.6 g/lb

[12] Process Water from Mine
Throughput Source: RS13 Tailings Basin Water Balance for year 10. Proportion of process water from mine and make up water from Colby Lake will vary by year, but this will not have a significant impact on the Hg balance.
Concentration Source: RS29T Mine Pit Water Quality Model
Mass Loading (lb/y) = water flow rate (gal/min) x 3.8 L/gal x 60 min/h x 8760 h/y x Hg concentration (ng/L) x 10^-9 g/ng / 453.6 g/lb

[13] Process water from Mine Water Treatment Plant (To be located at Mine Site)
Mine water to be treated for metals, hardness, other; water quality will match that in tailings basin; See EIS Study Reports RS29T for details on wastewater treatment technology and effluent concentrations.
Concentration Source: RS29T Wastewater Treatment Technology; 50% mercury removal assumed.
The small amount of Hg in WWTF sludge would be reintroduced into Hydrometalurgical Plant (to recover metals) or disposed of in Hydrometalurgical Residue Cells

[14] Process Consumables
Process Consumables added at Concentrating are similar to blended reagent sample

Consumable Name	Throughput (tph)	Where Added in Process	Included in Blend of Reagent Sample?	Specific Gravity	Concentration (ng/g)	Concentration ug/l	GPM
PAX - Collector	0.68	Concentrating	Yes	1.15			
MIBC - Frother	0.031	Concentrating	Yes	0.87			
DF 250 - Frother	0.010	Concentrating	No		2.25		
CuSO4	Recycled from EW	Concentrating	No				

Flotation Flocculant - M10	0.693	Concentrating	Yes	ND		0.0048	
Concentrating Total	**1.4138**						
Hydromet Solid Reagents							
Sodium Hydrosulfide (NaHS)	0.331	Hydromet Process	No		10		
Guar Gum	0.00128	Hydromet Process	No		ND		
Leach Residue Flocculant - 351	0.0284	Hydromet Process	No		10		
Hydrochloric Acid (NaCl in Pilot)	2.528	Hydromet Process	No		8.3		
Cobalt Sulphate (CoSO4)	0.00088	Hydromet Process	No		ND		
Plant Flocculant - M 342	1.40E-05	Hydromet Process	No	ND	10		
Coagulent - M368	1.69E-05	Hydromet Process	No		10		
Magnesium Oxide	4.47	Hydromet Process	No		10		
Limestone	31.88	Hydromet Process	No		8.3		
Lime	1.6	Hydromet Process	No		10		
Hydromet Solid Total	**40.839591**						
Hydromet Liquid Reagents							
Sulfuric Acid	1.36	Hydromet Process	No	1.76		0.002	3.077362
Diluent	0.017	Hydromet Process	No	0.819	1.29		0.085249
Extractant	0.003	Hydromet Process	No	0.96	1.29		0.010818
Liquid SO2	0.481	Hydromet Process	No	1.43	ND	ND	1.343509
Caustic	0.00839	Hydromet Process	No	1.5	ND	ND	0.022341
Hydromet Liquid Total	**1.87**						**4.539279**

Throughput Source: Polymet (via Bateman Metals (DFS Exectutive Summary and General and Process Design Criteria spreadsheet (Rev E1)provided by Bateman)); Note: concentration reagent throughputs was adjusted to reflect solution concentrations as described in General and Process Design Criteria spreadsheet because samples consisted of decanted, filtered liquid from the solutions used in the pilot study.

Concentration Source: Combined Flotation Reagent Sample: SGS Lakefield Research Limited, LR10054-003 Progress Report No. 6, 2000; average of disolved Hg concentration. Note: samples were filtered prior to analysis so any mercury in a solid phase would not be detected. Barr also sampled the flotation flocculent during the 2005 pilot study. This sampling produced a slightly lower result, so the combined sample result was used. Note: reagents changed somewhat between 2000 and 2005 pilot plants.
Data for hydromet plant consumables taken from Envrionmental Sampling and Analysis, Hydrometallurgical Process Liquids and Solids Sampling Results; RS32 Part 3. A weighted average concentration was calculated for all reagents sampled. NaCl was used in the pilot plant, while HCl will be used in the commercial scale plant. Different flocculents and/or coagulents may be used in the commercial scale facility. Liquid SO2 was not used during the pilot study, Hydrogen peroxide was used in the pilot scale plant but will not be used in the full scale plant; results were below the detection limit and were not included in the weighted average. Data was not obtained for CoSO4 and guar gum during the pilot study.
The concentration for compounds for which data was not obtained was assumed to the same as the weighted average of those for which data was obtained. The HCl usage rate from the design criteria spreadsheet was adjusted to reflect NaCl use in the pilot plant based on molecular weight.
Separate weighted averages were calculated for hydromet liquid and solid reagents.

Mass Loading liquids (lb/y) = liquid reagent flow rate (gal/min) x 3.8 L/gal x 60 min/h x 7884 h/y x Hg concentration (ng/L) x 10^-9 g/ng / 453.6 g/lb

Mass Loading Solids (lb/y) = solid usage rate (tph) * 2000 lb/ton * 453.6 g/lb * Hg concentration (ng/g) * 10^-9 g/ng * 7884 hr/yr

Specific gravity data used where necessary to convert mass flows to volume flows. Data obtained from General and Process Design Criteria Spreadsheet obtained from Bateman.

[15] Autoclave Wet Scrubbers
Emission calculations: RS57A. 25% control assumed for autoclave vent emissions. 72% control used for autoclave flash vent emissions, based on data from SGS 2005 Pilot Plant Study using EPA Method 29 for air emissions (Pilot Plant Environmental Results, RS 32, Part 4). Overall scrubber weighted control efficiency of 58% for Hg.
Oxidizing conditions in autoclave likely to drive Hg toward Hg2+ form; therefore, control efficiency for autoclave emissions likely to be higher than 25%.
Mercury captured in scrubber water is returned to hydrometalurgical process, where oxidized form likely goes to hydromet residue solids.

[16] Products
Throughput Source: Polymet (via Bateman Metals)
Concentration Source: Envrionmental Sampling and Analysis, Hydrometallurgical Process Liquids and Solids Sampling Results; RS32 Part 3. Appendix C RS28T. Weighted average concentration calculated from data for MHP and PGM Concentrate; Results below detection limit assigned a value of 1/2 the detection limit. Copper cathode not analyzed; assume no mercury present.

[17] Aproximately 35% of seeps from the tailings basin will be recycled in year 10; other years will vary. The balance will seep to the groundwater. See Tailings Basin Water Balance, RS13
Seepage to groundwater assumed at least 1 to 5 minutes of contact with tailings and associated reduction in mercury concentration in water to 1.0 ng/l, source: Bench-Scale Mercury Testing Report -May 2006 prepared by Northeast Technical Services, Inc.

[18] Throughput Source: Polymet Hydrometalurgical Plant Water Balance
Concentration Source: Mercury in leakage from residue cells expected to be the same as from tailings basin because leakage would flow through LTV tailings before reaching groundwater.

[19] Potential Emissions to Atmosphere; Future estimated actual emisisons are 7.3 lb/yr.
Concentration Source: RS 32 Pilot Plant Environmental Results -- Part 1, scaled up to full plant operation (see RS57A). Overall 58% scrubber control efficiency based on autoclave exhaust sampling results from 2005 pilot study, Aproximately one-half of estimated emissions based on non-detect values, in which one-half detection limit used to calculate emission rate. See note 15 for mercury control assumptions.

[20] As with other mining facilities, there is uncertainty regarding the amount of mercury in the solids and the air emissions from the proposed project. In this case. Additional measurements of mercury in ore, concentrator tailings, residue and other sources and sinks will be completed following project start-up.