Attachment 2-6

SRK Consulting. Overburden Geochemical Characterization Plan in Support of EIS – DRAFT, NorthMet Project. Memorandum to Stuart Arkley, MDNR. February 22, 2008.

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Memo

To:	Stuart Arkley, MDNR	**Date:**	February 22, 2008
cc:	John Borovsky, Barr Engineering Jim Scott, PolyMet	**From:**	Stephen Day Richard Patelke, PolyMet Nancy Dent, Barr Engineering
Subject:	Overburden Geochemical Characterization Plan in Support of EIS - DRAFT NorthMet Project	**Project #:**	1UP005.001

1 Objective

Mining and stockpile construction at the NorthMet Project will involve pre-stripping of an estimated 32 million tons of overburden (glacial drift) deposited by glacial action and subsequently formed soils in upland areas and depressions. It is currently estimated that 97% of overburden will be dominantly mineral material with the balance of 3% composed mainly of peat-type materials. Mineral overburden will be needed for waste rock stockpile foundation construction, road construction and soil covers on stockpiles for a total of about 17 million tons. The remaining balance will be placed in the waste rock stockpiles depending on its chemical reactivity to be determined by pre-mining characterization and monitoring.

To the extent practicable, peat will be stripped and stockpiled in a manner to allow for future reclamation use.

Overburden is typically composed of a mixture of locally- and distally-derived material comprised of rock derived by erosion and re-working of bedrock and pre-existing surficial material. In areas of bedrock mineralization it is possible, but not certain that the glacial drift could contain mineralized materials which could be a source of immediately or potentially soluble contaminants and acidity.

Therefore, the objective of this Overburden Geochemical Characterization Plan is to initiate data collection on the influence of mineralized bedrock on overburden composition in support of subsequent further characterization for permitting, development of plans for excavation, final disposal and water management of stockpile drainage.

At this stage, sufficient information is needed for the preparation of the Draft Environmental Impact Statement (DEIS). The information needed includes:

- estimation of potential reasonable worst case requirements for selective management of components of the overburden; and
- reasonable worst case prediction of immediate and future water quality from the stockpiles and other locations where overburden is used.

A higher level of monitoring information may be required to implement management of the overburden during operation. It is expected that management plans will be developed to support application for the Permit to Mine and could include characterization of overburden by drilling in advance of stripping to allow annual calculation of financial assurance payments, and on-site characterization of samples at the dig face. The scope of these plans will be determined following completion of the current characterization program for the DEIS.

2 Background

2.1 Regional Surficial Geology

2.1.1 Surficial Geology

Olcott and Siegel (1978) described the surficial geology of the copper-nickel study as being the result of two south-westward advances of the Rainy Lobe of the Laurentian ice sheet. The direction of ice movement was in part controlled by regional geologic structures. The lithological composition of rocks in the glacial deposits showed a contribution of the Duluth Complex units to ice contact and till deposits and less to outwash deposits.

Surficial geology in the area has been mapped by the Minnesota Geological Survey at a scale of 1:100,000 (Jennings and Reynolds 2005). Four units were described in approximate decreasing order of significance:

- Qrt – Till. This unit chiefly has a sandy loam matrix texture with common pebbles, cobbles and boulders. Where massive, compact layers are interpreted to have been deposited beneath moving ice, whereas stratified deposits were more likely deposited at the ice margin during moraine formation and retreat. The mapping indicates it occurs mainly in the eastern part of the project (Figure 1).

- Qrp – Till, re-sedimented till and sorted sediment. This unit marks the transition from a glacial to a proglacial setting (for example, ice contact delta fronts). It is interpreted as being created by deposition of basal Rainy lobe till at the ice front (Qrt) followed by re-working by gravity and slope processes down a steep morainal front. Due to the environment of formation, facies are not laterally continuous. The mapping indicates that this unit is mainly present in the proposed West Pit area.

- Qrm – Till. This unit is the same as Qrt but it is interpreted as being eroded by water concentrating coarse-grained clasts as a lag deposit at the surface.

- Qp – Peat. This unit is composed of organic material in various stages of decomposition. These are interpreted as formed in shallow depressions of glacial origin. Due to the scale of mapping, peat is shown as less extensive than actually occurs at the site.

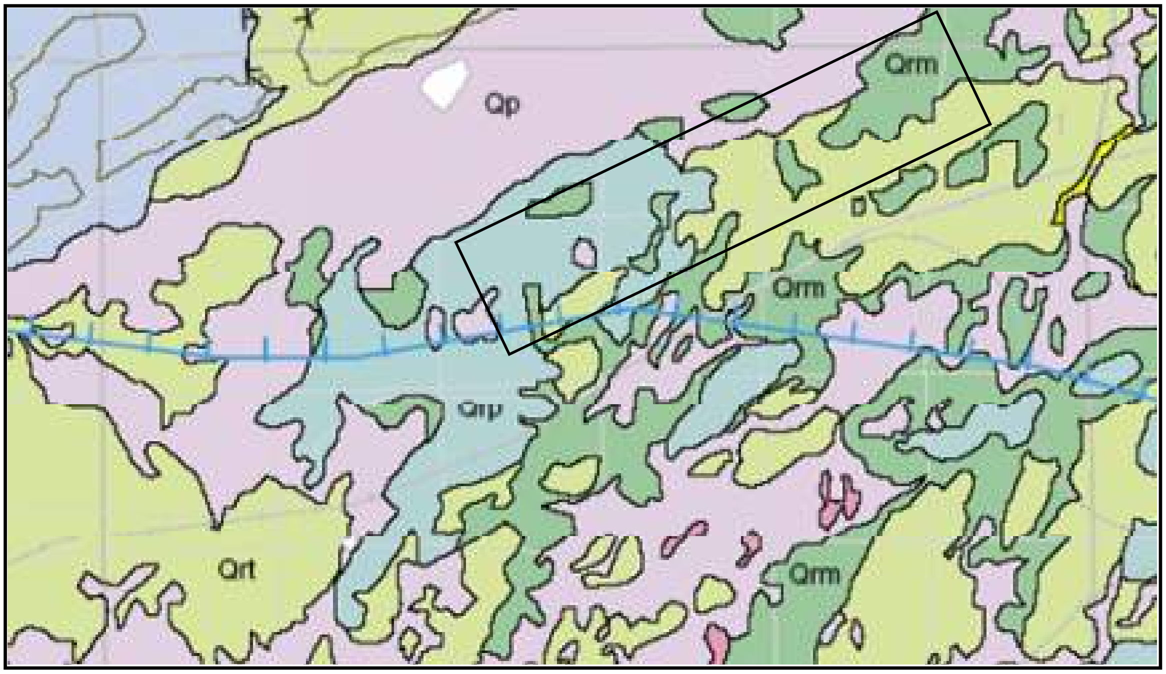

Figure 1. Excerpt from MN Geological Survey Map (M-164) (Jennings and Reynolds 2005). The blue line indicates an interpreted ice margin. The approximate footprint of the project is outlined.

Based on presence of rare Duluth Complex boulders north of the Virginia Formation-Duluth Complex contact, and ice flow directions referenced in Lehr and Hobbs (1992) PolyMet's geologists conclude that ice of the Rainy lobe generally moved from roughly east to north of northeast toward west to south of southwest. In other words, ice flow roughly paralleled the strike of units in the Partridge River intrusion of the Duluth Complex.

2.1.2 Overburden Geochemistry

Thorleifson et al (2007) describe a state-wide regional overburden sampling program. Two samples were collected from the Rainy lobe tills overlying the Duluth Complex (R12 and R13, 14 and 20 miles from the project site respectively). Due to the distance from the site, these samples only provide general information on the regional characteristics of tills. These samples were characterized by the presence of reddish volcanics (indicating Superior basin provenance), regionally relatively low carbonate content (less than 25th percentile, or 2.9% carbonate as dolomite and calcite), and regionally elevated nickel content (greater than 90th percentile, or 51 mg/kg). The latter, although present in the Duluth Complex, is regionally elevated in the northeast part of the state and appears to originate from beyond the local influence of the Duluth Complex.

Olcott and Siegel (1978) did not analyze their overburden samples but instead analyzed lake sediment samples. They noted no agreement between metal concentrations and proximity to the Duluth Complex.

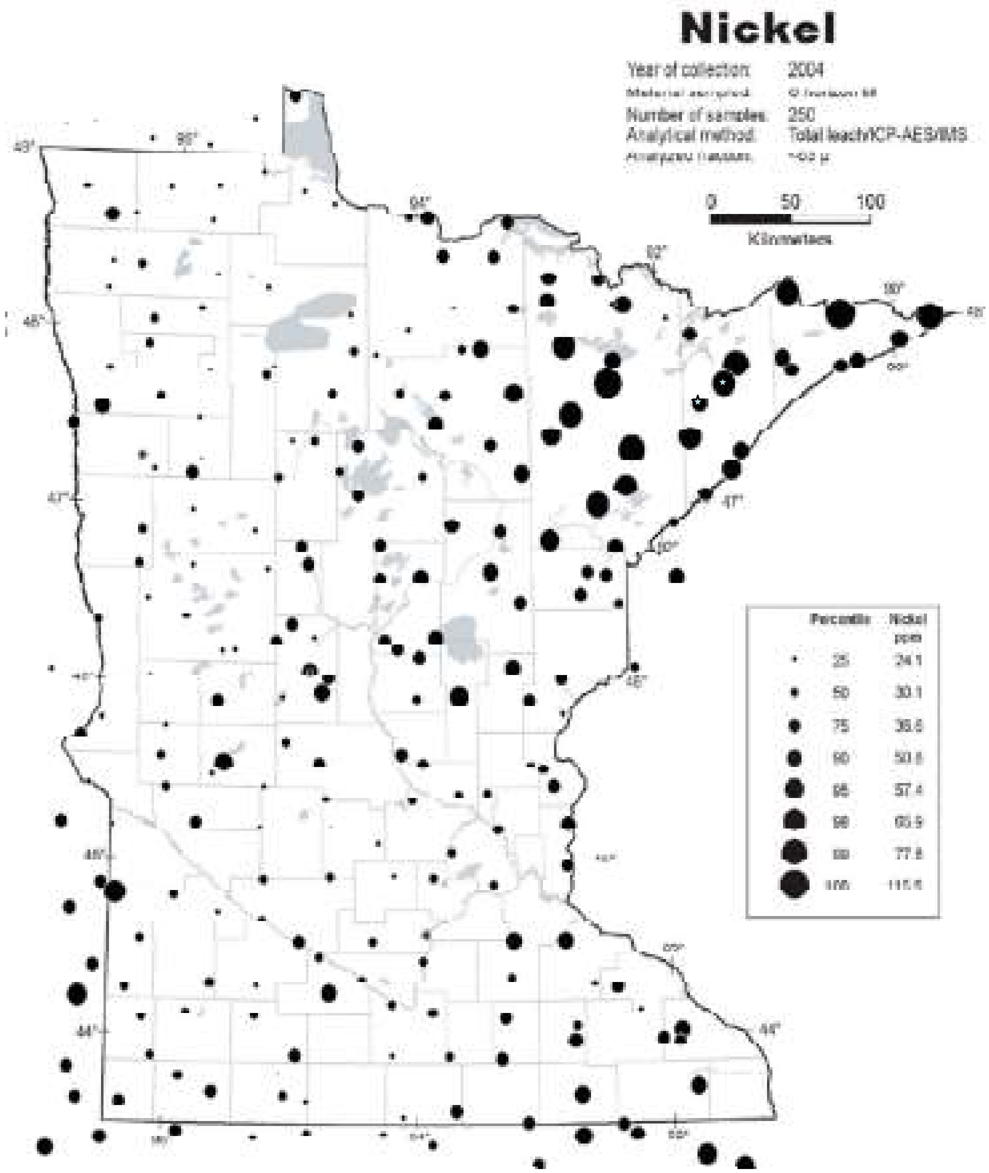

Figure 2. Nickel concentrations in regional overburden samples (Thorleifson et al 2007). The stars indicate samples collected nearest to the project site.

Mafic to ultramafic complexes like the Duluth Complex can exert a significant influence on regional geochemistry at a more local scale. Day and Matysek (1989) reported that stream sediments collected at a density of roughly 1 sample per 10 km^2 derived from an ultramafic complex in northern British Columbia contained average nickel and cobalt concentrations of 1356 mg/kg and 46 mg/kg (respectively) compared to nearby intermediate intrusions (4 to 11 mg/kg and 8 to 9 mg/kg, respectively).

3 Site Overburden Characteristics

Existing information relevant to the overburden characterization plan includes the thickness of overburden, the chemical characteristics of groundwater, and the chemistry of rock immediately in contact with the overburden deposits.

PolyMet has determined overburden thickness using exploration drilling records, regional and local outcrop mapping, test pits, and geophysical soundings. An overburden thickness map is provided in Figure 3. This mapping will be used as basis to estimate the volumes of different types of overburden indicated by the characterization work.

No data are available for the geochemical characteristics of overburden in the project area. However, shallow groundwater data in the mine area provides some indication of natural weathering characteristics (see RS02 and RS10A). Groundwater is non-acidic (lowest pH 6.6) but sulfate is variable (undetected to 66 mg/L in 21 samples) and at least two wells had elevated nickel (0.13 to 0.14 mg/L), copper (0.07 to 0.10 mg/L and/or cobalt (0.007 to 0.009 mg/L) compared to near detection (0.002, 0.002 and 0.001 mg/L respectively) in many other wells).

Figures 4 and 5 show the composition of rock at the overburden contact inferred from block modeling. Ore blocks are shown outside of the pit area because these are inferred rather than measured or indicated and therefore cannot be included in the ore reserve and pit design.

These maps confirm the presence of rock containing elevated sulfur and metal concentrations in these blocks though the degree to which this rock was transported into the overburden will be evaluated by the characterization plan.

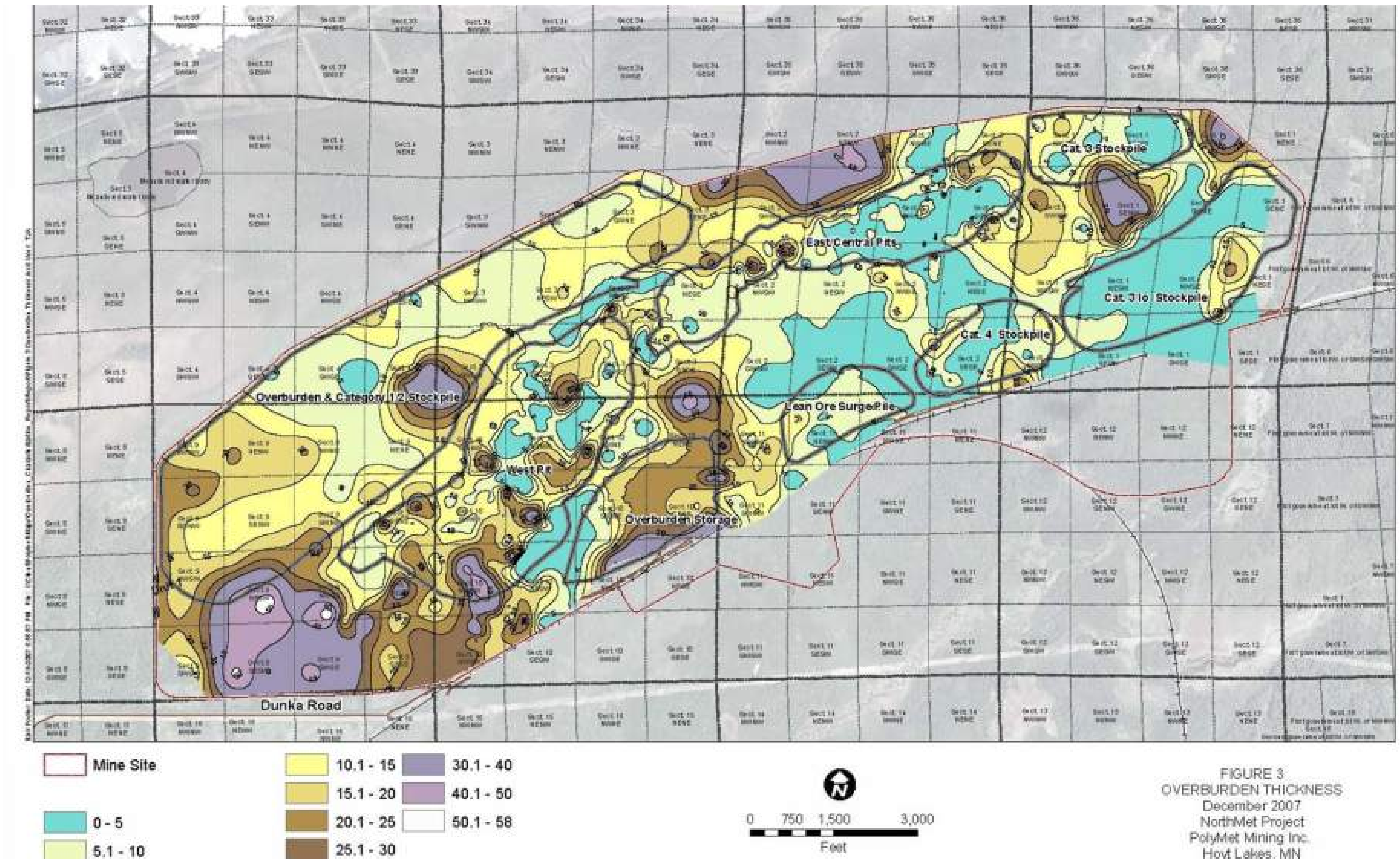

Figure 3. Overburden Thickness Map (in feet)

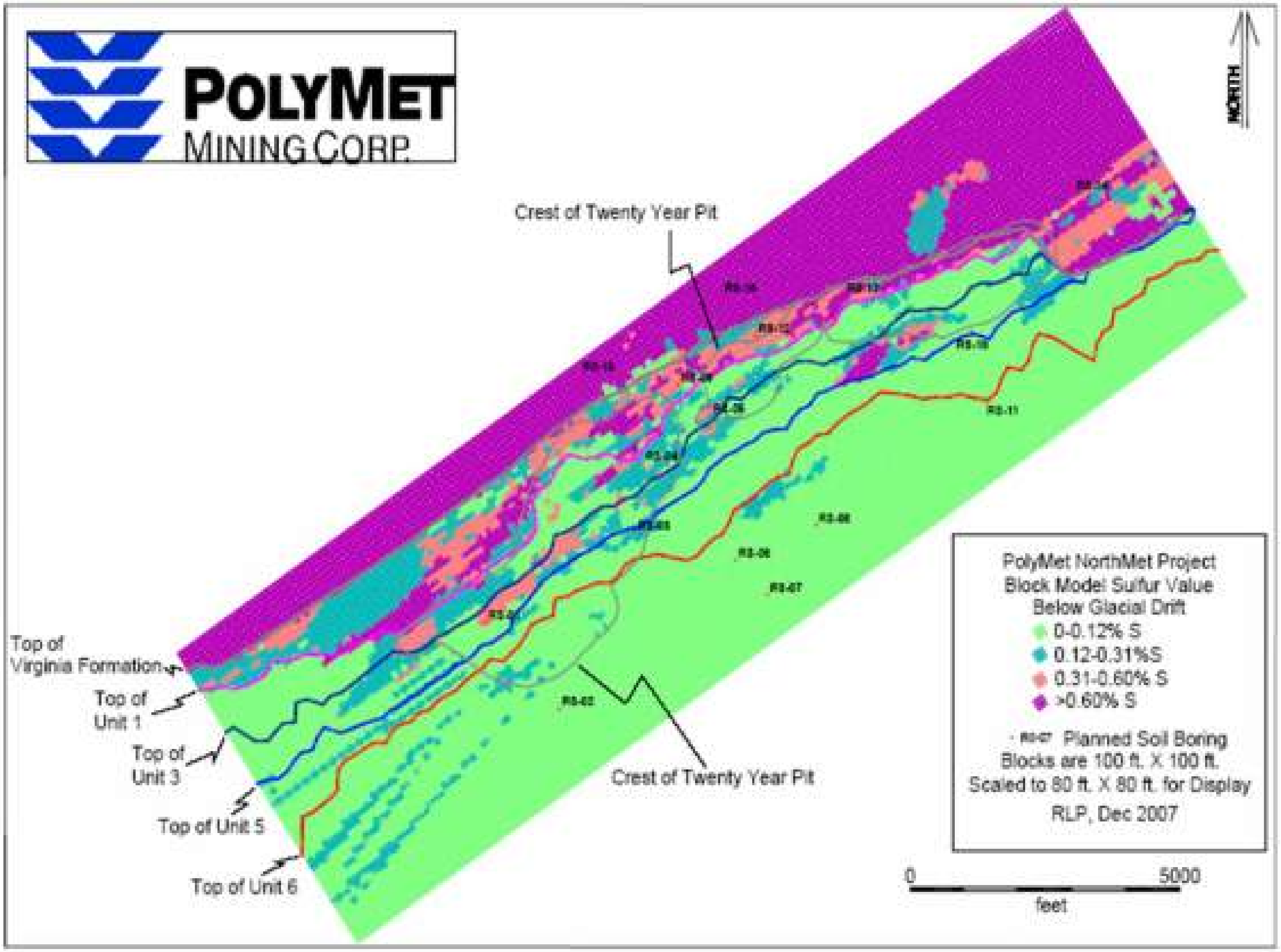

Figure 4. Sulfur Content in Blocks in Contact with Overburden

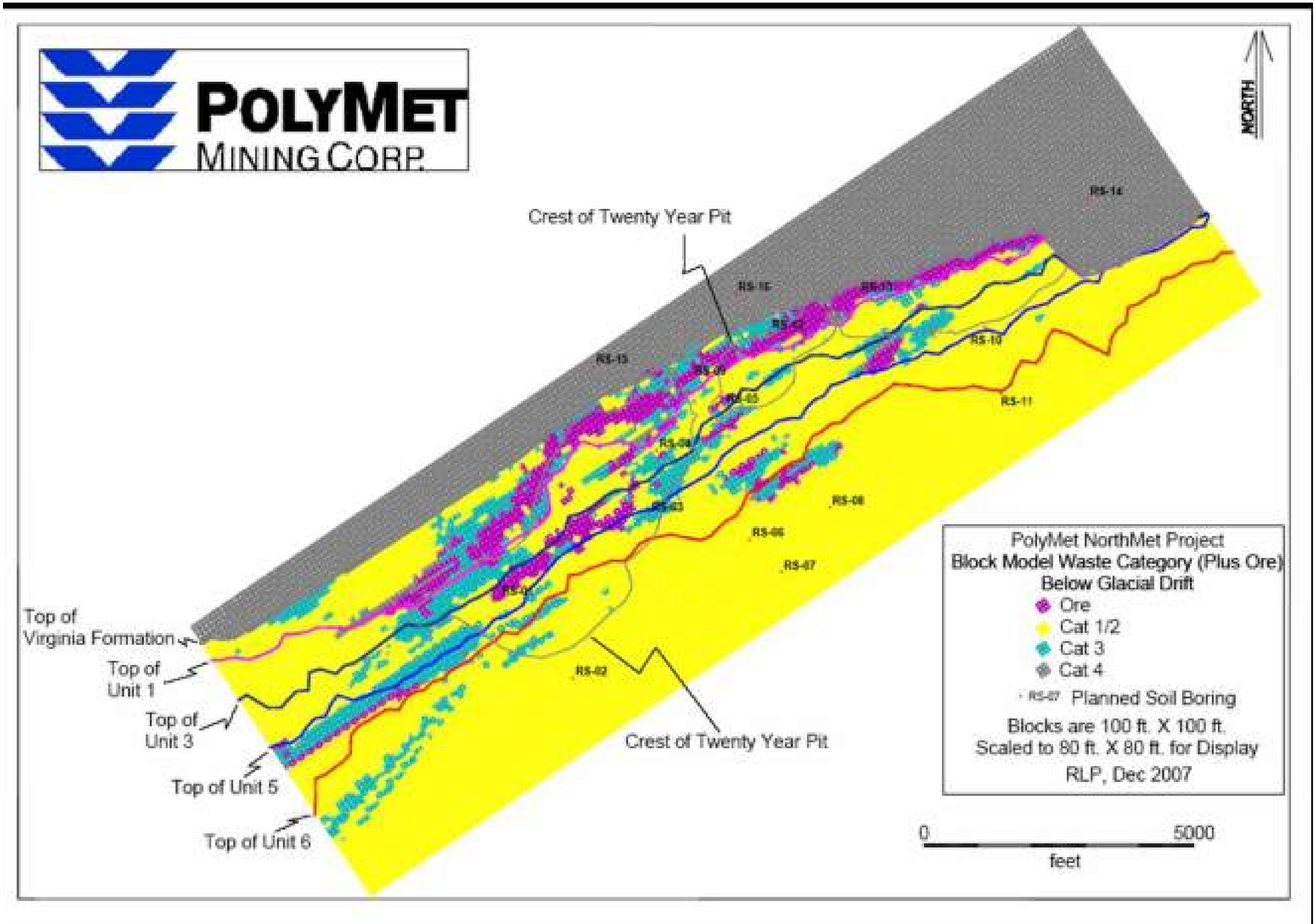

Figure 5. Waste and Ore Categorization of Blocks in Contact with Overburden

4 Program Design

4.1 Conceptual Geological and Geochemical Model

4.1.1 Glacial Processes

A conceptual model has been developed from first principles to guide design of the sampling program (Figure 6).

Based on the findings of Olcott and Siegel (1978), the bedrock in the area can be expected to have influenced the composition of glacial till in the area. The conceptual model is relatively simple. As ice contacted different units, rock was plucked from the near surface materials (which may have been already partially oxidized) and entrained in the glacial till as a wide range of particle sizes including clays to boulders. This leads to a dispersion train in the till which becomes progressively “diluted” by mixing with rock sourced further downstream (Figure 6a). As the ice direction parallels or nearly parallels the geological structure, the degree of dilution may be relatively small (Figure 6b).

The above concept appears to apply to the eastern two-thirds of the project site. Jennings and Reynolds (2005) describe a local transition to “re-sedimented” till in the western part of the property. In this area, periglacial processes can be expected to have resulted in locally highly variable deposits possibly resulting in disruption of the dispersion trains at the property scale shown in Figure 6 but also locally concentrating indicator minerals.

4.1.2 Post-Glacial Processes

Following retreat of the ice, surficial materials begin to weather and oxidize depending on the material characteristics (physical and geochemical), overall thickness of the deposit, and the degree of saturation. Clayey materials can be expected to oxidize slower than sandy materials due to the lower oxygen entry. Tills below the water table can also be expected to oxidize much less rapidly than unsaturated tills. The weathering processes can be expected to result in conversion of silicate minerals to clays, dissolution of carbonate minerals and oxidation of sulfide minerals. As with weathering of waste rock, some of these weathering products may be retained as secondary minerals whereas others will be leached into groundwater. There is some evidence of the latter in existing groundwater data.

Leaching of weathering products to groundwater may result in local accumulation of metals in low points formed where groundwater emerges. If metals are enriched in groundwater but under less-oxidizing conditions, iron may precipitate from emergent seepage and cause co-precipitation of metals. Similarly, peats may contain elevated metals as sulfides where reduction of sulfate has occurred.

4.1.3 Effect of Stripping

During stripping of overburden, rock particles will be exposed to leaching by incident precipitation. Drift, whether un-oxidized or oxidized, will then be exposed to conditions allowing greater oxidation rates. When exposed and placed in the overburden stockpile, existing soluble weathering products will be leached resulting in an initial flush of water containing elevated dissolved solids. Subsequently, oxidation and weathering will control water chemistry in much the same way that the same processes control water chemistry during waste rock weathering. Therefore, variables such as sulfur and carbonate mineral content are expected to control water chemistry by controlling pH and metal leaching.

Exposure of peat could result in oxidation of syngenetic (formed at same time as surrounding material, or formed in place) sulfide minerals, sorbed ions or organic compounds resulting in release of metals. Metal hydroxide precipitates may be exposed as peats are excavated resulting in exposure to leaching.

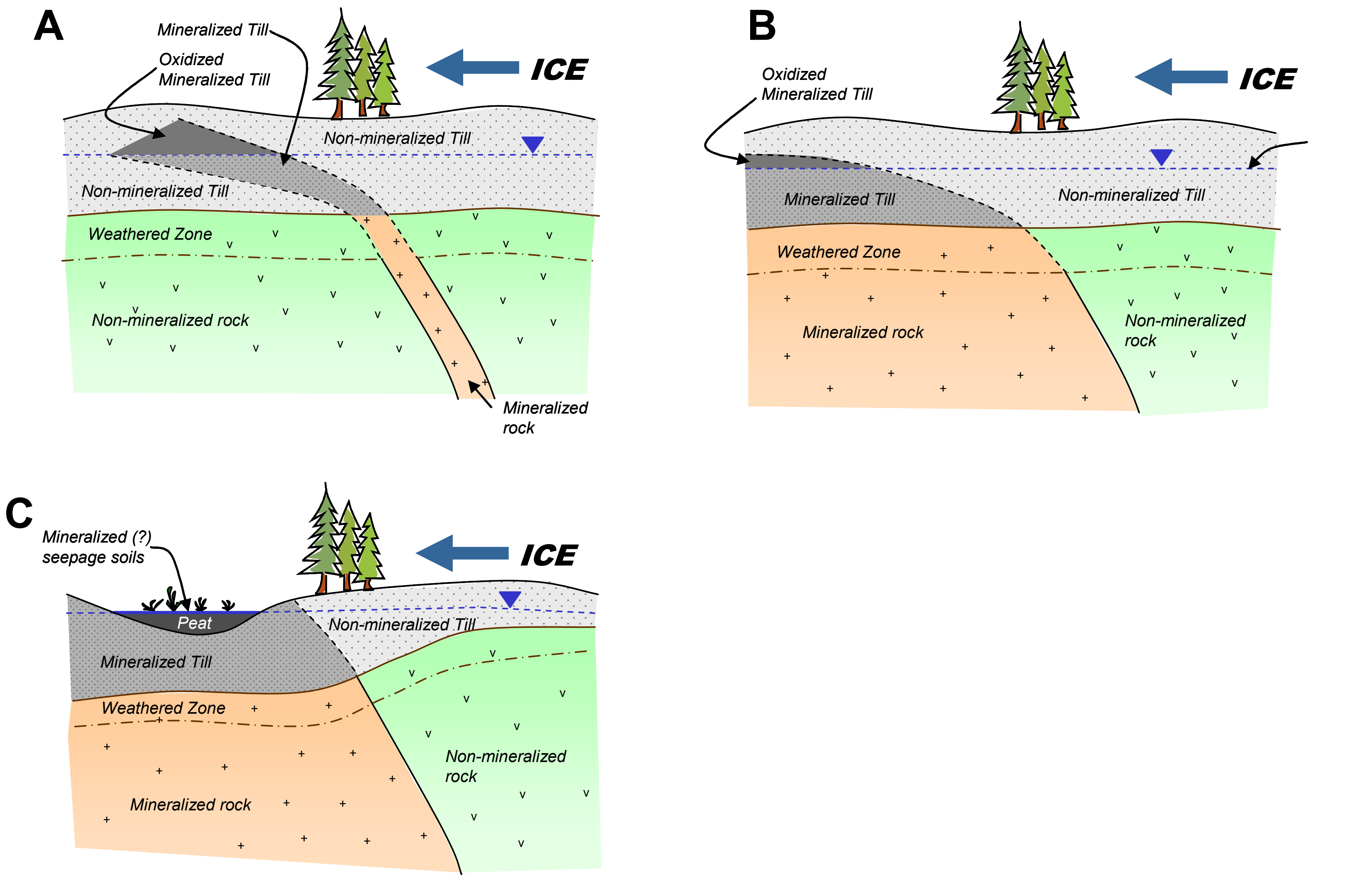

Figure 6. Conceptual Models for Dispersion of Bedrock Material in Glacial Overburden

4.2 Application of the Conceptual Model to Characterization Design

The conceptual model indicates variables in the natural system that could be considered in the characterization program (Table 1).

Table 1. Variables Considered in Experimental Design

	Variable	Effect	Values	Characterization Component
1	Up-ice origin of glacial till	• Regional mineralogical composition of till. • Acid buffering.	• Rainy Lobe.	• Up-ice sampling locations
2	Underlying bed rock geology and large scale mineralization	• Overall reactivity. • Source of leachable salts when exposed to precipitation during mining. • Potential for long term oxidation	• Sulfide mineralized Virginia Formation • Sulfide mineralized Unit 1 of the Partridge River Intrusion • Other less to unmineralized units of the Partridge River Intrusion	• Sampling locations within each of the three major units.
3	Distance from source of sulfur and metals (mineralized Duluth Complex and host rocks).	• Dilution of source effect	• Distance of sampling point from known bedrock mineralization indicated by drilling.	• Down-ice sampling locations
4	Glacial and Periglacial Depositional environment	• Mixing of till. • Degree of heterogeneity of till. • Potential for syngenetic sulfides	• Till • Re-sedimenting of till • Peat	• Samples in areas of both types of till. • Samples in wetlands.
5	Groundwater level during deposition	• Degree of oxidation of till.	• Oxidized below current water level. • Un-oxidized below current water level. • Above current water level.	• Description and sampling of oxidation state during drilling
6	Current position of water table	• Degree of oxidation of till • Presence of seepage soils	• Oxidized • Un-oxidized	• Mapping of water level while sampling. • Observation of mottling, • Samples above and below water table. • Sampling of peat

Consideration of these variables leads to the waste characterization plan design which at this stage is intended to evaluate the variability in acid generation and metal leaching associated with each variable (last column of Table 1).

Analytical methods have been selected to evaluate potential for immediate release of acidity and metals when exposed to meteoric water, and potential for long term leaching due to the oxidation of sulfide minerals and change in pH conditions.

5 Sampling and Analysis Plan

5.1 Field Program

5.1.1 Locations

Sampling locations (Figure 7) were selected to provide information to address each of the variables indicated in Table 1. Due to requirements of the US Forest Service, drilling locations are along existing roads in the project area and the number of locations has been fixed. This placed some constraints on the design of the program including lack of suitable sites to characterize till up-ice on the property in the Partridge River intrusion, and limited opportunities to characterize till overlying Virginia Formation at depth. However, the program as described provides sufficient coverage of other variables in the context of the overall objectives of the program.

Table 2. Selection of Drill Holes and Variables Characterized

DH	Depth	Up-ice origin of glacial till	Underlying bed rock geology and large scale mineralization			Dispersion Train[1]			Glacial and Periglacial Depositional environment			Groundwater level during deposition	Current position of water table	
	ft	-	VF	Unit 1	Others[2]	VF	Unit 1	Others[2]	Till	Re-sedimented Till	Peat	-	Saturated	Unsaturated
1	23				X			Down		X		X	X	X
2	13				X			Down		X		X	X	X
3	25?				X			Mid		X	X	X	X	
4	12				X			Mid		X	X	X	X	
5	16				X			Mid	X			X	X	X
6	23				X			Mid		X		X	X	X
7	16		X					Mid	X		X	X	X	
8	18				X			Mid	X			X	X	X
9	17			X			Down			X	X[3]	X	X	X[3]
10	17				X			Mid	X			X	X	X
11	15				X			Mid	X			X	X	X
12	15			X			Mid		X		X[3]	X	X	X[3]
13	14			X			Mid		X		X[3]	X	X	X[3]
14	7	X	X			Up			X			X	X	X
15*	27		X			Mid			X					X
16*	19		X			Down				X				X

Notes:

* - Hand borings

1. Units 1, and other (Units 2 to 7).
2. Relative dispersion distances – up = up-ice; mid = mid station; down = down-ice.
3. One of borings 9, 12 and 13 will be adjusted in the field to obtain peat samples. Movement to peat will result in these locations representing saturated conditions.

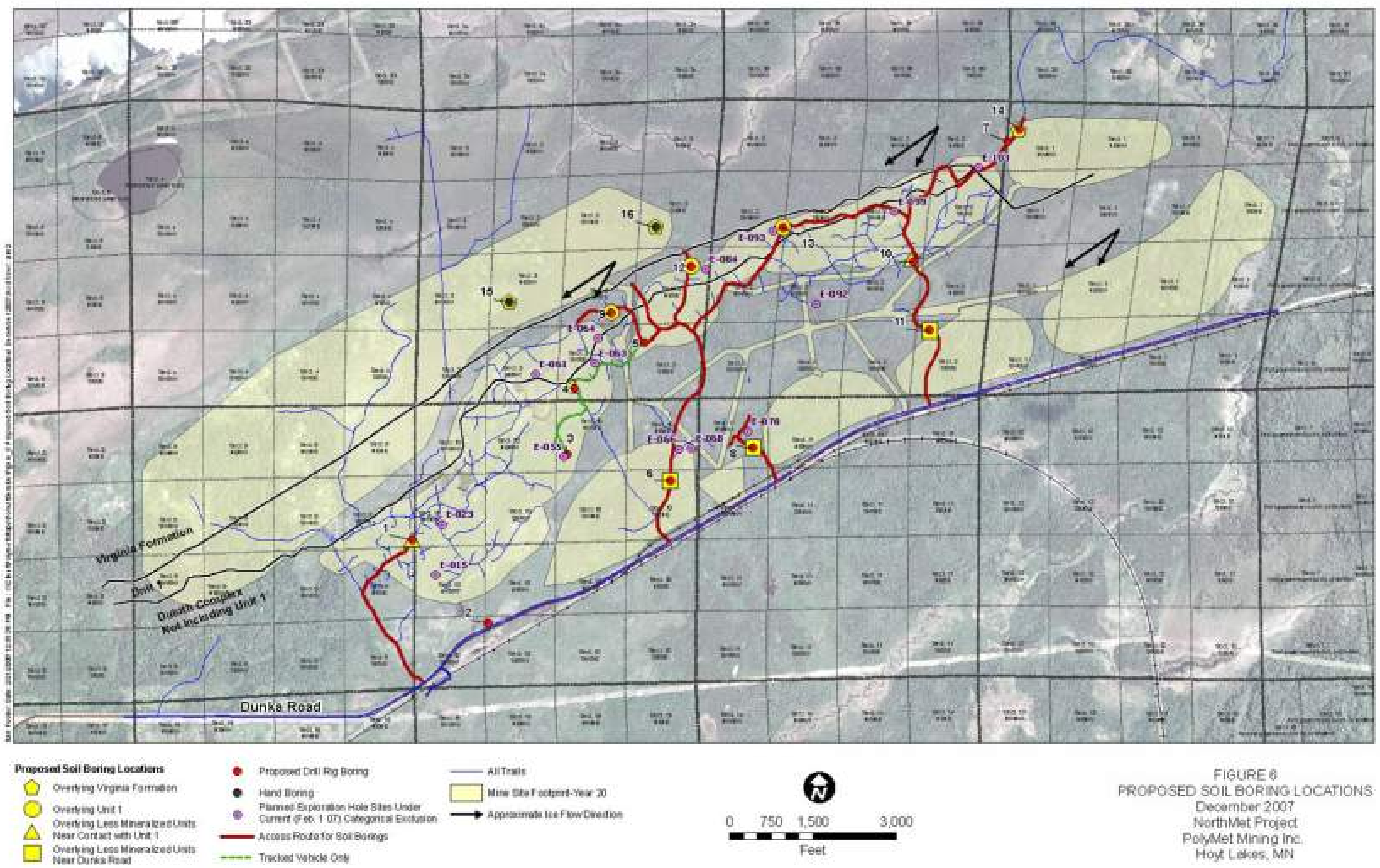

Figure 7. Proposed drilling locations in the context of the mine footprint, geology and wetlands.

5.1.2 Drilling Method

Locations 1 to 14 will be drilled using a rotosonic rig. See pdf files at www.geotechinc.com/equip_rotosonicdrilling.html for description of rotosonic process.

The drilling method is capable of drilling through rocky material; however, in the event of refusal before intersecting bedrock (as indicated by current understanding of overburden thickness in Figure 3), the drill rig will be moved a short distance and the hole re-started.

Locations 15 to 16 will be drilled using manual equipment due to access limitations. A hand auger will be used. Since the ground is frozen and rocks may be encountered, the hand boring is likely to penetrate to a maximum depth of about 5 feet.

5.1.3 Field Observations

Field logs prepared by Barr Engineering and PolyMet Mining staff will include the following information:

- Color of matrix and mottles (Munsell).
- Estimate percentage of lithic materials in coarse clasts.
- Sulfide mineralogy and quantity of each mineral of coarse clasts.
- Texture of materials.
- Percentage of organic matter.
- Relative moisture content.
- Oxidation features.

5.1.4 Field Analysis

Field analysis on all visibly distinct layers indicated by textural, color and compositional changes will include:

- Semi-quantitative rating of reaction of 10% hydrochloric acid with matrix and selected coarse clasts.
- Field rinse test for soluble salts. The procedure will involve stirring of 50 g of the matrix with 50 mL of de-ionized water to form a slurry. The resulting pH and specific conductivity of the supernatant will be recorded.

Field observations and sampling intervals will be compiled into logs and spreadsheets by Barr Engineering staff. These will be transferred to SRK for interpretation and selection of samples for laboratory analysis.

5.1.5 Sample Collection

Samples will be collected roughly every five feet and stored in plastic bags. Actual sampling intervals will be determined in the field from the core logs. In each hole, specific intervals will be selected by field personnel to characterize expected variations which will include changes in observed lithology, degree of oxidation and saturation. Barr Engineering will conduct the field sampling activities with support from SRK. Representatives of the DNR have made arrangements to observe the field sampling activities and collect split samples if desired.

As field conditions and core recovery allow, the goal will be to obtain 10 lbs of sample from each interval. This quantity of material may prove impractical, particularly at manual sampling locations.

Samples will be shipped in coolers to Canadian Environmental and Metallurgical Inc. (CEMI) in Vancouver, British Columbia for analysis. Samples will be refrigerated until the analysis plan is agreed with the DNR to minimize weathering and oxidation of unstable components.

5.2 Physical Analyses

A portion of each sample will be shipped to Barr Engineering for physical analysis which include:

- Atterberg limits (ASTM D 4318 - Liquid Limit, Plastic Limit, and Plasticity Index of Soils)
- Grain Size (ASTM D 421 - Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soils or ASTM D 2217 - Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants, and ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils)
- Consolidation (ASTM D 2435 - One-Dimensional Consolidation Properties of Soils)
- Permeability (ASTM D 5084 - Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter)
- Strength (ASTM D 2850 - Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression, and/or ASTM D 2166 - Unconfined Compressive Strength of Cohesive Soil, and/or ASTM 4767 - Consolidated Undrained Triaxial Compression Test for Cohesive Soils)

5.3 Chemical Analysis

5.3.1 Sample Processing

Upon arrival at the laboratory, all samples of inorganic soils will be weighed and a sub-sample obtained for moisture content. These samples will be dried and screened to obtain three particles sizes nominally to represent the coarse (greater than 2 mm) and sand (2 mm to 74 µm) and silt to to clay (less than 74 µm) components. The latter will represent the potentially more reactive component of the soils.

Peat samples will be handled to minimize loss of syngenetic components formed under chemically reducing conditions. As indicated above, all samples will be refrigerated prior to analysis.

5.3.2 Selection of Samples for Analysis

SRK will select a subset of samples for analysis in consultation with the MDNR based on the field observations and field analysis results. In addition to testing samples to characterize the variables shown in Table 2, the field measured pH of the samples will be used to select a range of pH for evaluation of metal leachability.

5.3.3 Acid Generation Potential

Acid generation potential will be estimated using acid-base accounting on matrix and clast materials of overburden materials. The acid-base accounting procedure will include:

- Total sulfur (Leco Furnace)
- Sulfur as sulfate (HCl soluble, Sobek et al 1978)
- Neutralization potential (Sobek et al 1978)
- Total carbon (Leco Furnace)
- Total inorganic carbon (direct determination by evolved CO_2 by reaction with hydrochloric acid)

5.3.4 Metal Leaching Potential

Metal leaching potential will be evaluated using two methods:

- Total metal content of the matrix and clast materials using aqua regia and four acid digestions.
- Meteoric water mobility procedure (MWMP, NDEP 1996) will be performed on whole overburden samples.

Initial samples for this procedure will be selected in consultation with the MDNR based on the results of the field screening procedures. A second set of analyses may be completed in consultation with the MDNR based on the initial results.

5.4 Sample Archive

All samples obtained for this program will be archived for future analysis.

6 Data Analysis

The data obtained from this program will be used for two specific applications:

- **Evaluate the differences in geochemical characteristics for overburden collected over different rock units and the effect of variations in depositional environment and existing oxidation condition.** The evaluation will be performed by grouping the data to evaluate the various combinations of variables (for example, bedrock type, degree of saturation, distance along ice flow direction, depth) and will indicate the potential need for segregation of overburden and what the segregation criteria might need to be. At an initial level, comparative averages and range measures (percentiles, confidence limits) will be compared. If the data permit, more sophisticated methods (e,g, analysis of variance) may be used to evaluate the significance of different variables)
- **Predict water chemistry for different segregated materials.** This evaluation will be based on leaching tests but depending on the characteristics observed will also include the use of data obtained from the waste rock and lean ore characterization programs.

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