

# FINAL DRAFT

## Brown McDade Waste Rock Pile Mount Nansen Mine Site, Yukon Geochemical Characterization



Prepared for:  
Assessment and Abandoned Mines Branch  
Energy, Mines and Resources  
Government of Yukon

February 2009



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## 1.0 Introduction

### 1.1 Purpose of Document

This document presents an evaluation of the waste rock geochemical and physical characteristics to support development of a decommissioning plan for the Brown McDade waste rock pile located at the closed Mount Nansen mine site in central Yukon.

### 1.2 Overview

As mentioned above, the Mount Nansen mine site is located in central Yukon (Figure 1.1), approximately 60 km west of the community of Carmacks and within the traditional territory of the Little Salmon Carmacks First Nation. The mine site is permanently closed and is under care and maintenance, while studies are underway to support development of a comprehensive site closure plan, slated to be underway in 2009.



Figure 1.1 Location of Mount Nansen Mine Site (from Conor Pacific, 2000)

The Brown McDade deposit was mined via open pit from the fall of 1996 to early 1999, and during this period in the order of 1 million tonnes of waste rock was placed in piles immediately to the west of the Brown McDade pit. Numerous operational and permit-related issues resulted in the closure of the mine in February 1999. The site was placed in receivership and reverted to the responsibility of the Water Resources Division of Indian and Northern Affairs Canada, and then to the Assessment and Abandoned Mines Branch of the Ministry of Energy and Mines of the Government of Yukon. These agencies have taken responsibility for the care of the remaining facilities of the site, and ensuring that water discharge from the site meets effluent quality standards.

The Assessment and Abandoned Mines Branch has worked extensively with the local community and the Little Salmon Carmacks First Nation in disseminating information about the site, and seeking input on concerns and suggestions for future use of the site.

### **1.3 Objectives and Scope**

#### **1.3.1 Mount Nansen Closure Objectives**

As previously mentioned, input from the local community and First Nation has been sought, and Closure Objectives for the Mount Nansen site were derived which form the basis for the next phase of site closure planning. The following is an excerpt from the Closure Objectives circular (Mount Nansen Closure Objectives):

*These objectives were gathered through traditional knowledge interviews, community meetings and mine site tours.*

*A complete review of the closure options by workers from Little Salmon Carmacks First Nation, Yukon and federal governments will happen before final options are chosen.*

*The closure options will be measured against the closure objectives to help the governments come up with the best option for cleaning up the mine site.*

#### ***Protect human health and safety***

- *People using the area will be safe from remaining mine hazards.*
- *Animals, plants and berries around the mine site are safe to harvest and will stay that way.*
- *Water at mine site and downstream will be clean and safe for people to use.*
- *Mine metals in dust will not be able to build up more on plants and soils in years to come around the mine site.*

#### ***Protect the environment including land, air, water, fish and wildlife***

- *Animals using the area will be safe from remaining mine hazards.*
- *Water at the mine site, in the ground, and downstream will be as clean and safe as possible for the health of animals, plants and bugs.*
- *Mine metals in dust will not continue to build up on plants and soils around the mine site. This will help protect and improve the health of plants, animals and soils.*
- *Restore the land and water so that plants and animals can live there in the way they did before the mine.*

#### ***Return Mine Site to an acceptable state of use that reflects original use where possible***

- *Quality of water at the mine site and downstream will be clean and safe so it will not limit traditional use.*
- *The opportunity for traditional uses of the area will be restored and as close to before mining use as possible.*

- *Make the clean up so that, as the years go by, there will not have to be much work at the mine site to keep it clean and safe.*

***Maximize local, Yukon and First Nation benefits***

- *Local people will be hired to help clean up at the mine.*

***Community Closure Planning Core Values:***

*The community and the knowledge of local people will always be recognized and a part of decisions made about the Mount Nansen mine site.*

*The safety of the plants, animals, fish, and water will continue to be checked on and people will know how safe they are.*

*People will be kept up to date about what it is like at the mine site.*

*The LSFN [Little Salmon First Nation] Final Agreement will be followed.*

### **1.3.2 Scope of this Project**

Altura Environmental Consulting was approached by the Assessment and Abandoned Mines Branch of the Government of Yukon to perform a detailed assessment of the Brown McDade waste rock pile site in order to plan for future decommissioning. There are five scope items for the study:

1. If possible, a broad classification and designation of the waste rock piles by lithology, alteration, size or competency;
2. A validation of previous acid rock drainage/metal leaching (ARD/ML) characteristics of the main lithologies / alterations;
3. Establish criteria for selection of waste rock material for segregation and mitigation of ARD/ML potential, waste rock suitable for remediation related construction purposes, and any other classifications in between;
4. An assessment of types of native vegetation currently growing on portions of the piles and factors promoting growth in those areas; and
5. Conceptual proposal for reclamation (resloping and revegetation) of the piles.

This report, “Geochemical Characterization”, addresses scope items 1 through 3. A separate report, “Ecological Restoration Strategy” addressing items 4 and 5 will be issued under separate cover.

## 2.0 Local Setting

The Mount Nansen property is located within the Dawson Range, with the terrain consisting of rounded ridges and shallow valleys with a light cover of vegetation and small trees. Elevations range from 945 metres to 1525 metres above sea level. The Nisling River drains the area to the west, which ultimately drains into the Yukon River via the Donjek and White Rivers. Drainage from the property flows in two moderate sized tributaries to the Nisling River: Nansen Creek to the west and Victoria Creek to the east (Figure 2.1). Back Creek and Dome Creek are tributaries of Victoria Creek on the east side of the property, where the workings of the Mount Nansen mine are located.

Many historic prospects and minor hard rock mine workings are located in the region; in addition placer operations, both historical and active, are located along Back Creek and other higher tributaries to Victoria Creek. Dome Creek is directly impacted by the Mount Nansen mine site, primarily by the historical Heustis underground mine workings, the mill facility, and the tailings impoundment. Pony Creek is a tributary of Back Creek that is potentially impacted by the historic Brown McDade underground workings, and the Brown-McDade open pit. The Brown McDade waste rock pile straddles the divide between the Back Creek and Dome Creek drainages.

### 2.1 Climate

Climate data was reviewed as part of this study. From previous studies, average annual temperature at the Mount Nansen site is estimated at  $-1.1^{\circ}\text{C}$ , total annual precipitation 270 mm, and average annual evaporation of 350 to 400 mm. Accumulated snowpack is in the order of 50 to 70 mm. The slight positive balance of evaporation with respect to precipitation indicates that under typical climatic conditions, a large influx of net infiltration into the waste rock pile is unlikely except during spring runoff and extreme climatic events.

It is also noted that there is very limited site data available, and most all climatic parameters were estimated in previous studies using data from lower elevation sites such as Carmacks and from Fort Selkirk (45 km to the east and 80 kilometres to the north respectively).

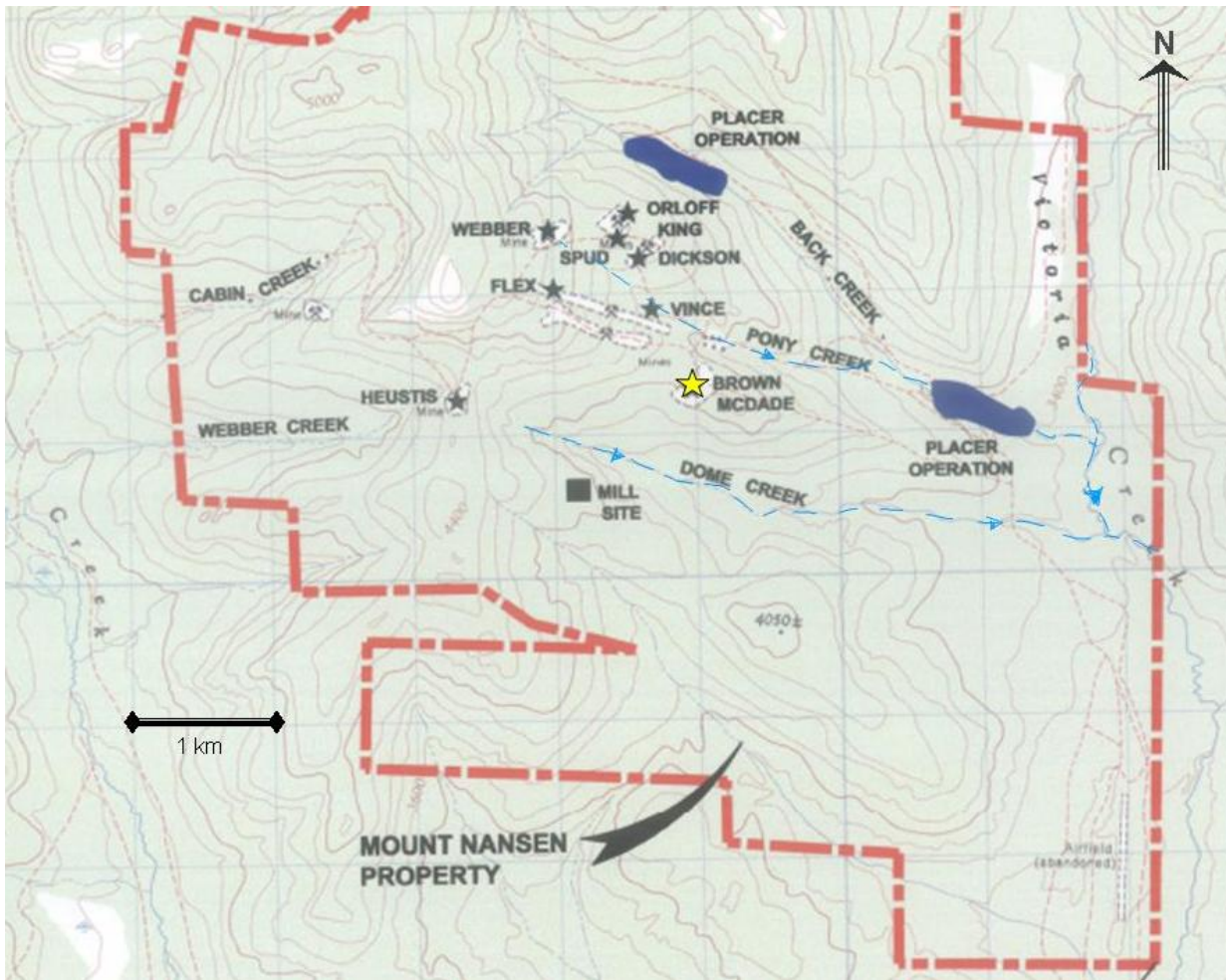


Figure 2.1 Mount Nansen Property and Local Drainages and Workings (adapted from Conor Pacific, 2000)

## 2.2 Physiography and Soil Conditions

The Mount Nansen area lies within the Yukon Central Plateau of the Boreal Cordillera Ecozone (Government of Yukon, 2008), and has similar characteristics to the Spruce-Willow-Birch biogeoclimatic zone (SWB) in British Columbia.

As previously mentioned, local terrain consists of gently rounded hills and shallow valleys. Permafrost is discontinuous, but is evident at shallow depths (0.4 metres) in east and north facing slopes valleys and benchlands where surficial sediments and bedrock have a thick organic or moss cover (Photo 2a).



*Photo 2a View of Mount Nansen area in vicinity of Brown McDade pit and waste rock pile, looking south (from EDI, 2007).*

This area is one of the few areas of North America to have been ice-free during the last glaciation period (approximately 10,000 to 26,000 years before present). Hence, surface weathering tends to be deep, with rock demonstrating pervasive surface oxidation (or supergene alteration) to depths of 10 metres or more.

Soil development is generally poor across the property; typically represented by several centimetres of organics overlying a layer of volcanic tephra, which itself overlies decomposed bedrock (EDI, 2007). Unconsolidated alluvium has been mapped on the property, principally occurring in the Victoria and Nansen Creek Valley bottoms. Loess and volcanic ash have been observed in scattered patches throughout the property. The loess occurs as fine sand mantling some of the lower slopes. White ash appears as a few centimetres of soil exposed in road cuts, and is postulated to be from a recent eruption (1,230 years ago) in the Wrangell Mountains to the northwest. North facing slopes are typically permafrost-bound, as evidenced by thick moss cover and stunted conifers. The south facing slopes are well-drained and can be grassy to barren of vegetation.

## 2.3 Local Geology

Local host rocks are metamorphic rocks of Mississippian in age (approximately 356 million years), and in the immediate area of the Brown McDade deposit, plutonic rocks of granodioritic composition of Late Triassic to Mid Jurassic age (105 to 224 million years ago). A volcanic quartz feldspar porphyry complex intrudes the granodiorite at the Brown McDade deposit.

A generalized bench plan view of the upper Brown McDade zone geology is shown in Figure 2.2. Prior to mining the zone was approximately 500 metres long by 200 metres wide and consisted of quartz veins and associated feldspar porphyry dykes developed in the hangingwall of a strong fault (Footwall Fault), striking southeasterly and dipping 50 to 70 degrees to the southwest. The fault cut obliquely across a contact between granodiorite and a minor amount of metamorphic rock. Footwall rock tends to be relatively massive granodiorite, while hanging wall rocks are fractured and clay altered.

Ore mineralization consists of pyrite, arsenopyrite, galena, sulphosalts, and sphalerite, generally fine-grained and occurring in disseminated form and in veinlets. Supergene weathering converted the near surface sulphide minerals to limonite and other oxides. The oxidation gradually diminished with depth, and total oxidation was estimated to range from 5 metres' depth at the north end of the zone to at least 75 metres at the south end (TW Higgs, 1994).

Five hypogene alteration facies were identified in the Brown McDade zone and other adjacent mineralized zones, listed as follows from weakest to strongest facies:

- Propylitic Alteration: slight chloritization of hornblende, fine pyrite wholly or partially replacing mafic minerals, and locally abundant interstitial calcite;
- Argillic Alteration: subdivided into montmorillonite (feldspars and mafic minerals altered to chlorite montmorillonite and calcite) and kaolinite (bleached appearance due to total destruction of mafic minerals) facies;
- Phyllic Alteration: original rock-forming minerals totally altered to an extremely fine-grained mixture of quartz and sericite. Dominant facies within a 7 to 30 metre-wide breccia zone immediately in the hangingwall of the Footwall Fault; and
- Silicic Alteration: pervasive replacement by quartz; this alteration is rare and usually found directly adjacent to mineralized quartz veins.

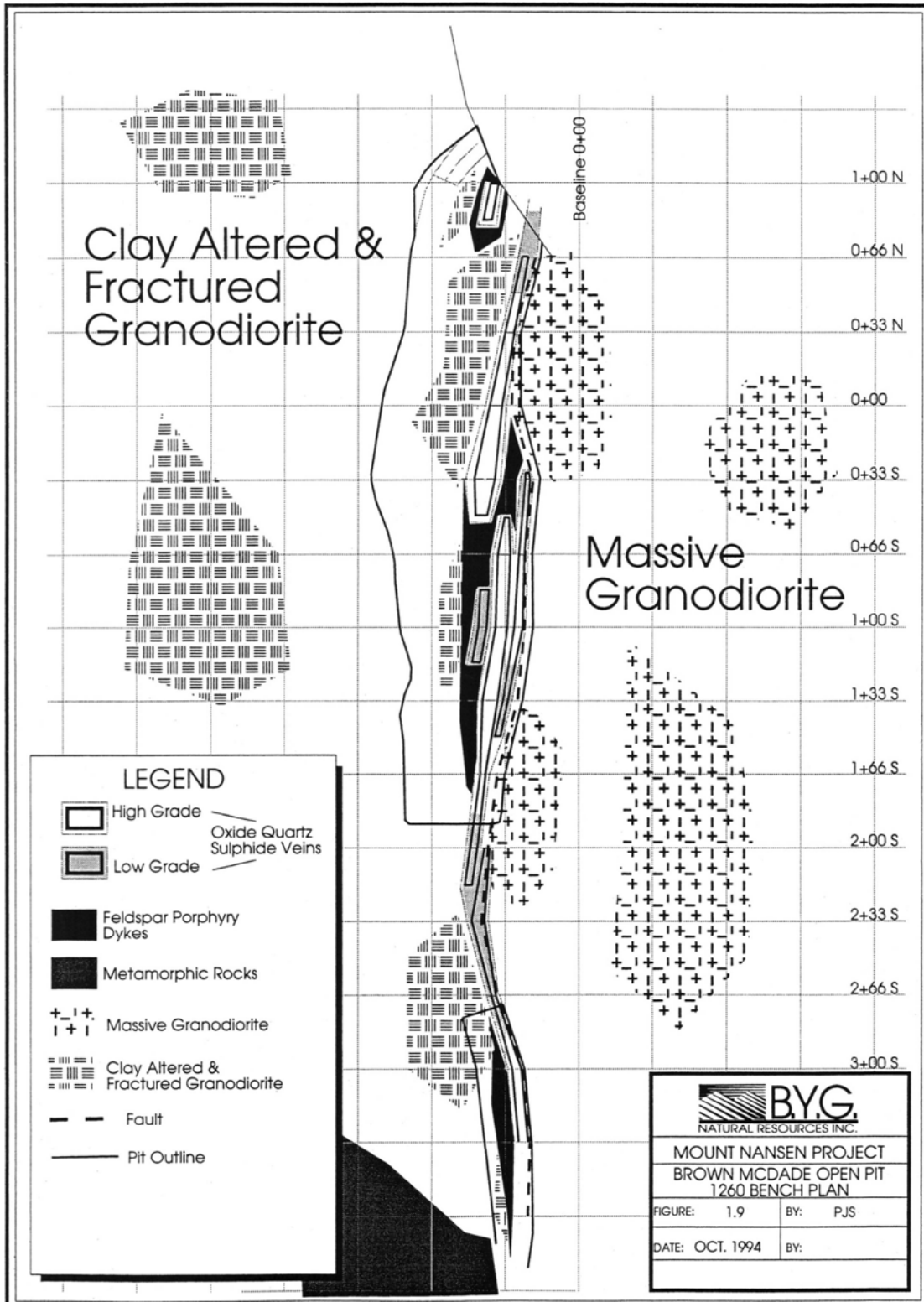


Figure 2.2 Brown McDade Zone Geology, 1260 Bench (from TW Higgs, 1994)

## **2.4 Socioeconomic and Cultural Values**

The Mount Nansen area lies within the traditional territory of the Little Salmon Carmacks First Nation (LSCFN). Both the LSFN and the general Yukon community use the area for subsistence and recreational purposes.

The area sees gold placer mining activity in many of the small drainages, and exploration works for gold have been ongoing in the region for decades.

### 3.0 Overview of Work Program

In order to address the required scope items for this study, a number of key questions were derived and a complementary work program component developed. These aspects are summarized in Table 3.1. Sections 4.0 and 5.0 present an overview of the program results.

*Table 3.1. Summary of Key Questions and Work Program for the Geochemical Characterization Study*

<b>Key Question</b>	<b>Work Program Component</b>
What is the history of development of the Brown McDade waste rock pile?	Review of available historical documents and maps: <ul style="list-style-type: none"> <li>• Yukon Water Board</li> <li>• Supplied by Assessment and Abandoned Mines</li> </ul> Personal interviews with past employees
Where was the waste rock placed during mining? Any other areas besides the waste rock pile?	Personal interviews with past employees
How much waste rock is stored in the main Brown McDade pile and in other areas?	Review of available historical documents Digitizing of rock pile areas Comparison with estimate of pit volume
What is the geochemical status of the stored waste rock in the Brown McDade pile?	Field pH of rock Test pits Lysimeter installation for future monitoring (Spring 2009) Review of historical geochemistry data and integration of results where appropriate
Is the stored waste rock segregated into distinguishable sectors of different rock types, or does it tend to be well mixed?	Test pits Surface reconnaissance
Is there any evidence of seepage or surface runoff from the main Brown McDade waste rock pile?	Perimeter toe surveys, ponding surveys
Is there likely any significant water infiltration into the waste rock pile? If so, what are the characteristics of the water once it has contacted the waste rock?	Shallow lysimeter installation, two sites, for monitoring starting in 2009 Implementation of seepage monitoring – quality and quantity

## 4.0 Description of the Project Site

### 4.1 Layout and Geometry

Waste rock piles cover an approximately 9 hectare area immediately adjacent to the Brown McDade pit, with the piles located at elevations ranging from 1185 to 1235 metres above sea level. The waste rock pile area is divided into three discrete sectors: a northwest, an east, and a south and west sector. Within the south and west sectors are several smaller contiguous piles, which for the purposes of this study, have been referred to by the names given in Table 4.1, and shown in Figure 4.1. All of the Brown McDade waste rock piles have maximum height from original ground in the order of 10 metres. More than 85 percent of the pile area is flat to slightly inclined platform areas, with the remainder being angle of repose slopes in the order of 32 degrees. Overall angle from the toe of the pile to the uppermost sections is shallow, measuring from 13 to 16 degrees.

The rock pile area is situated on a height of land separating Dome and Pony Creeks. The majority of waste rock is located over original ground that slopes towards Dome Creek. Most rock pile slopes have a west to southwest aspect, and only a minor fraction of the slopes are east to north-facing. Photo 4a shows an oblique aerial view of the rock pile and surrounding area.

Areas and volumes, roughly estimated from the latest available topographic information, are given in Table 4.1. Original topographic information, likely archived in site information stores, was not available for the purposes of calculated stored volume of material. Based on this estimate and assuming a bulk density of 1.7 t/m<sup>3</sup>, it appears that there is in the order of 1 million tonnes of waste rock stored in the pile area. It should be noted that this value falls short relative to the total estimated volume of material removed from the pit, calculated to be just over 1.0 Mm<sup>3</sup> of ore and waste rock. Considering a 2.5 t/m<sup>3</sup> specific gravity and 2.8:1 strip ratio, the pit volume estimate indicates that approximately 740,000 m<sup>3</sup>, or 1.85 Mt of waste rock was removed from the pit. Nonetheless, as mentioned in section 4.2, an unknown quantity of waste rock was reportedly placed in other areas for road construction purposes.

Table 4.1 Sectors and Approximate Areas and Volumes of the Brown McDade Waste Rock Pile

Sector	Estimated Area (m <sup>2</sup> )	Estimated Average Thickness (m)	Estimated Volume (m <sup>3</sup> )
Northwest	19300	7	135100
East	9000	4	36000
South and West Sectors	62500	m <sup>2</sup> including:	
South	12200	4	48800
Southwest Upper	10000	5	50000
Southwest Lower	6800	6	40800
West Lower	16000	7	112000
West Mid	16900	5	84500
Ore Stockpile	600	3	1800
<b>TOTAL</b>	<b>90800</b>		<b>509000</b>

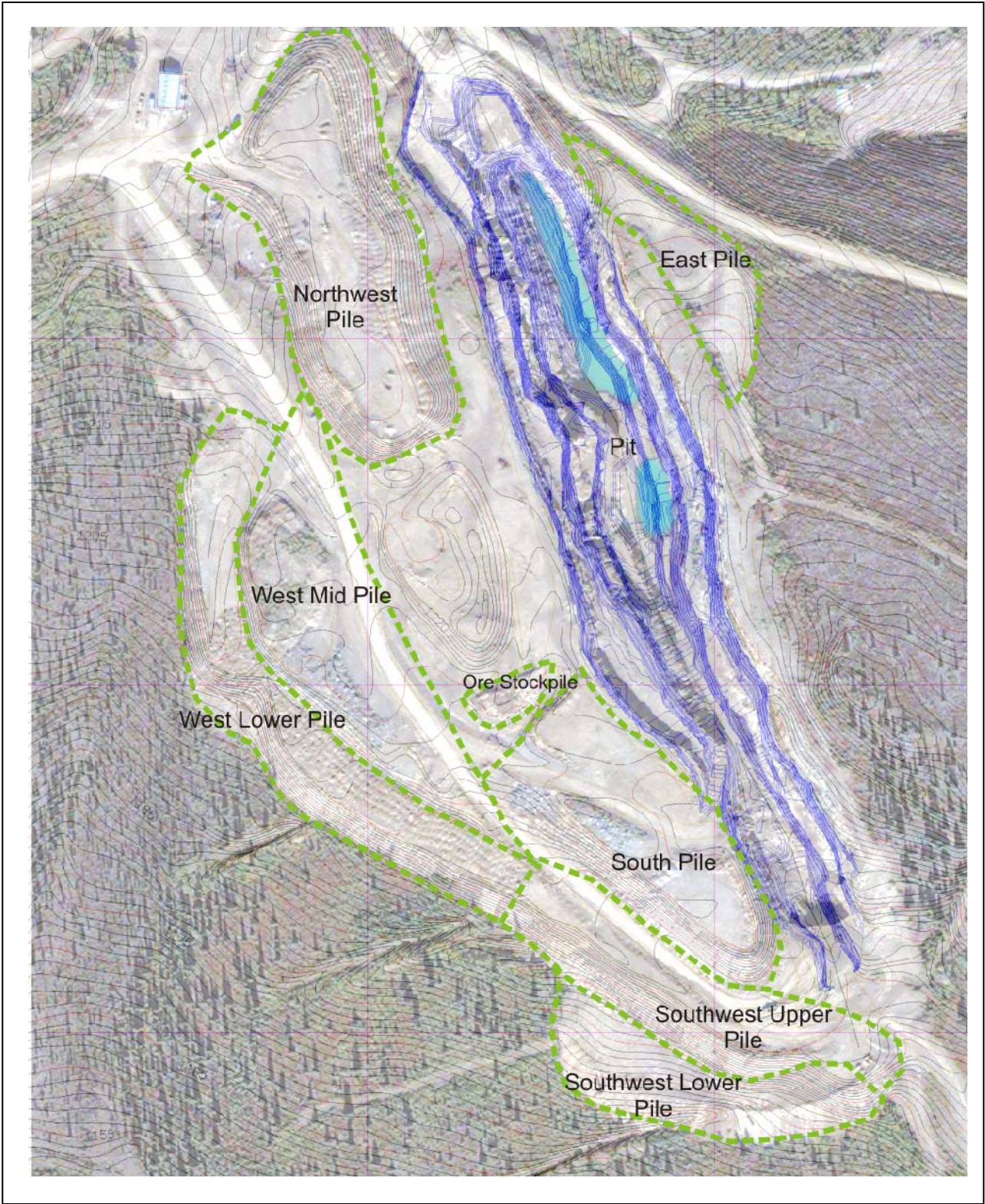


Figure 4.1 Sectors of the Brown McDade Waste Rock Pile



*Photo 4a Aerial view of Brown McDade waste rock pile looking east. Pit is immediately behind waste rock area.*

## 4.2 Construction History

As previously mentioned, mining operations from the Brown McDade pit were carried out from the fall of 1996 to early 1999, producing in the order of 1 to 2 million tonnes of waste rock.

There are no systematic mining records or status maps compiled. Instead, an approximate history of the Brown McDade waste rock pile development was compiled based on: i) interviews with former BYG employees, and ii) interim status maps from June 1997, late (?) 1998, and final rock pile layout. Figure 4.2 shows available status map information with respect to waste rock pile advances during mining of the Brown McDade pit. The overall sequence of mining and rock placement is summarized in Table 4.2, and additional detail is provided in the following paragraphs.

Overburden from the Brown McDade zone was stripped likely in the late 1980's, years prior to commencement of mining in late 1996 (Stroshein and Mann, pers. comm.). During the pre-operational period, rock (presumably from near-surface and at the north end of the pit) was placed in the East Pile.

It should be noted that in the original mine plan (T.W. Higgs Associates, 1994) separate mining from a larger North and smaller South pit was envisaged (as shown in Figure 2.2), however for both geological and operational reasons, the two zones were ultimately mined as a single pit.

Mining commenced in fall of 1996, and focused on upper levels of the north end, with the pit reportedly extending down to approximately the 1260 bench level<sup>1</sup> by mid 1997 (Stroshein, pers. comm.). During this initial mining phase, activities focussed on maximizing ore production rather than mining the benches to design limits. As a result, by mid-1997 the east side of the pit consisted of a steep highwall in the order of 25 m height. Mann (1997) reported that by June 1997 approximately 300,000 tonnes of waste rock had been removed from the Brown McDade pit. Based on a map provided in this same report, the majority of this material had been deposited in the West Mid-level Pile area with platform elevation of approximately 1215 m (see Figure 4.2)

From fall 1997 to early 1998 efforts focused on a 'pushback' of both the footwall and remaining hangingwall zones, as well as extending the pit extents southward (Stroshein, pers. comm.). Mining of ore proceeded downward into less oxidized material. During the pushback period and likely through most of 1998 the Northwest, South, Southwest Upper, and West Lower Piles were developed. Fresher material from the footwall granodiorite was reportedly used for haul road fill.

By comparing the last available as-built supplied through Underhill Geomatics to the final layout as depicted on the September 2008 satellite image, one can see that the Southwest Lower Pile was one of

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<sup>1</sup> Note that an elevation discrepancy exists between the pit bench levels and the topographic data for the waste rock pile and surrounding area. It is estimated that the pit bench levels designations are in the order of 48 metres above the topographic datum for the surrounding area.

the last new areas for waste rock placement. This likely occurred from late 1998 until suspension of mine operations in January 1999. It is also possible that many of the loads of 'free-dumped' waste rock without subsequent contouring were also placed during this final phase of mining. Based on interviews with BYG personnel (Stroshein, pers. comm.), most mining was from the south sector of the pit during this period.

A large ore stockpile measuring approximately 100 m by 60 m by 6 m high is shown on the last available topographic survey of the rock pile area. As seen in Figure 4.2, this pile has since been removed, leaving only a very small remnant clay ore stockpile approximately 25 m to the south.

*Table 4.2 Approximate History of Brown McDade Waste Rock Pile Development*

<b>Period</b>	<b>Main Active Area(s) of Pit</b>	<b>Likely Destination of Material</b>	<b>Other Comments</b>
Pre-Mining (prior to Fall 1996)	<ul style="list-style-type: none"> <li>Overburden Stripping, entire Brown McDade zone</li> <li>Footwall?, pit North Sector</li> </ul>	<ul style="list-style-type: none"> <li>Extreme South of Rock Pile</li> <li>East Pile</li> </ul>	
Mining: Fall 1996 to June 1997	<ul style="list-style-type: none"> <li>North Sector of Pit</li> </ul>	<ul style="list-style-type: none"> <li>West Mid Pile, 1215 m lift</li> <li>Haul Road Fill</li> </ul>	
July 1997 to Late? 1998	<ul style="list-style-type: none"> <li>Hangingwall Pushback, North Sector</li> <li>Footwall Pushback, North and South Sector</li> <li>Hangingwall Pushback, South Sector</li> </ul>	<ul style="list-style-type: none"> <li>Northwest Pile</li> <li>West Lower Pile</li> <li>Haul Road Fill</li> <li>South Pile</li> <li>Southwest Upper Pile</li> </ul>	
Late? 1998 to January 1999	<ul style="list-style-type: none"> <li>South Sector, deeper zones</li> </ul>	<ul style="list-style-type: none"> <li>Southwest Lower Pile</li> <li>Free dump piles on West Mid Pile, South Pile (unaltered granodiorite)</li> </ul>	Majority of stockpiled ore transported to mill during this period

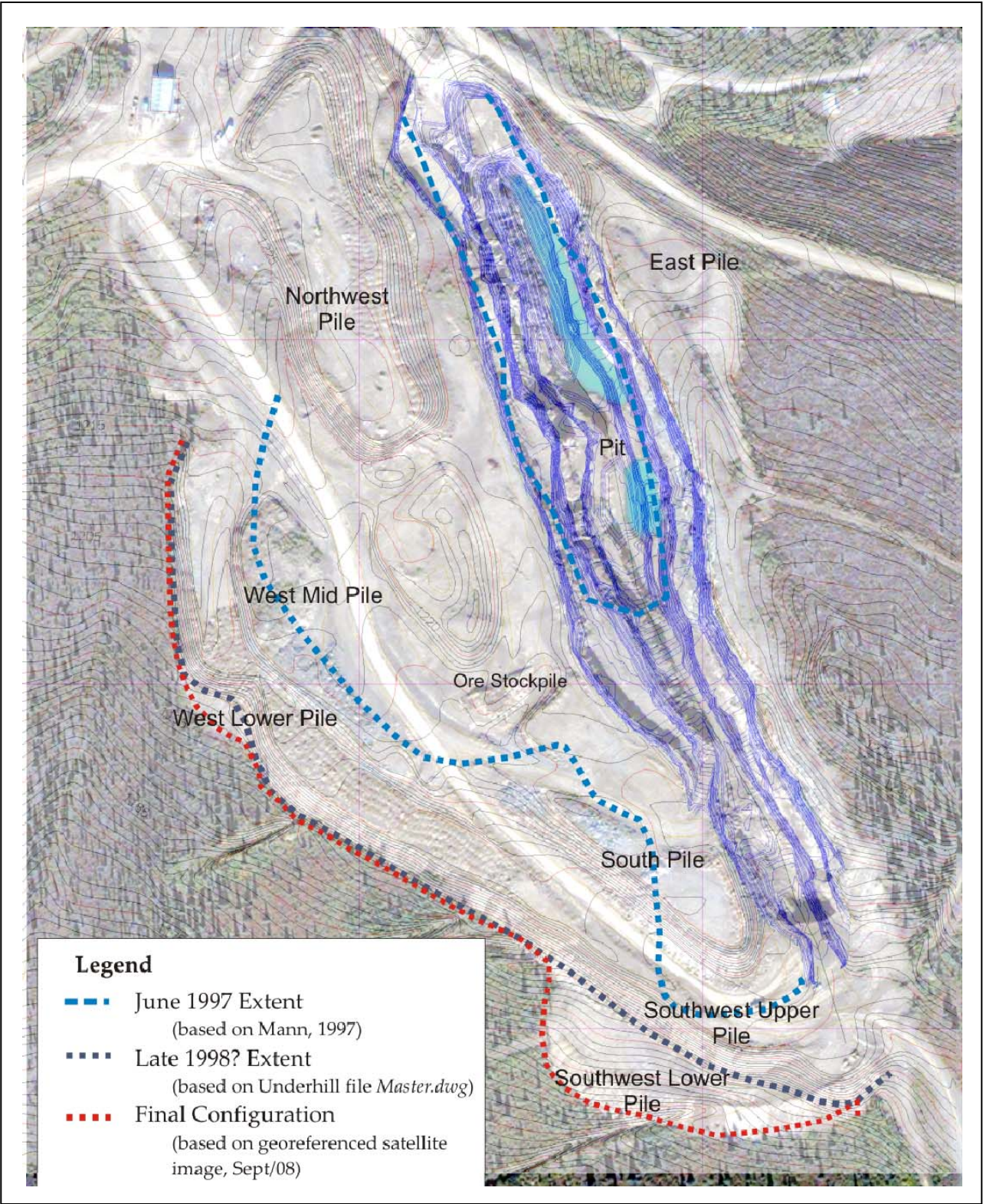


Figure 4.2 Historic Limits of the Brown McDade Waste Rock Pile

### 4.3 Seepage, Runoff and Erosion Considerations

As mentioned in section 2.1, there is likely a slight positive balance of evaporation with respect to precipitation at the Mount Nansen site, indicating that under typical climatic conditions, a large influx of net infiltration into the waste rock pile is unlikely except during spring runoff and extreme climatic events. The depth to groundwater is estimated in previous studies (Gartner Lee, 2008) to be in the order of ten meters in the area of the west rock pile toe, and several tens of metres in other area.

Where there are low areas on the surface of the waste rock pile, runoff can concentrate and form ponds following precipitation events and during snowmelt periods. This can result in localized infiltration, and seeps from the pile toe may occur. For this reason, surface and perimeter reconnaissance was conducted to identify both ponding and seep areas, as well as to ascertain any active erosional processes on the waste rock pile.

#### 4.3.1 Surface Ponding

Heavy rains in late August provided an opportunity for observation of zones of surface ponding in the rock pile area; two main sites were identified, as shown in Figure 4.3:

- *Ponding Area A:* This site is a low spot located between the north toe of the South Pile and the remains of the Ore Stockpile, as shown in Photo 4b. Runoff from the South Pile and Ore Stockpile area report to this site. Although minimal water was ponded at this site when observed on September 1, there is an approximately 40 m<sup>2</sup> accumulation of moist orange to brown-coloured silt and clay indicating that water likely collects at this site during snow melt periods and extreme rainfall events.
- *Ponding Area B:* This area is located immediately west of the main haul road in the area of the Northwest Pile, in the vicinity of a rock drain or buried culvert. A small accumulation of water at this site on September 1 was of 860 µS/cm conductivity and a slightly alkaline pH of between 7 and 8.

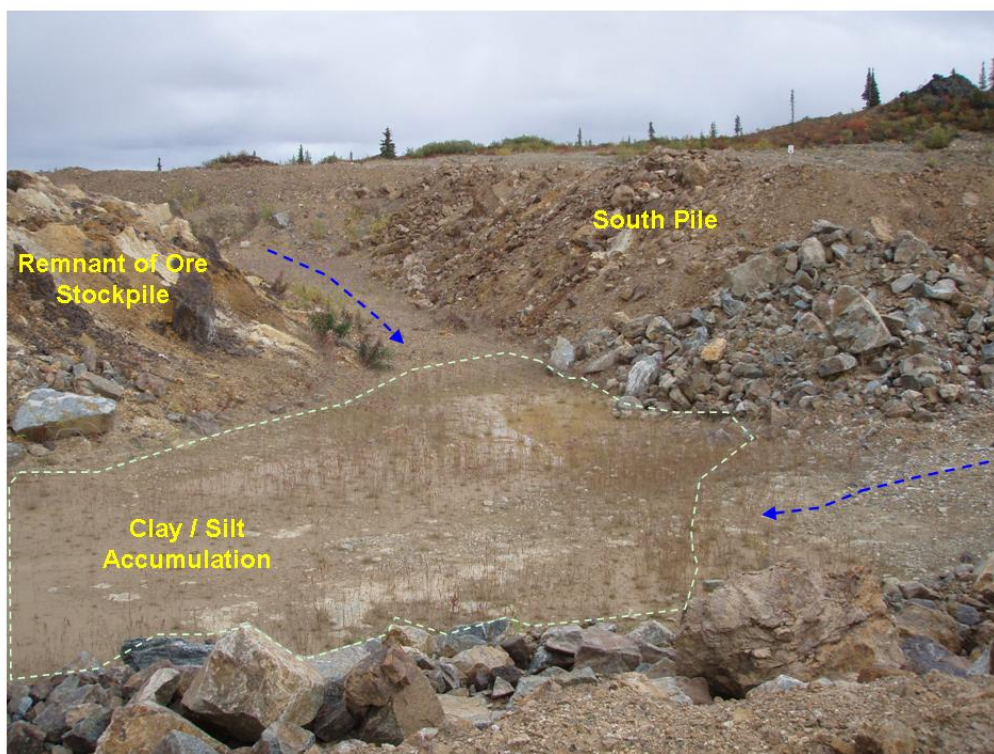


Photo 4b. Ponding Area A, between South Pile and Remnant Ore Stockpile

#### 4.3.2 Seepage Areas

Two seepage points were identified during August and September reconnaissance, as described in the following paragraphs and shown in Figure 4.3 and Photos 4c and 4d:

- *NW Seep-01*: This site is located on the east toe of the Northwest Pile, and was first observed on September 1, 2008. Judging by the local vegetation enrichment in the immediate area, the site appears to be a perennial, albeit low volume seepage. A drainpipe was installed and a plastic half-drum placed in a collection sump. Flow through the collection pipe was 0.05 L/min on September 3, with conductivity elevated at 2120  $\mu\text{S}/\text{cm}$  and pH is neutral at 7.18. A water quality sample was taken during routine site monitoring on September 19 by EDI Environmental Dynamics Inc. personnel. Results are given in Table A.# of Appendix A, and are compared with water from other mine workings as well as applicable standards. The elevated concentrations of sulphate, calcium, and zinc levels are indicative of contact with waste rock. Total dissolved solids, at 1780 mg/L, exceeds Water Licence Criteria; however it is noted that the 50 mg/L standard is extremely low and is often exceeded at background surface water sites in the area. Zinc, at 0.238 mg/L, is anomalous but below the 0.3 mg/L Water License Standard, and is lower than typical water that accumulates in the open pit (0.3 to 2.3 mg/l). All other metals are well below applicable standards.

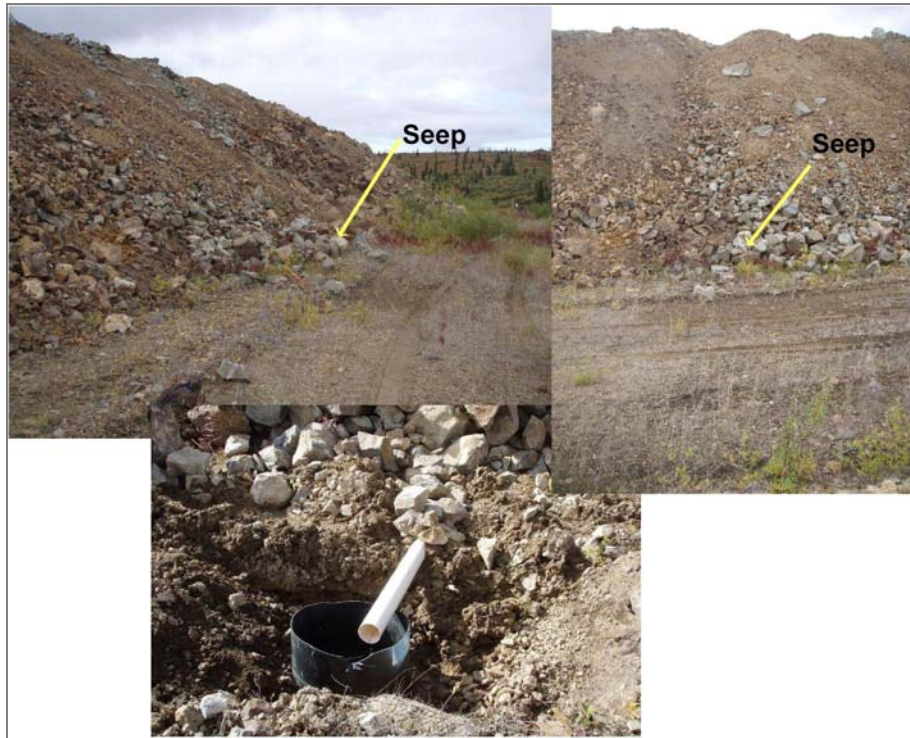
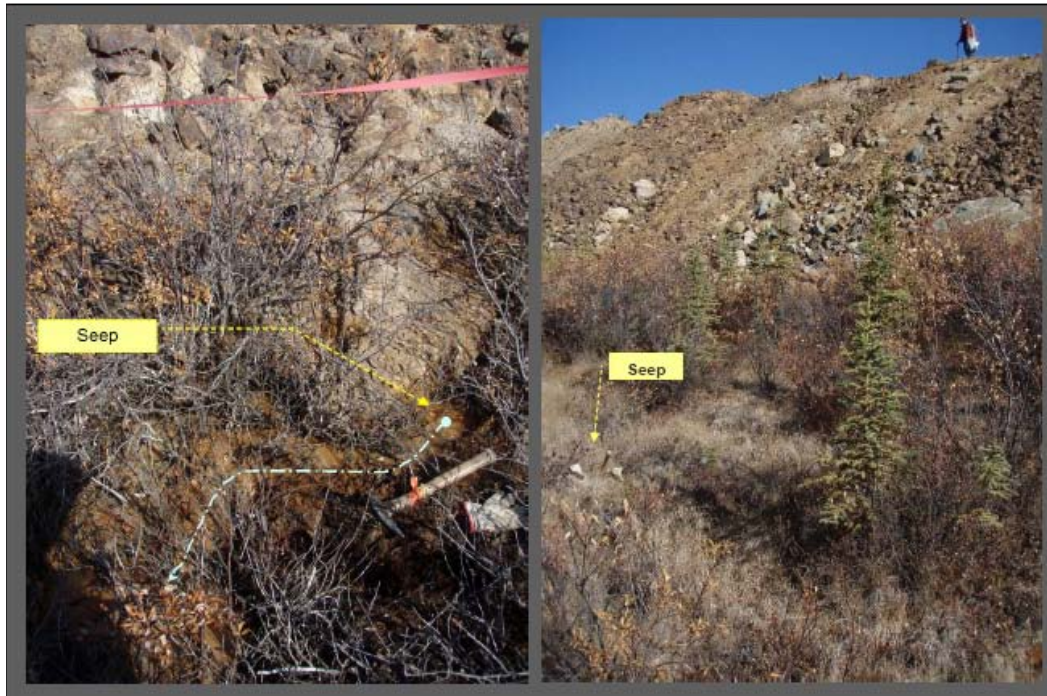


Photo 4c NW Seep-01 and installed collection pipe. Estimated flow through pipe of 0.05 L/min on September 3, with field pH 7.18.

- *LW-Seep-01*: observed during reconnaissance of western extent of the toe of the West and Southwest Lower Piles on September 21. Flow at this site consisted of several small channels flowing over vegetation. Rust and orange-coloured gelatinous precipitate/algae was seen forming over the moss. Rate of flow was estimated at 10 L/min. There was no well-developed channel or vegetation enrichment at this site, suggesting either a newly-developed flow path, or a very sporadic occurrence of flow at this location. Field measurements indicate a slightly acidic pH in the order of 5.7, and elevated conductivity of 2700  $\mu\text{S}/\text{cm}$ . No sampling was conducted due to the lateness of the season. It is noted that this site is downgradient and approximately 150 m from Ponding Area A and the Ore Stockpile. Water quality sampling in 2009 is recommended to provide clearer information as to the provenance of this water.



*Photo 4d LW Seep-01, note orange-coloured gelatinous precipitate along flow path in left photo, estimated aggregate flow of 10L/min on September 21, with field pH 5.7.*

### 4.3.3 Erosion Features

No macro-scale surface erosion features such as rilling and gullying are observed on the Brown McDade waste rock pile platforms or slopes. Nonetheless, it is noted that the fine-grained size particles tend to form a thin and weak indurated crust in many areas of the rock pile. This armouring may be a result of a combination of: i) raindrop erosion (where the impact of raindrop entrains clay and fine silt particles leaving a cement-like crust of coarser sand-size material), ii) freeze-thaw processes (USDA, 1996) and iii) dissolution and evaporation of readily soluble salts. Photo 4e shows a number of examples of the surface condition of slopes and platforms of the waste rock pile.

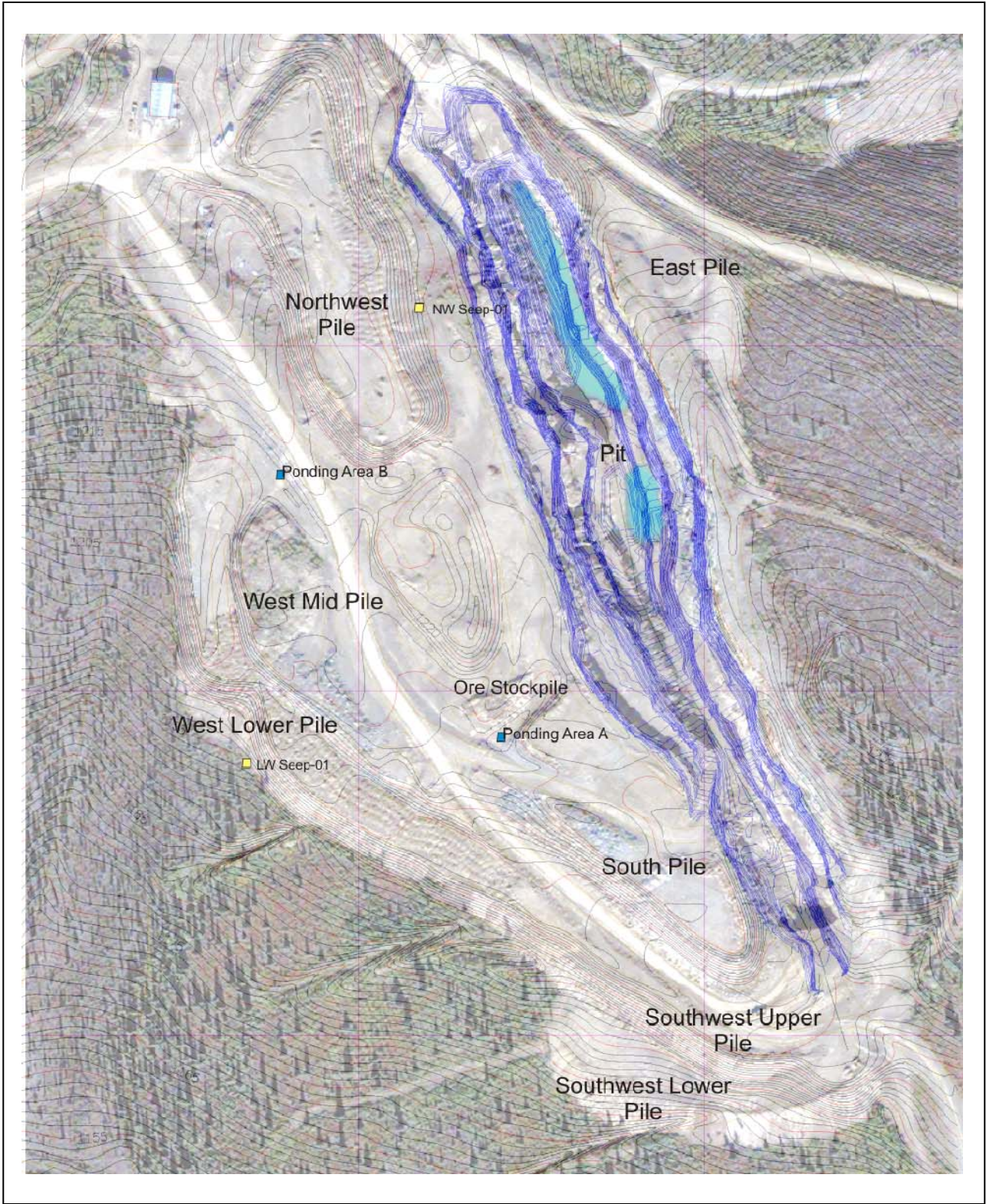


Figure 4.3 Ponding and Seepage Areas of the Brown McDade Waste Rock Pile, September 2008

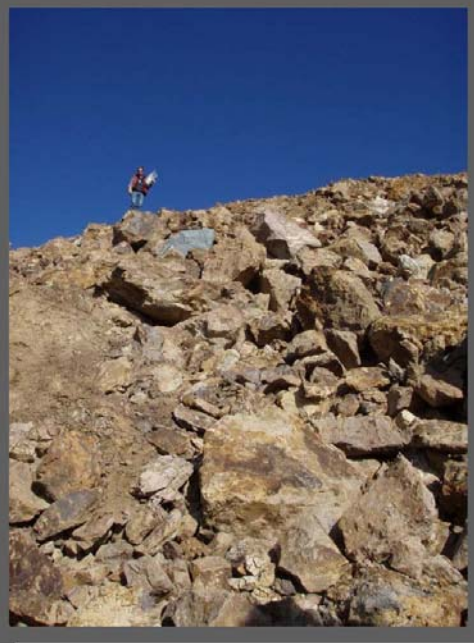


*left: old ore stockpile area with remnant pile in background*

*middle left: west flank of Northwest Pile*

*middle right: coarse rock angle of repose slope, West Lower Pile*

*bottom left: slope of Southwest Upper and platform of Southwest Lower Pile (note trees protruding from slope, indicating shallowness of rock)*



*Photo 4e Examples of the surface condition of slopes and platforms of the waste rock pile*

## **5.0 Waste Rock Characterization**

### **5.1 Summary of Studies**

Several studies have been conducted to assess the acid rock drainage and metal-leaching potential of Brown McDade waste rock, beginning with preliminary property-wide sampling in 1985. The various studies and available data, including information gathered during 2008, are summarized in Table 5.1. Figure 5.1 shows the location of samples taken from waste rock pile and pit areas in 1997, 1999, and 2008.

### **5.2 2008 Field Program**

As summarized in section 3.0, a rock characterization field program involving excavation of test pits, general mapping, and lysimeter installation was conducted during the fall of 2008. The data generated from this work was intended to both augment data collected in previous years by others, and to more systematically document waste rock conditions after over 9 years of weathering under ambient site conditions.

Specific details of field and laboratory methodology, and detailed results are given in Appendix A. Photographs of some of the work activities are given in Photos 5a to 5d.

Table 5.1. Summary of Brown McDade Waste Rock Geochemical Studies

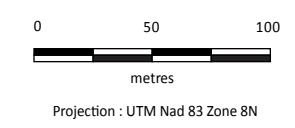
Year	Agency/Firm	Reference	Sampling	Testing and Method	Incorporation into this Report
1985	Norecol	IEE, Section 4.6.1, and Table 4-1	3 samples consisting of marginal ore [2] and “wall rock” [1].	ABA via Unspecified method	Qualitative review of results only (eg. data not incorporated in database)
1989	Norecol	IEE, Section 4.6.2 and Table 4-2	11 representative waste rock[8?] and ore [3?] samples of drill core from 0.1 to 1.5 metres in length	ABA (NP method not specified, modified AP via sulphide sulphur content	ABA results incorporated into stats database
1994	Process Research – T.W: Higgs Associates	IEE, Section 4.6.3 and Appendix V	37 drill core samples from drill holes across the strike length of the deposit. Samples selected randomly from pieces of broken core over the designated intervals (1-15 m). Average sample length approximately 8 m. These samples were then composited into 5 lithological composite samples.	<p><u>Individual Samples (n=37):</u></p> <ul style="list-style-type: none"> <li>• ABA (NP via Sobek method, Modified AP via sulphide sulphur content)</li> <li>• ICP metals, specific method not indicated.</li> <li>• Whole Rock (major element) analysis</li> </ul> <p><u>Lithological Composites (n=5):</u></p> <ul style="list-style-type: none"> <li>• ICP metals, specific method not indicated.</li> <li>• Whole rock (major element analyses)</li> <li>• Leachate extraction at 5:1 liquid:solid, in distilled deionized water, analyzed for pH, SO<sub>4</sub>, ICP metals.</li> </ul>	<p><u>Individual Samples:</u> ABA results and select ICP parameters incorporated into stats database</p> <p><u>Lithological Composites</u> were not incorporated into this report</p>
1997	BYG Natural Resources Inc.	1997 Annual Report Water Licence QZ94-004 (Feb/98), Appendix 8.	13 samples from Brown McDade pit walls, and 14 samples from toe of the westernmost advance of the waste rock pile	<ul style="list-style-type: none"> <li>• ABA via modified method</li> <li>• ICP metals via ICP AES</li> </ul>	ABA results and select ICP parameters incorporated into stats database

Year	Agency/Firm	Reference	Sampling	Testing and Method	Incorporation into this Report
1999	Conor Pacific Environmental Technologies Inc.	Mount Nansen Minesite – Historical Review, Site Assessment, and Field Sampling Program. Final Report Version 2	6 sites in Brown McDade pit, one sample taken from each site	<ul style="list-style-type: none"> <li>• ABA via modified method</li> <li>• Solids analysis for metals via ICP AES</li> <li>• Leachate extraction via Modified SWEP, with pH and metals via ICP-AES</li> </ul>	ABA results and select ICP solids and leachate extraction parameters incorporated into stats database
2007	Yukon Government, Assessment & Abandoned Mines	Internal memo <i>Nansen 2007 ARD.pdf</i>	6 samples from North West waste rock pile	<ul style="list-style-type: none"> <li>• ABA and solids analysis on non-screened sample (not fines fraction)</li> <li>• ABA via modified method</li> <li>• Solids analysis using ICP metals via ICP OES and digestion using 1:1 nitric acid and hydrochloric acid</li> <li>• Leachate extraction via TCLP, with pH and metals via ICP-OES</li> <li>• Moisture content, soil conductivity and pH</li> </ul>	All ABA results, ICP solids, and TCLP metals and final pH incorporated into stats database
2008	Altura Environmental Consulting	---	<ul style="list-style-type: none"> <li>- Installation and rock sampling of two 12-15 m<sup>3</sup> lysimeters (monitoring to commence in 2009)</li> <li>- Excavation and sampling of 21 test pits</li> <li>- Seep identification and preliminary sampling</li> </ul>	<ul style="list-style-type: none"> <li>• Solids analysis on -1/4" (0.6 mm) fraction as a standard method.</li> <li>• 48 ABA via modified method</li> <li>• 49 metal solids analysis via ICP-MS</li> <li>• 27 leachate extraction via 3:1 24h Shake Flask Extraction (SFE), with pH, general parameters. Metals via ICP-MS</li> <li>• Moisture content (n=16), grain size analysis (n=7)</li> </ul> See Appendix A for further detail	All results incorporated into this report



- Sample Symbols**
- △ Waste Rock Pit or Surface Sample
  - ◊ Waste Rock Lysimeter
  - 🌿 Waste Rock Seep
  - \* Physical Properties Sample
  - 1999 Conor Pacific Sample
  - 1997 BYG Sample

- Other Symbols**
- Contour (5m Interval)



**Mount Nansen Mine Site**  
**Brown McDade Waste Rock Pile**  
**Figure 5.1 Geochemistry Sample Sites**  
 Rev : February 1, 2009  
 By : DL/RS

i)



ii)



*Photo 5a Lysimeter Installation, First Steps: i) sand and geofabric underlay, lysimeter L1; ii) backfilling over geomembrane liner at lysimeter L2, showing riser pipe and 10 cm diameter collection drainpipe.*

i)



ii)



*Photo 5b Lysimeter Installation, Final Steps: i) liner trimmed and backfilling partially complete, lysimeter L1; ii) installation complete, lysimeter L1.*



*Photo 5c Naturally colonizing willow species on the top of the South Pile.*



*Photo 5d Test pit excavation, pit TP-1 on the Northwest Pile.*

### 5.2.1 Lysimeter Installation

The lysimeters are essentially buried bathtub'-like structures designed to intercept and collect water infiltrating into the waste rock pile. A simple shallow lysimeter design (less than 1.0 m depth) was selected in order to best ensure that some amount of infiltrating water would be collected during the spring 2009 snowmelt period.

Two shallow lysimeters were installed, one on the Northwest Pile and one on the West Lower Pile. Site L1, on the Northwest Pile, was selected as a potentially anomalous zone, as it was noted to have heavy iron oxide stain, and field pH tests in the vicinity measuring from 3 to 6. Site L2 on the West Lower Pile was selected as more indicative of typical waste rock quality.

Full details of the lysimeter installation methodology are presented in Appendix A, and selected photographs are given in Photos 5a and 5b. Table 5.2 summarizes the location and key dimensions of the installations.

Table 5.2 *Dimensions of Lysimeters, Brown McDade Waste Rock Pile*

Site	Coordinates (NAD 83 UTM)	Estimated Liner Area (m <sup>2</sup> )	Estimated Volume of Contained Waste Rock (m <sup>3</sup> )	Estimated Mass of Contained Waste Rock (t) <sup>1</sup>
Lysimeter L1 – Northwest Pile	388766 E 6881664 N Elev. 1237 m	26.6	15	22
Lysimeter L2 – West Lower Pile	388712 E 6881457 N Elev. 1218 m	17.5	12	18

<sup>1</sup> assuming bulk density of 1.5 t/m<sup>3</sup> – looser than typical waste rock piles at 1.7-1.8 t/m<sup>3</sup>

## 5.3 Results: Physical Characteristics

### 5.3.1 Heterogeneity and Compaction

Waste rock in the piles tends to be highly variable in grain size, texture, colour and lithology. As seen in the example test pit photographs (Photos 5e and 5f), much of the material is soil-like in texture with variably-size rock fragments and blocks interspersed throughout. Geochemically, the stored material can vary substantially within a few metres' distance, as demonstrated in photo 5e.

With the exception of main haul road routes, only the upper 10 to 20 cm of waste rock piles platform surfaces were found to have any notable degree of compaction.



*Photo 5e Example of physical and geochemical variability in the waste rock pile, test pit TP-9, South Pile, and TP-19, West Lower Pile. Both pits are 1 metre in depth.*

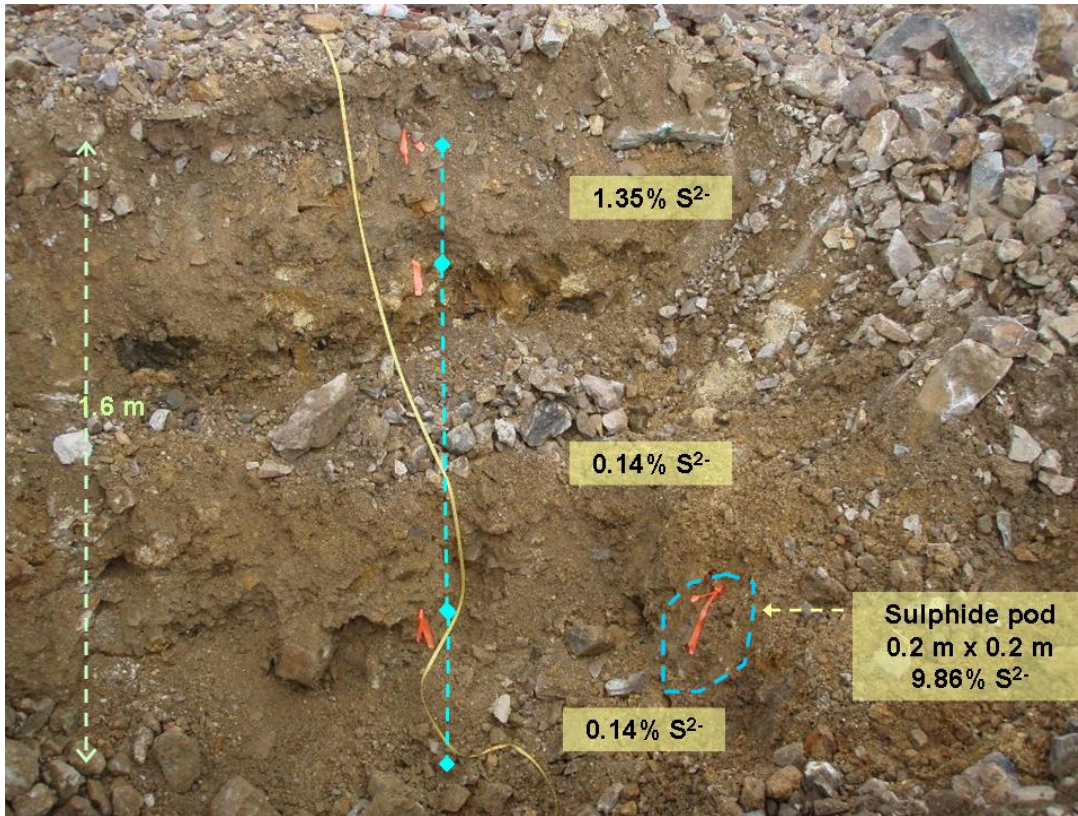


Photo 5f Example of physical and geochemical variability in the waste rock pile, test pit TP-4, Northwest Pile.

### 5.3.2 Saturation and Moisture Content

No water or saturated zones were encountered in any of the excavated test pits. One notably moist zone was encountered at 1.0 m depth in pit TP-10, and returned a moisture content of 13.0wt%. The fifteen other moisture content samples from various areas of the waste rock pile ranged from 5.3 to 11.1wt%, with an average of 9.2wt%.

The highest moisture content values in the test pits are observed from 0.4 to 0.8m depth, as shown in Figure 5.2.

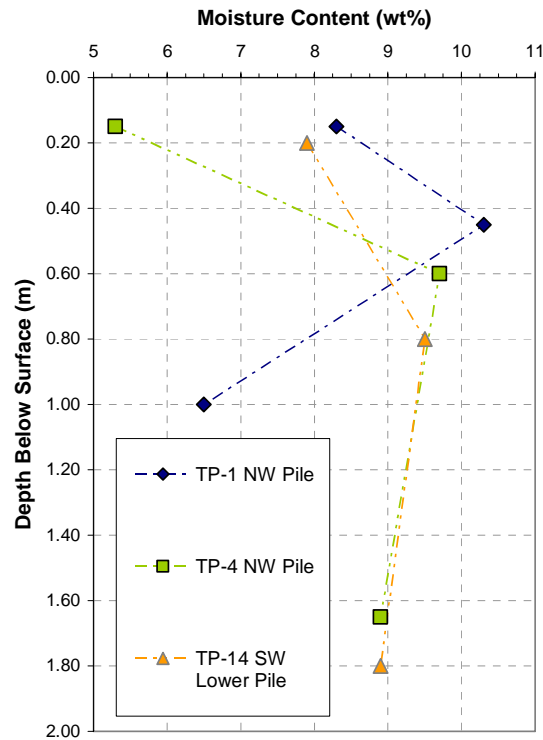


Figure 5.2 Moisture content profiles in test pits, September 2-3, 2008

### 5.3.3 Grain Size Distribution and Estimated Particle Surface Area

Particle size distribution for the seven waste rock pile samples (each comprised of fragments and particles less than approximately -3”) is shown in Figure 5.3. Approximately half of the sample weight is comprised of particle sizes less than 10 mm size.

Grain 3.0<sup>®</sup>,<sup>TM</sup> (from MDAG Publishing at [www.mdag.com/grain30.html](http://www.mdag.com/grain30.html)) was used to calculate particle surface area. Results indicate a particle surface area range from 4.4 to 9.5 m<sup>2</sup>/kg.

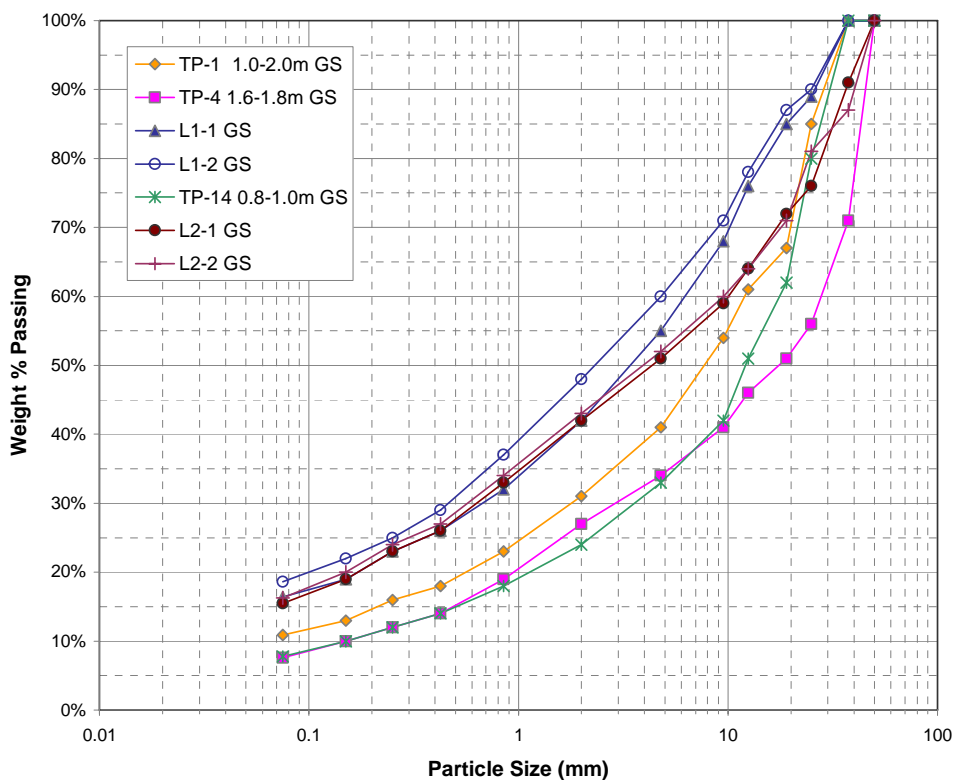


Figure 5.3 Particle size distribution of waste rock pile samples

## 5.4 Results: Geochemical Characteristics

An overview of results with respect to acid base accounting, solids geochemistry, and leachate extraction analyses is briefly presented in the following sections.

In order to assist with development of a waste rock management and decommissioning plan, an equally important aspect discussed is the correlating and/or controlling relationships between the geochemical characteristics and the geological and spatial characteristics of the stored waste rock. Sections 5.5 and 5.6 give a synthesis of results with respect to key comparisons, and fundamental relationships related to net acidity and/or metal leaching.

### 5.4.1 Acid Base Accounting

Since the year 1989 a total of 135 Brown McDade waste rock samples have been analysed for acid base accounting (ABA) parameters. ABA analyses are typically used for a screening tool intended to provide a quantitative determination of the balance between acid-producing (sulphide) and acid consuming minerals of a rock or soil sample. The sample's paste pH and paste conductivity also provide a simple measure of the readily soluble products in the rock.

Care must be taken when comparing and using data from different studies and time periods, since ABA methods do vary slightly, and have changed somewhat over the years. In addition, sampling source and sampling method also need to be carefully considered in any interpretation of results. In the case of the Brown McDade samples, a key sampling factor is that only the 2008 samples analysed the minus ¼” fraction of waste rock, in order to get better representativity of the higher surface area (and hence more reactive) particles. Secondly, it is important to keep in mind that for the purposes of determining the existing state of the rock stored in the waste rock piles, the 2007 and 2008 sampling data is the most relevant as only these samples are representative of waste rock subjected to ambient pile conditions for 8+ years.

All sampling data since 1989 are presented in Appendices A and B, along with comparative statistical illustrations by year and by sample type. Where relevant, historical data is incorporated into the analysis discussed in this section.

Table 5.3 summarizes overall acid base accounting characteristics of the waste rock samples, using the -¼” fraction analyses carried out in 2008. Complete acid base accounting results and statistics for 2008 tabulated in Appendix A, along with graphical representations of the database with respect to geological factors, waste rock pile sector, and other parameters.

Overall, neutralization potential of the waste rock pile samples tends to be low to moderate, with a median value of 29.0 mg CaCO<sub>3</sub>/t. Most samples were assigned a hydrochloric fizz rating of “Slight” (showing only a trace of effervescence). Mann (pers. comm.) reported that waste rock from deeper in the pit tended to have more preserved carbonate, and thus higher neutralization potential. While likely the case, the trend is difficult to discern in the historical data, likely in part due to both the patchiness of oxidation the lower pit extents, and the longer sampling intervals incorporated in earlier testing.

Median total sulphur in the 2008 sample set is 0.57%. It is worthwhile to note that this median value is significantly higher than the 0.33% median value of the 1994 pre-operation test work dataset. This may be are result of several factors: i) the pre-operational testing may not have considered as deep sectors of the Brown McDade pit as was actually excavated, ii) the 2008 testing ensured that anomalous rock was tested in order to determine geochemical variability while the 1994 test work attempted to identify ‘average’ conditions, and iii) sulphur concentrations may tend to be slightly higher the – ¼” fraction material.

Percent sulphur oxidation (determined by the ratio of sulphate to total sulphur) showed great variability in the dataset, but overall with about half of the total sulphur in the form of sulphide. Nonetheless, as indicated by the low median sulphide value of 0.15%, half of the samples tested in 2008 have negligible sulphide content, and in turn, low to nil potential for net acidity. Although present, elevated sulphide samples occur only sporadically in the dataset (see Figure 5.4).

Table 5.3 Summary Statistics of Acid Base Accounting Parameters for -¼" Fraction of Waste Rock (2008 Samples)

Statistic	Paste pH	Paste Conductivity (µS/cm)	Total Inorganic Carbon (%)	NP via Carbonate (kgCaCO <sub>3</sub> /t)	Total S (%)	Sulphate (%)	Sulphide (%)	% Sulphur Oxidation	Acid Potential (kgCaCO <sub>3</sub> /t)	Neutralization Potential (kgCaCO <sub>3</sub> /t)	Net Neutralization Potential (kgCaCO <sub>3</sub> /t)	Neutralization Potential : Acid Potential
No. of samples	48	48	48	48	48	48	48	48	48	48	48	48
Minimum	3.94	135	<0.01	0.8	<0.01	<0.01	<0.01	6%	<0.3	-3.0	-311.1	-9.33
Maximum	8.41	2090	0.72	60.0	10.50	1.21	9.86	115%	308.1	59.8	57.9	166.00
1st Quartile	7.36	294	0.11	9.4	0.11	0.05	0.04	40%	1.2	11.7	4.6	1.59
Median	7.71	1389	0.34	27.9	0.57	0.20	0.15	55%	4.5	29.0	15.5	4.14
3rd Quartile	8.08	1626	0.47	39.0	1.04	0.62	0.41	77%	12.7	36.3	27.5	13.67
Mean	7.49	1030	0.31	25.4	0.86	0.36	0.51	59%	15.8	25.5	9.8	15.84
Standard deviation	0.94	667	0.20	16.9	1.53	0.35	1.43	0.28	44.6	16.0	49.8	31.25
Geometric mean		756	0.18	15.0	0.34	0.17	0.12	50%	3.9			
Geom. Standard deviation		2	3.91	4.0	4.78	4.23	5.60	1.96	5.6			

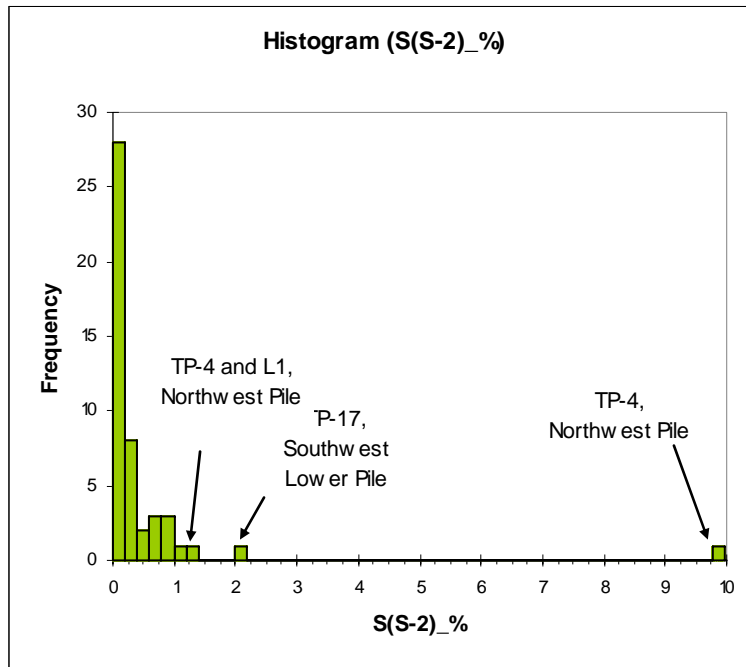
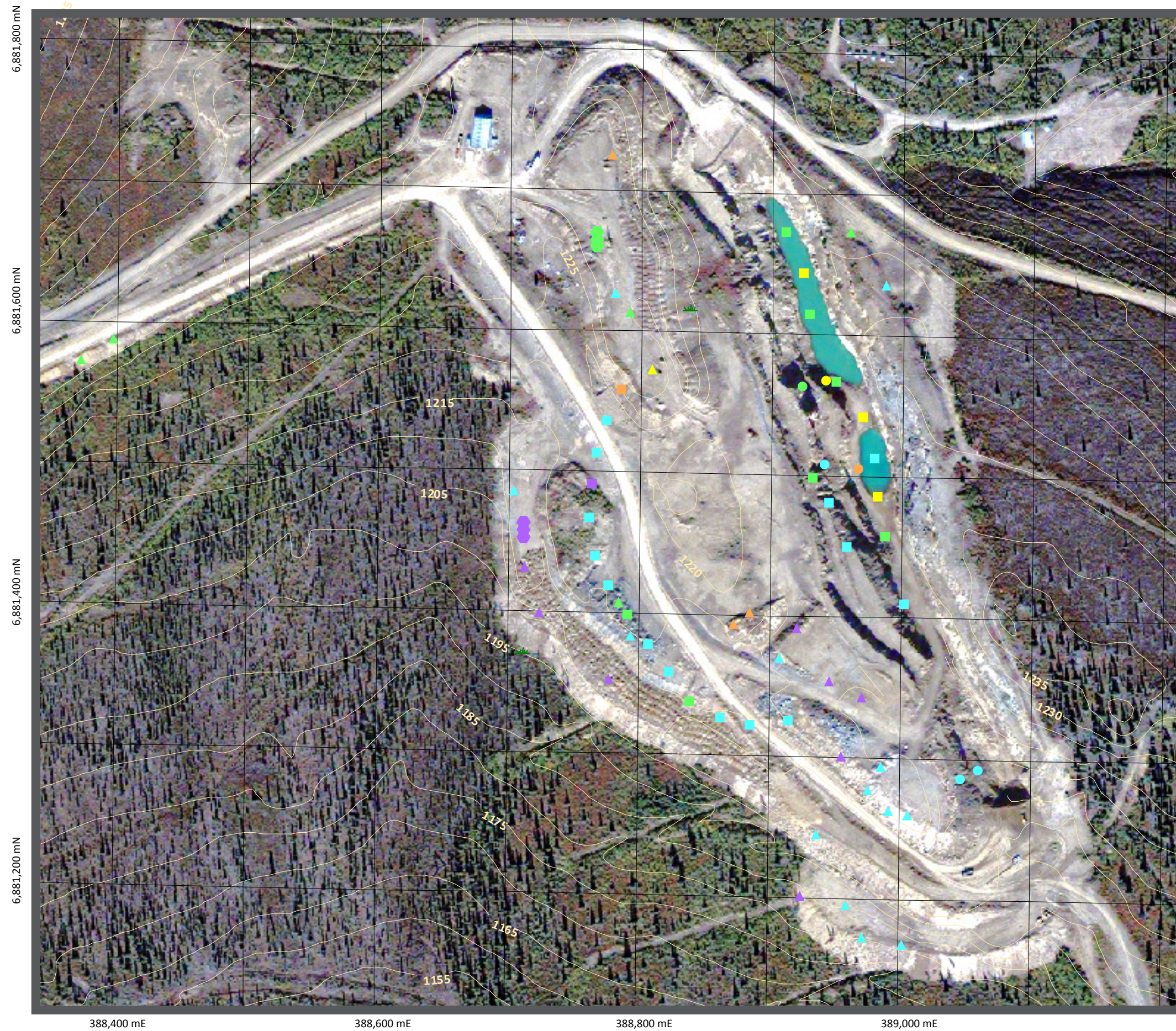


Figure 5.4 Frequency Distribution of Sulphide in the 2008 Waste Rock Samples (n=48)

Select acid base accounting parameters (paste pH and Neutralization Potential to Acid Potential Ratio) for waste rock pile and pit samples are shown on photo maps in Figures 5.5 and 5.6.

Four of the 48 samples tested have net acidic pH (less 6.5). Two of the four samples were from the ore stockpile, and the other two from the Northwest Pile. All other samples have paste pH values of over 7.1.



**Sample Symbols**

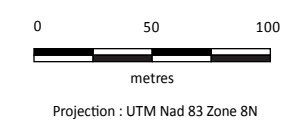
- △ Waste Rock Pit or Surface Sample
- ◊ Waste Rock Lysimeter
- ▲ Waste Rock Seep
- \* Physical Properties Sample
- 1999 Conor Pacific Sample
- 1997 BYG Sample

**Other Symbols**

- Contour (5m Interval)

**Colour Symbols**

- Alkaline [  $\geq 8$  ]
- Weakly Alkaline [ 7.5 - 7.99 ]
- Neutral [ 6.5 - 7.49 ]
- Weakly Acidic [ 5.5 - 6.49 ]
- Acidic [  $< 5.5$  ]



**Mount Nansen Mine Site**  
**Brown McDade Waste Rock Pile**  
**Figure 5.5 Paste pH of Rock Samples**  
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 By : DL/RS



**Sample Symbols**

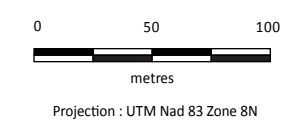
- △ Waste Rock Pit or Surface Sample
- Waste Rock Lysimeter
- ▲ Waste Rock Seep
- \* Physical Properties Sample
- 1999 Conor Pacific Sample
- 1997 BYG Sample

**Other Symbols**

- Contour (5m Interval)

**Colour Symbols**

- Non-Acid Generating [  $\geq 3$  ]
- Uncertain Acid Generating Potential (Higher Range) [ 2 - 2.99 ]
- Uncertain Acid Generating Potential (Lower Range) [ 1 - 1.99 ]
- Potentially Acid Generating [  $<1$  ]



**Mount Nansen Mine Site**  
**Brown McDade Waste Rock Pile**  
**Figure 5.6 NP:AP Ratio of Rock Samples**  
 Rev : February 1, 2009  
 By : DL/RS

### 5.4.2 Solids Analysis for Metals

Summary results for metals in waste rock are given in Table 5.4. The tabulated statistics consider all 1989 to 2008 samples for Ag, As, Ca, Cd, Cu, Pb, Sb, and Zn (n=125), and 2007 and 2008 data for other elements (n=55).

Of particular note is the elevated median zinc concentration for this dataset (1201 ppm). As noted by Mann (1997), rock and soil in the Mount Nansen area are commonly enriched in this element. Figure 5.7 shows zinc values in the waste rock pile and pit samples.

Table 5.4. Summary Statistics of ICP Metals Analysis for Waste Rock, 1989 to 2008 Samples

Statistic	Ag (ppm)	Al (%)	As (ppm)	Ca (%)	Cd (ppm)	Cu (ppm)	Fe (%)
No. of samples	125	55	125	125	125	125	55
Minimum	0.1	0.26	5	0.06	0.1	3	1.02
Maximum	381	1.65	9280	3.32	175	22846	10.00
Median	2.0	0.58	218	1.12	13	98	3.43
Mean	8.1	0.69	617	1.14	18	346	3.63
Standard deviation	34	0.32	1218	0.64	21	2039	1.44
Geometric mean	2.27	0.62	221	0.90	10	88	3.40
Geometric standard deviation	4.21	1.56	4.29	2.23	3.57	3.64	1.44

Statistic	K (%)	Mg (%)	Mn (ppm)	Na (%)	Pb (ppm)	Sb (ppm)	Zn (ppm)
No. of samples	55	55	55	55	125	125	125
Minimum	0.09	0.01	83	0.01	11	1	50
Maximum	0.54	1.14	10300	1.06	12524	1336	10380
Median	0.17	0.24	2175	0.01	243	19	1201
Mean	0.21	0.27	2316	0.03	503	57	1601
Standard deviation	0.10	0.22	1549	0.14	1186	140	1650
Geometric mean	0.19	0.19	1832	0.01	212	17	1032
Geometric standard deviation	1.49	2.57	2.28	2.00	3.77	4.99	2.73

### 5.4.3 Leachate Extraction Analyses

Summary results for leachate extraction for the 2008 waste rock samples are given in Table 5.5. Although some leachate extraction tests were conducted in other years (1999 and 2007), for summary statistical purposes these results were not considered because of higher detection limit used (1999 samples) and substantial differences in methodology (2007 samples).

Of the 27 samples, only four samples produced acidic leachate. A sample, taken from an approximately 0.2x0.2 m soft sulphide-rich pod in the Northwest Pile (see Photo 5f) produced the most acidic leachate at pH 2.96. The two samples taken from ore stockpile area produced leachate in the order of pH 5. A sample from test pit TP-1 in Northwest Pile had slightly acidic leachate pH of 6.38.

Calcium and sulphate were the major ions present in the leachate solutions. Of the heavy metals, only zinc tended to show the most elevated loadings, but nonetheless it is very important to note that only the acidic-leachate samples show elevated loadings – all 23 of the neutral to alkaline-leachate samples reported low zinc loadings of less than 1.0 mg/kg.

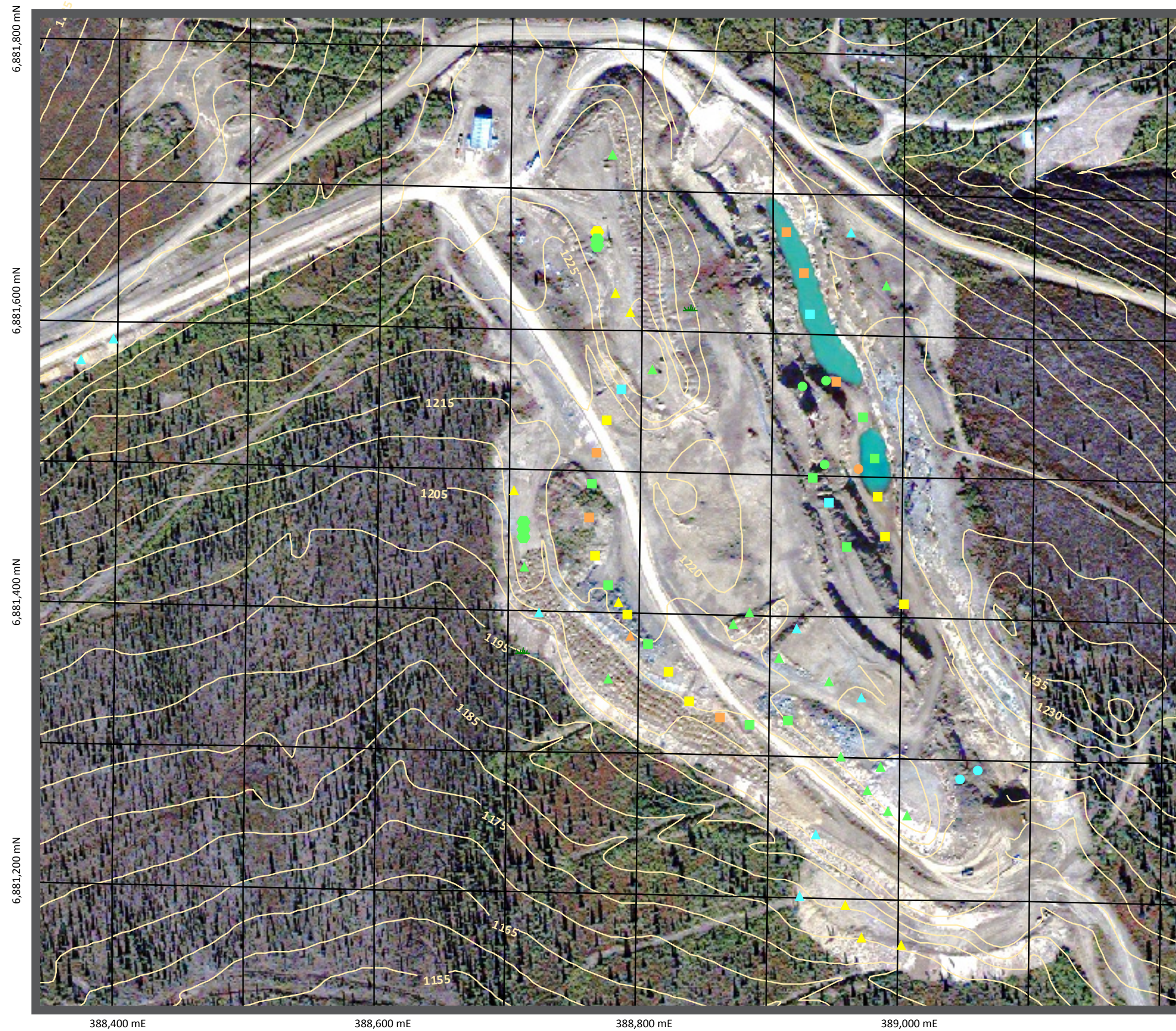
Table 5.5 Summary Statistics of Leachate Extraction Tests for Waste Rock, 2008 Samples<sup>1</sup>

Statistic	pH	Total Acidity (mg CaCO <sub>3</sub> )	Total Alkalinity (mg CaCO <sub>3</sub> )	SO <sub>4</sub> (mg)	Hardness (mg CaCO <sub>3</sub> )
No. of samples	27	27	27	27	27
Minimum	2.96	5.2	-0.7	9	68.4
Maximum	8.12	1350.0	225.3	5352	5760
Median	7.62	13.0	110.6	852	828
Mean	7.28	64.2	123.0	1645	1771.6
Standard deviation	1.19	252.4	77.3	1828.5	1817.4
Geometric mean	7.14	14.3		428	896
Geometric standard deviation	1.25	3.0		9.0	3.7

Statistic	Al	Sb	As	Cd	Ca	Cu	Fe	Pb
No. of samples	27	27	27	27	27	27	27	27
Minimum	0.00	0.00	0.00	0.00	20.76	0.00	0.00	0.00
Maximum	38.70	0.12	0.09	1.58	1848.00	4.59	84.30	0.19
Median	0.03	0.00	0.02	0.00	239.40	0.00	0.02	0.00
Mean	1.49	0.01	0.03	0.07	591.99	0.21	3.14	0.01
Standard deviation	7.30	0.02	0.02	0.30	624.74	0.87	15.92	0.04
Geometric mean	0.04	0.01	0.02	0.00	275.74	0.01	0.02	0.00
Geometric standard deviation	5.42	2.98	3.16	12.90	3.96	7.27	6.19	5.45

Statistic	Mg	Mn	K	Si	Ag	Na	Zn
No. of samples	27	27	27	27	27	27	27
Minimum	3.99	0.00	0.57	1.90	0.00	0.54	0.00
Maximum	276.90	217.80	21.12	16.74	0.03	10.05	85.50
Median	38.70	0.01	9.72	5.64	0.00	1.38	0.04
Mean	71.10	10.37	9.72	6.05	0.00	2.06	4.36
Standard deviation	74.24	41.31	4.51	2.79	0.01	2.15	16.32
Geometric mean	41.03	0.04	8.31	5.52	0.00	1.52	0.09
Geometric standard deviation	3.08	35.72	1.99	1.55	6.75	2.03	15.34

<sup>1</sup> Except for pH, all loading values in table are in mg of constituent in aqueous form released per kilogram of sample.



**Sample Symbols**

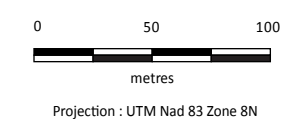
- △ Waste Rock Pit or Surface Sample
- ◊ Waste Rock Lysimeter
- ▲ Waste Rock Seep
- \* Physical Properties Sample
- 1999 Conor Pacific Sample
- 1997 BYG Sample

**Other Symbols**

- Contour (5m Interval)

**Colour Symbols**

- 0 - 499 ppm
- 500 - 1499 ppm
- 1500 - 2499 ppm
- ≥ 2500 ppm



**Mount Nansen Mine Site**  
**Brown McDade Waste Rock Pile**  
**Figure 5.7 Zinc Concentrations of Rock Samples**  
 Rev : February 1, 2009  
 By : DL/RS

#### 5.4.4 Other Results

##### *Construction Rock*

Two potential sites were reviewed for geochemical suitability for competent construction rock for applications such as rip rap, crush, or filter material: i) free dump piles on the West Lower Pile platform, and ii) free dump piles on the West Mid Pile platform. In these areas, competent to slightly fractured cobble to large boulder material has been placed on the rock pile platform (see Photos 5g and 5h). Five sample sites were selected and both a 'Coarse' (consisting of chip samples from larger cobbles and boulders), and a 'Fine' (pebble to silt fraction-size material accumulating in void spaces) sample was taken from each site. The location of these sites is shown in Figure 5.1 as samples LW-Fine-01 through 03 and W-Fine-01 and 02. Complete results are presented in Appendix A.

The rock on the West Mid Pile is weakly altered granodiorite (propylitic alteration) with occasional silicified fragments, and likely originates from the footwall area of the Brown McDade pit. This material covers an approximately 1000 m<sup>2</sup> area, and a small amounts of similar material are also located on the South Pile. A trace amount of sulphide minerals was observed, mainly as pyrite and chalcopyrite on fractures. Although by appearances this material seemed a good candidate for use in construction, upon analysis sulphide values were found to range from 0.13 to 1.51%, with all results from the two sample sites yielding a neutralizing to acid potential ratio (NP:AP) of 2:1 or less. The leachate extraction test performed on one of the fine fraction samples indicated zinc loading of 0.6 mg/kg, which while not elevated to a level of concern, is high relative to that typically found in Brown McDade waste rock, and would likely preclude use of this material for sensitive applications.

The rock on the West Lower Pile covers an approximately 5,000 m<sup>2</sup> platform area and is variably altered massive porphyry and/or other fine-grained intrusive and granodiorite, with some rocks highly fractured and healed over with quartz. The rock appears to be overall of low sulphide content, but tends to be more prone to fracturing, and contains more fines than that on the West Mid pile. Occasional pods and piles of obviously sulphidic material are noted amongst the rock piles on this platform, particularly towards the southeast. Results of sampling from two of the three sites produced very favourable results with sulphide concentrations ranging from 0.01 to 0.06% and an NP:AP ranging from 21.8 to 269, well exceeding the 3:1 or 4:1 screening criteria often applied to construction material. At the third sample site, some fine-grained pyrite was observed in boulders and cobbles as pod-like inclusions and along fractures. Analyses from this site produced mixed results with the coarse sample yielding elevated sulphide concentration of 0.38% and an NP:AP of 1.6, while fines from the same area had favourable results similar to those from the other two sites. Leachable metals from this site were low for both fine and coarse samples.

Overall, rock on West Lower Pile shows promise as source for construction material, nonetheless the sporadic occurrence of sulphidic material within this site is a significant issue. Due to elevated sulphide content, the material stacked on the West Mid Pile is of concern for general construction use, although there may suitable application if this rock is left in its coarse form and not used in water management-related works. Further reconnaissance and sampling of both potential sites is considered necessary.



Photo 5g Coarse rock on West Mid Pile



Photo 5h Coarse Rock on West Lower Pile

### *Haul Road Berms and Slopes*

Several zones of prominently bleached and yellow-weathered rock can be observed on berms and slopes of the haul road connecting the Brown McDade waste rock pile area and the mill site, as shown in Photo 5i. Near-surface samples were taken from two such zones in 2008. Results indicate a highly leached but neutral material: total sulphur and sulphide at detection limit levels, and paste pH from 7.1 to 7.2. No leachate extraction tests were conducted in this phase. It is recommended that additional field reconnaissance be systematically conducted to determine if there is potentially more reactive material below the surface, and through field paste pH measurements identify any zones of net acidity.



*Photo 5i Bleached zone along berms and slope of haul road west of the waste rock pile*

### *Ore Stockpile*

Results of two samples taken from the small remaining ore stockpile area (samples OS-1-1 and OS-1-2; see Figure 5.1 for site location) indicate that the rock is net acidic and contains high levels of soluble zinc. Of concern is that as noted in section 4.3.1, runoff from this pile this pile accumulates in a nearby low spot (Ponding Area A), and as a result any water not evaporated infiltrates into the rock pile. Possibly linked with this site is the occurrence of LW-Seep-01, approximately 150 m to the west, which has a slightly acidic pH of 5.7 and a rust to orange gelatinous precipitate.

## 5.5 Relationships Related to Net Acidity and/or Metal Leaching

Results of the various geochemical sampling programs on the Brown McDade waste rock indicate that with the exception of the ore stockpile and sporadic zones in the rock piles, the stored waste rock is producing neutral to alkaline products.

The results also indicate that if localized net acidity is present, solubilization of zinc to anomalous levels will likely occur. This can be illustrated in the 2008 and 1999 leachate extraction data, as shown in Figure 5.8. All samples with acidic paste pH tend to have zinc loadings of over 5 mg/kg. The neutral to alkaline-pH samples show only a minor degree of zinc solubilization. From this relationship, it is concluded for the purposes of waste rock management that there is a strong likelihood that Brown McDade waste rock sectors with acidic paste pH have anomalous soluble zinc levels. This conclusion is also logical in light of the overall elevated concentrations of zinc in the waste rock.

The figure also indicates that samples in the waste rock pile that are net acidic tend to have total sulphur contents in the order of 1 percent or higher. It can also be observed this same figure that there are several samples with similarly elevated total sulphur that are not producing net acidity at this time. When the degree of oxidation is shown on a similar plot, as in Figure 5.9, it can be seen by the red-marked points that there are several relatively unoxidized samples with elevated total sulphur. Depending on rock competence and site factors, in time, some of these samples may ultimately generate a degree of net acidity, and with it, solubilization of zinc.

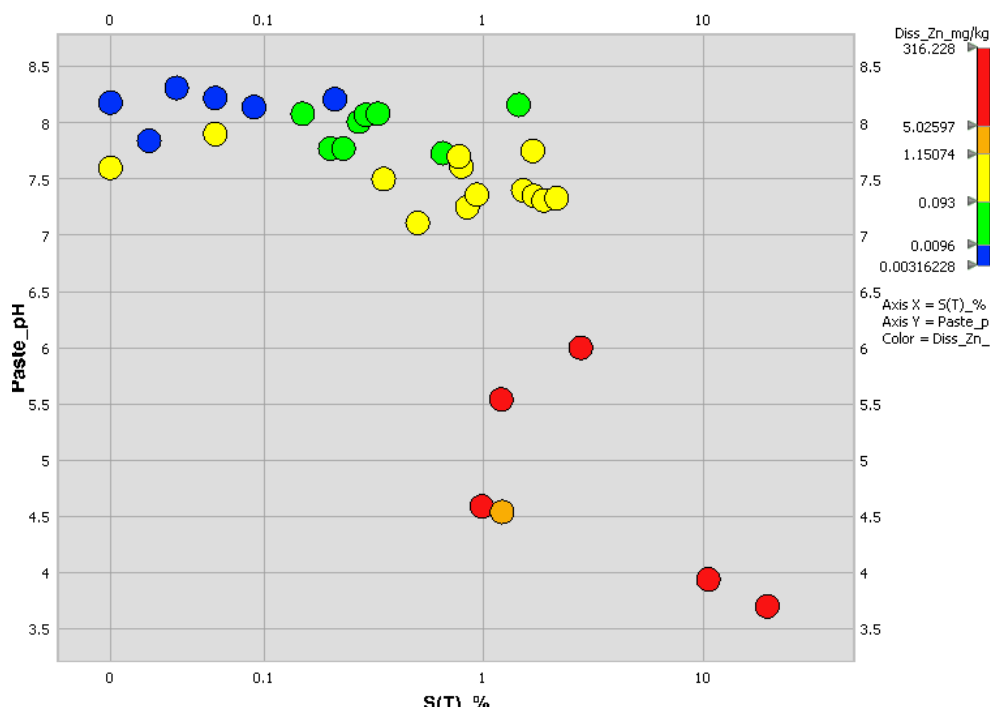


Figure 5.8 Paste pH versus Total Sulphur for the 1999 and 2008 Leachate Extraction Analyses, and Zinc Loading. Colour of the points indicates the amount of zinc loading in mg/kg, with orange and red colours greater than 1 mg/kg.

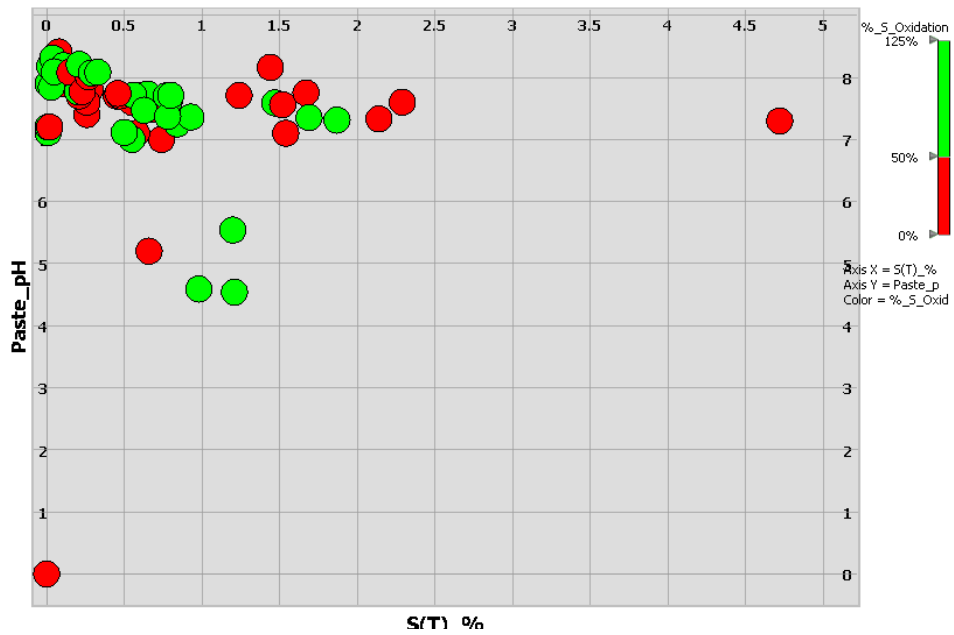


Figure 5.9 Paste pH versus Total Sulphur for the 1997, 2007 and 2008 Waste Rock Pile Samples, with Depiction of Percent Sulphur Oxidation. Colour of the points depicts the percentage of total sulphur as sulphate, with red indicating 50 percent or less sulphate (hence more sulphide).

## 5.6 Definition of Marginal Samples

As discussed in section 5.5, with the exception of a small sample subset from the ore stockpile and from sporadic zones in the rock piles, the sampling indicates that the stored waste rock is producing neutral to alkaline products.

Although it is highly unlikely that a large-scale net acidity issue will ever occur, with the elevated zinc signature of the Brown McDade waste rock, wherever there is localized net acidity there is some potential for zinc solubilization issues. Results have confirmed that zinc solubilization is currently occurring where there are pods or 'pockets' of net acidic waste rock.

Results also show that a certain number of neutral-pH samples are relatively unoxidized and have elevated sulphur content. This indicates that in time, some of these samples may ultimately generate a degree of net acidity, and with it, solubilization of zinc.

For this reason it is important to define working criteria for samples that are 'Marginal', that is to say both those samples that are now generating net acidity, and those that although may not be generating net acidity at this time, are viewed to have significant potential to do so in the future. Once these Marginal samples are identified in the database, the characteristics and location of these individual samples can be examined. From this, potential field identification and management methods may be determined.

Based on the previous analysis, the working criteria for Marginal samples have been adopted as follows:

- *Elevated Total Sulphur and with Low Degree of Oxidation:* total sulphur  $\geq 0.50\%$  and 50% of total sulphur oxidized to sulphate; or
- *Net Acidity:* paste pH less than 6.5

Figure 5.10 shows the working criteria applied to all waste rock pile samples (1997, 2007, and 2008, n=69).

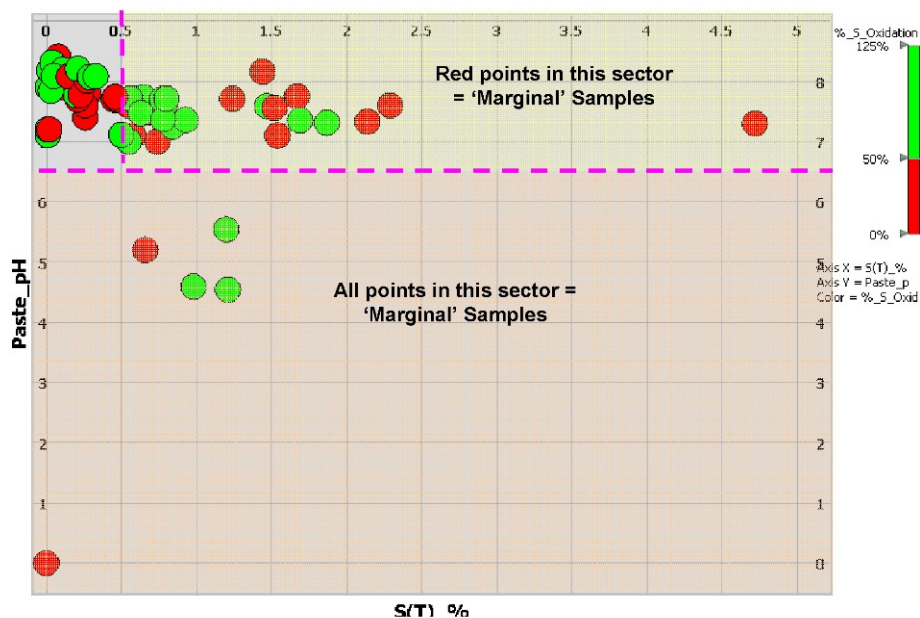


Figure 5.10 Paste pH versus Total Sulphur for the 1997, 2007 and 2008 Waste Rock Pile Samples, with Depiction of Percent Sulphur Oxidation and Areas of 'Marginal' Samples.

When the working criteria are applied to the 69-sample waste rock pile database, 20 samples are identified as Marginal. On reviewing information such as rock type, mineralogy, and waste rock pile sector, the following tendencies for these Marginal samples are observed:

- Rock Type: where it was possible to identify original rock type in the waste rock sample, most Marginal samples tend to contain a notable proportion of altered and fractured porphyry fragments (eg. 20% or more);
- Sulphide Minerals: most samples have at least a trace of observable sulphide minerals (pyrite or other);
- Location: as detailed in Table 5.6, a greater percentage of Marginal samples tend to occur in the Northwest Pile, South Pile, Southwest Lower Pile, and Ore Stockpile.

Table 5.6. Distribution by Sector of Brown McDade Marginal Waste Rock Samples (using 1997, 2007, and 2008 samples, n=69). Sectors with 30 percent or more Marginal samples shown in gray shading.

<b>Sector</b>	<b>Total # of Samples</b>	<b># of Marginal Samples</b>	<b>% Marginal Samples</b>
<i>Total</i>	69 <sup>1</sup>	20	29%
East Pile	2	0	0%
Haul Road Berms	2	0	0%
Northwest Pile	21	9	43%
Ore Stockpile	2	2	100%
South Pile	10	3	30%
Southwest Lower Pile	8	3	38%
Southwest Upper Pile	1	0	0%
West Lower Pile	7	0	0%
West Mid Pile	16	3	19%

<sup>1</sup> ICP sulphur value (1.17%) used for sample TP-15 0.3m.

## 6.0 Conclusions and Recommendations

### 6.1 Conclusions

#### 6.1.1 Current Status of Waste Rock Pile and Correlation with Previous Studies

This study confirms the overall conclusions of previous reviews and studies (Conor Pacific, 2000, Mann, 1997, and T.W. Higgs, 1994) – that there is no large scale net acidity issue occurring in the Brown McDade waste rock. Furthermore, due to the generally low sulphide content and weathered nature of the material, it is considered highly unlikely that a large-scale net acidity issue will ever occur in the Brown McDade waste rock pile.

Nonetheless, waste rock geochemistry as well as seep monitoring indicates that zinc solubilization is a factor that requires consideration and management during the decommissioning of the waste rock piles. This issue was not recognized in the 1994 and 1997 studies. While metal solubilization is noted in pit samples analysed by Conor Pacific, their report does not specifically discuss its implications or effects with respect to the Brown McDade waste rock pile.

#### 6.1.2 Effects to Receiving Environment

Evidence to date indicates that there is some, but very little migration of rock pile ‘contact water’ to the receiving environment. Reconnaissance in fall of 2008 indicated few instances of ponding areas where net infiltration was or had recently occurred in the rock pile and two instances where water could be observed exiting the rock pile toe to the receiving environment. One of these seepage sites did have slightly acidic field pH (5.7); however the site appeared to be either a new or very intermittent drainage. The observation of relatively few seepage sites is consistent with the site climatic conditions where average annual evaporation exceeds that of precipitation. In addition, the rock pile is favourably sited on a small ridge, and is thus effectively isolated from surface water inflows from other sources. The depth to groundwater is estimated in previous studies (Gartner Lee, 2008) to be in the order of ten meters in the area of the west rock pile toe, and several tens of metres in other area. Note that as mentioned in section 6.2.2, additional seep and surface ponding reconnaissance is recommended for 2009 to provide further verification as to receiving environment effects, and as possible identify potential source areas of the seeps.

#### 6.1.3 Net Acidity and Metal Leaching Characteristics

Geological and geochemical evidence support the overall conclusion that the rock excavated later in the mine life from the deeper sectors of the Brown McDade pit is the most problematic in terms of producing localized areas of net acidity, and contributing to metal enrichment of any infiltrating water. Geochemistry and rock pile construction history also support the conclusion that the Northwest, South, and Southwest Lower Piles contain higher proportions of this Marginal material than other sectors.

Most if not all of the small remaining Ore Stockpile is net acidic and requires specific management, as indicated in Table 6.1 in the following section.

#### **6.1.4 Segregation of Material**

Overall, the material in the piles appears to be a heterogeneous mix of rock of various degrees of weathering. This tends to be seen most in the Northwest, South, and Southwest Lower Piles, while the West Lower and Southwest Mid Piles appear somewhat more uniform in texture, weathering and rock type. It is suggested that management for decommissioning purposes be broadly carried out on a larger scale (eg. an overall management designation by rock pile area), with on-the ground confirmation and screening during any earthworks and relocation. Potential Criteria for segregation of material is given in section 6.2.1.

### **6.2 Recommendations**

#### **6.2.1 Potential Criteria for Material Identification, Segregation, and Management**

The Brown McDade waste rock material is partially oxidized, with overall low potential for net acidity. Thus, the long term closure management issue is where necessary, to control the mobility of metals, a portion of which are in soluble form in the waste rock. This control is best done by minimizing contact with water by way appropriate grading, compaction, and if necessary due to climatic and/or geochemical conditions, capping with a low permeability cover.

Submergence in water is a measure often considered for unoxidized material with acid generation potential, however in the case of the Brown McDade waste rock could cause increased dissolution of soluble metals. Based on the studies conducted to date, it is therefore recommended that any rock designated for backfill in the lower sections of the open pit be carefully evaluated and selected to ensure low metal mobility. Subject to further study, a potential candidate material for placement in the 'saturated' zone of the pit may be the rock piles located on the West Lower Pile. As stated in section 5.4.4, there is considerable inventory of this material available, and the occasional occurrence of sulphidic rock should not present a significant issue under submerged conditions.

Four rock management units have been designated: Marginal Rock, Non-Reactive Rock, Construction Rock, and Ore Stockpile Rock. Table 6.1 outlines the characteristics of each, potential field identification criteria, and possible management strategies. As noted in the table, further work is required to characterize and identify suitable sources of competent rock for general construction purposes.

Table 6.1 Preliminary Criteria for Material Identification, Segregation and Management, Brown McDade Waste Rock Pile

<b>Rock Management Unit Used in this Study</b>	<b>Potential Zones <sup>1</sup></b>	<b>Potential Field Identification Criteria<sup>1</sup></b>	<b>Possible Management</b>
<b>Marginal Rock</b> (potential for elevated zinc solubilization, and localized acidity)	Areas that show 30% or more Marginal samples: Northwest Pile, South Pile, Southwest Lower Pile, and Ore Stockpile	<ul style="list-style-type: none"> <li>• paste pH &lt; than 6.5, or any visible sulphides</li> <li>• notable amounts (eg. 20% or more) of porphyry</li> </ul>	Storage with appropriate grading such that infiltration is minimized. Unless the material in question is virtually unoxidized, submergence is not recommended as a management technique.
<b>Low-Reactivity Rock</b> (low potential for zinc solubilization and net acidity)	Areas that show less than 30% Marginal samples: East Pile, Southwest Upper Pile, West Lower Pile, West Mid Pile	<ul style="list-style-type: none"> <li>• paste pH ≥ than 6.5, and no visible sulphides</li> <li>• no notable amounts (eg. less than 20%) of porphyry</li> </ul>	<p>No special management techniques required.</p> <p>May be suitable for submergence, subject to rigorous segregation and additional site-specific testing.</p> <p>Generally low competence, hence unsuitable as riprap crush, or filter material.</p>
<b>Construction Rock</b> (competent material with low potential for zinc solubilization and net acidity)	Potential sites of competent rock include free dump piles on West Mid, West Lower, and certain areas of South Pile	Criteria to be determined <sup>2</sup>	<p>To be determined<sup>2</sup></p> <p>Potential candidate material for backfill in submerged zone of Brown McDade pit</p>
<b>Ore Stockpile Rock</b> (highly oxidized with net acidity, potential for acidic and metal-rich water migration)	Ore Stockpile	All material remaining in ore stockpile	<p>Relocation away from area for potential water ponding</p> <p>Storage separate from other waste rock products, under conditions where infiltration of water is prevented.</p> <p>Possible lime amelioration?</p>

<sup>1</sup> Note that these criteria represent general tendencies based on available data.

<sup>2</sup> As discussed in Section 5.4.4, further characterization work is required

## 6.2.2 Future Work and Information Needs

### *Field Work and Monitoring Recommendations*

- Construction rock characterization: further work is required to characterize and identify competent rock suitable for construction purposes, as the 2008 testing and field reconnaissance raises questions as to the suitability of the coarse rock piles on the West Upper and West Lower Piles (see section 5.4.4).
- Site climate monitoring: installation of a reliable, continuously operating site climate monitoring station is strongly recommended. In particular, precipitation data is important for interpretation of seep and lysimeter monitoring. If installation of a continuous monitoring station is for some reason not possible, as a minimum a simple manual rainfall gauge should be set up in the waste rock pile area to be read and emptied whenever the lysimeters are checked. A drop of oil can be added into the gauge to minimize evaporation of the accumulated water.
- Snowpack monitoring: commencing in March 2009, regular snowpack measurements, as a minimum at the peak period of snowpack (likely around mid to end of March) are recommended to aid in interpretation of seep and lysimeter monitoring. It should be noted that very little special equipment is required to conduct a basic snowpack survey (a 1.5 m length of plastic pipe of known inside diameter, a large graduated cylinder, and plastic sample bags).
- Continued water monitoring of lysimeter installations and seeps:
  - Lysimeters: it is recommended that the lysimeters be checked and sampled every two weeks during spring snowmelt, and every two weeks to monthly thereafter. A dedicated inexpensive low volume DC-powered marine bilge pump or similar should be acquired for each lysimeter for lowering into the collection sumps for sampling. In addition to obtaining a water quality sample of the water and checking for field parameters, as much of the accumulated volume of water as possible should be removed, and this volume measured. Once this is done a few times it will be possible to develop an understanding of infiltration rates. Paired with the monitoring should be records of the cumulative site precipitation since the last monitoring, and towards the end of each winter, a measurement of the accumulated snowpack over each of the two lysimeters.
  - Seeps: starting in spring 2009, the two seeps identified in this study (and any others subsequently identified) should be checked every two weeks. Field water quality parameters (pH, conductivity) should be measured, and flow rate measured or estimated. If flow is sufficient, it would be of benefit to collect carry out detailed water quality analysis (general parameters, dissolved metals via ICP-MS) at least three times during the 2009 season.

- Additional reconnaissance for new seeps and surface ponding: reconnaissance in spring 2009 for additional seep locations is recommended, since the water infiltration will likely be at its maximum during this time of the year. Monitoring should note both field water quality parameters and estimated flow rate. Basic mapping of any surface ponding sites should be done concurrently.
- Late winter aerial reconnaissance of rock pile area: if any aerial flights are planned prior to spring 2009, it is suggested that the waste rock pile area be carefully observed with respect to the presence/absence of any snow melt or heat generating sectors. This information could help to better identify any zones requiring special management.
- Additional sampling of potential construction material: as noted in this study, rock on West Lower Pile shows promise as source for construction material, nonetheless the sporadic occurrence of sulphidic material within this site is a significant issue. Due to elevated sulphide content, the material stacked on the West Mid Pile is of concern for general construction use, although there may suitable application if this rock is left in its coarse form and not used in water management-related works. Further reconnaissance and sampling of both potential sites is considered necessary.
- Additional geochemical sampling of the pit walls: Altura's review of previous studies indicates that there are very few samples from the final pit walls (four samples by Conor Pacific in 1999). The 13 BYG samples taken in 1997 were of interim pit walls and the report recommended additional sampling at end of mine life. Hence systematic sampling is recommended for estimates of geochemical loading and evaluation of closure alternatives.

#### *Information Recommendations*

- Update existing topographic data: the existing topographic data is not updated with respect to the current layout (does not show the Southwest Lower Pile, and shows the large Ore Stockpile that has since been removed).
- Source digital version of pre-mine topography: it was not possible to obtain pre-mine topographic information for this study, although it is understood that the data likely exists in archival storage or possibly with a survey consultant. This data would assist with refining volume estimates of waste rock pile and with better defining the location of original ground in the area between the Northwest and the South Pile. The information would also likely be of benefit to numerous other aspects of closure planning.

## 7.0 Closure

This report was prepared for the Assessment and Abandoned Mines Branch, Department of Energy, Mines and Resources of the Government of Yukon. The report, which specifically includes all text, figures, tables and appendices, is based on information provided by the client, and on data and information collected during the investigations conducted by Altura Environmental Consulting.

The work described in this report was conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Altura Environmental Consulting sincerely appreciates the opportunity to participate in and contribute to the decommissioning phase of the Mount Nansen site. Please direct any questions regarding the contents of this report to the undersigned at 867-335-2006.

Prepared by:

**ALTURA ENVIRONMENTAL CONSULTING**



Diane Lister, M.A.Sc., P.Eng.

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