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Zeehan Zinc Limited

Comstock Mine

Access Road and Polishing Pond Construction Material AMD Assessment

October 2007

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

1.1 Background

Zeehan Zinc Pty Ltd (Zeehan Zinc) commissioned GHD Pty Ltd (GHD) to review the acid and metalliferous drainage (AMD) potential of material from the Tailings Storage Facility (TSF) rock borrow used in the construction of the Polishing Pond embankment and access roads at the Comstock Mine.

1.2 Scope of Works

The scope of work for the review comprised the following:

- Design a sampling and testing program based on the rock type and tonnage of material to be used for construction;
- Obtain samples and submit for laboratory analysis;
- Review ARD analysis results and determine the ARD classification of the materia; and
- Make recommendations for any additional assessment if required.

1.3 Assessment Guidelines

The ARD data have been assessed against:

- AMIRA International *ARD Test Handbook* May 2002; and
- Department of Industry Tourism and Resources (ITR) *Managing Acid and Metalliferous Drainage Handbook* February 2007

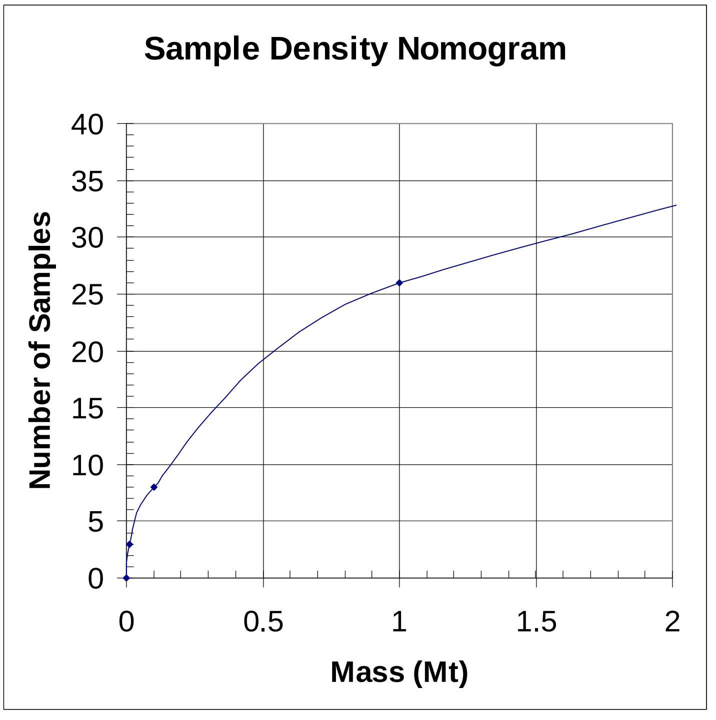
As none of the above documents give guidance on the appropriate sampling density, the preliminary sampling density given in the Queensland DME guidelines on the occurrence, testing and management of ARD in Queensland have been used. The recommended sampling density, based on the tonnage of material to be mined is given in Table 1 below

Table 1 Queensland DME ARD Sampling Density

Mass of each Separate rock type (tonnes)	Minimum number of samples
<10,000	3
<100,000	8
<1,000,000	26
<10,000,000	80

This sampling density, for masses of less than 2 Mt can be expressed as the sample nomogram below (Figure 1).

Figure 1 Sample Density Nomogram



In reviewing ARD characteristics of a site, several parameters are measured including:

- Net Acid Producing Potential (NAPP):
- Net Acid Generation (NAG)

NAPP calculates the balance between the theoretical acid producing capacity based on the sulfur content of the material, and the acid neutralising capacity measured by titration. Material with a NAPP greater than 0 is considered potentially acid forming (PAF) and less than 0 is considered acid neutralising.

In NAG testing, a sample of material is oxidised with a hydrogen peroxide solution, then the pH of the oxidised sample measured (NAGpH or pH_{OX}). The sample is then titrated to determine the acid (expressed as kg H_2SO_4/t) required to be neutralised to bring a sample up to a pH of 4.5 (NAG (pH4.5)) then a pH of 7 (NAG(pH7)).

Samples with a NAGpH of less than 4.5 are considered to be PAF. The higher the NAG(pH4.5) or NAG(pH7) value, the greater the amount of acid produced on oxidisation.

Typically the NAGpH and NAPP are plotted together to characterise the material as being:

- PAF – (NAGpH ,<4.5 and NAPP >0);
- Non-acid forming (NAF) - (NAGpH >4.5 and NAPP <0); and
- Uncertain (UC) - (NAGpH <4.5 and NAPP <0 or NAGpH >4.5 and NAPP >0)

The NAG test can give erroneously low acid concentrations if the hydrogen peroxide is fully consumed before the sulfide in the sample is fully oxidised. This occurs in samples with a sulfur content of greater than 2% (AMIRA 2002). In this case *Sequential NAG testing* is performed to ensure complete oxidisation of sulfides, where peroxide solutions are added in successive stages, with the pH measured after each addition, until there is no change in pH between successive stages.

The ITR (2007) guidelines also give a classification based on NAPP and NAGpH (Table 2)

Table 2 Typical geochemical classification criteria based on NAPP and NAG test data

Primary Geochemical Waste Type	NAPP kg H_2SO_4/t	NAG pH (pHox)
Potentially Acid Forming (PAF)	>10*	<4.5
Potentially Acid Forming-Low Capacity (PAF-LC)	0 to 10*	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (ACM)	Less than -100	≥4.5
Uncertain#	Positive	≥4.5
	Negative	<4.5
	Positive	<4.5

* Site-specific but typically in the range 5 to 20 kgH_2SO_4/t.

Further testing required to confirm material classification.

1.4 Mine Geology

The Comstock mine area contains the following distinct waste-rock lithologies (SEMF 2007):

- carbonaceous shales;
- siliceous shales;
- sandstones;
- talcose altered dolomites;
- gabbro;
- grey shale; and
- weathered volcanic rocks.

The proposed construction materials, the subject of this report, comprised “grey shale”.

2. Methodology

Given a volume of approximately 60,000m^3, comprising 20,000 m^3 in the polishing pond walls and 40,000 m^3 in site access roads, a total of 25 samples (Appendix A Table A1) (Figure 2)of the grey shale construction material were collected by hand and submitted for analysis by Burnie Research Laboratories for:

- Net Acid Producing Potential (NAPP) – Initially NAPP was determined using the Maximum Potential Acidity (MPA) based on the LECO sulfur content less the Acid Neutralising Capacity (ANC) based on the total inorganic carbon content, assumed to exist as carbonate. As this is a non-standard method, the NAPP was later re-calculated using the standard ANC by HCl titration (AMIRA 2002) and MPA based on total sulfur;
- Net Acid Generation – Analysis was consistent with the NAG methodology given in AMIRA (2002) but the NAG was only recorded for the pH 7 end point;
- 1:2 EC and pH – Crushed rock mixed with distilled water in the ratio of 1:2 ad the pH and EC measured to gain an indication of existing acidity and salinity; and
- Metal analysis of NAG leachate. Three representative (PAF, UC and NAF) leachate samples were analysed for common trace metal toxicants Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn.

The results of the grey shale analyses, along with previous AMD for the site from SEMF(2007) have been tabulated and included in Appendix A.

Figure 2 Mill Site Access Road Grey Shale Sample Locations

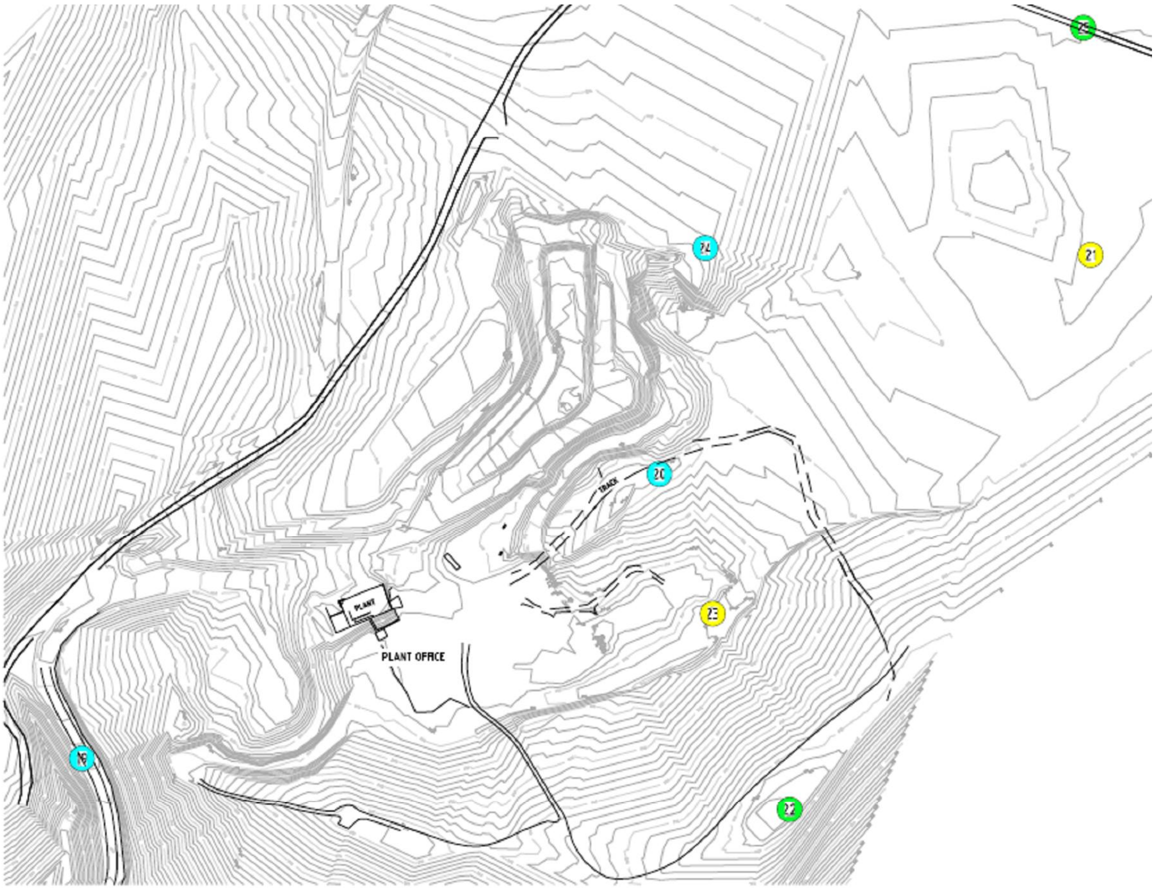
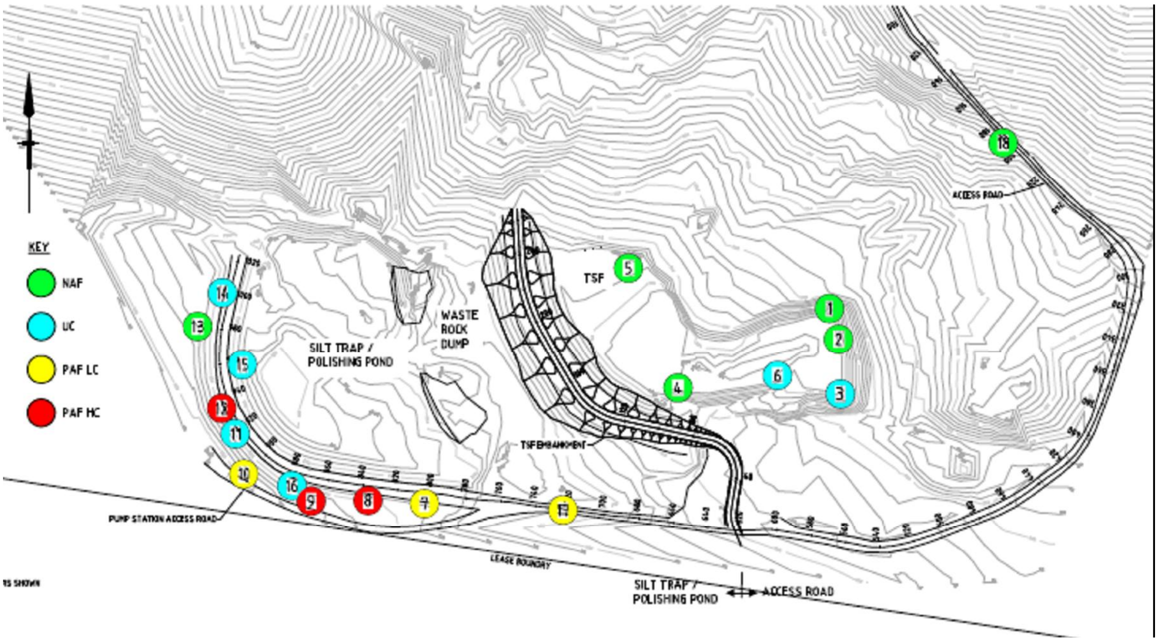


Figure 2a Polishing Pond, TSF Rock Borrow Grey Shale Sample Locations



3. Results

3.1 EC and pH

The water leach solution from un-oxidised samples of grey shale were neutral to alkaline (pH range 5 to 9.23 – median 7.97) and fresh to moderately saline (EC range 96 uS/cm to 940 uS/cm – median 403 uS/cm.

3.2 ARD Classification

The AMD data are presented below as plots of NAGpH against NAPP for all AMD analyses for the site (Figure) and for the grey shale used for road and Polishing Pond construction only (Figure) , and classified using the methods given in Amira (2002). Acid/base account plots of ANC against MPA for the grey shale are presented as Figure .

The acid-derived NAG testing generally indicates significantly lower acid generating capacity than the sulfur-derived NAPP values, but with conversely less neutralising capacity than the ANC/NAPP results indicate. This suggests that not all the sulfur is in the form of readily oxidise pyrite, but not all neutralising capacity is in the form of calcium carbonate.

Based on the abovementioned plots, the grey shale ranges from PAF (7 samples) to NAF (8 samples), with a significant number of UC samples (10 samples). As approximately half of the samples have and ANC more than twice the MPA (Figure) the material has a relatively high overall neutralising capacity although there are likely to be isolated hotspots of acid generating material. Based on the statistics summarised in Table 3, overall the grey shale can be considered borderline NAF/PAF-LC (PAF with low acid generating capacity of <10 kg H2SO4/t). This is classified as Low-NAG under the *Waste Rock Management Plan - Placement and Sampling Plan* (GHD 2007). Three samples from the Polishing Pond embankment (ZZ08, ZZ09 and ZZ12), however, are classed as PAF-HC based on the NAPP of greater than 10 kg H_2SO_4/t. If classified using NAG at pH 7, all samples have less than 10 kg H_2SO_4/t and therefore have only low capacity to generate acid,

The theoretical liming rate (mass of calcium carbonate required to neutralise the potential acid load) based on the NAG values at pH 7, ranges from 0 to 7 kg/t.

Table 3 NAG and NAPP Statistics

Statistic	NAG pH7 (kg H_2SO_4/t)	NAPP (kg H_2SO_4/t)
Average	2.9	-6.72
Median	2.9	-8.9
95%UCL	3.4	0.4
Maximum	4.9	23.6
Minimum	0.0	-51.2

Figure 3 ARD Classification By NAGpH and NAPP – All Samples From Site

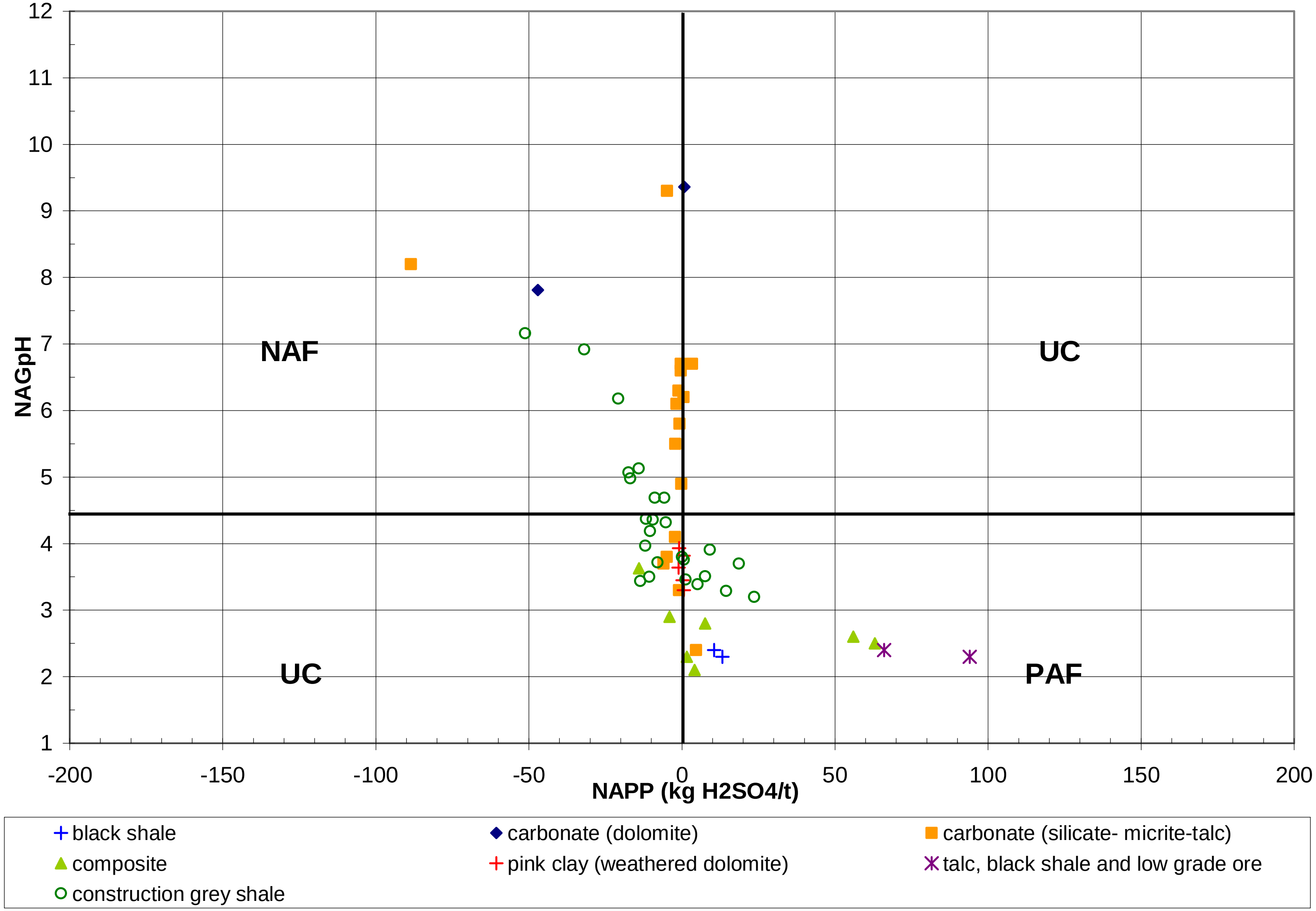


Figure 4 ARD Classification By NAGpH and NAPP Grey Shale Only

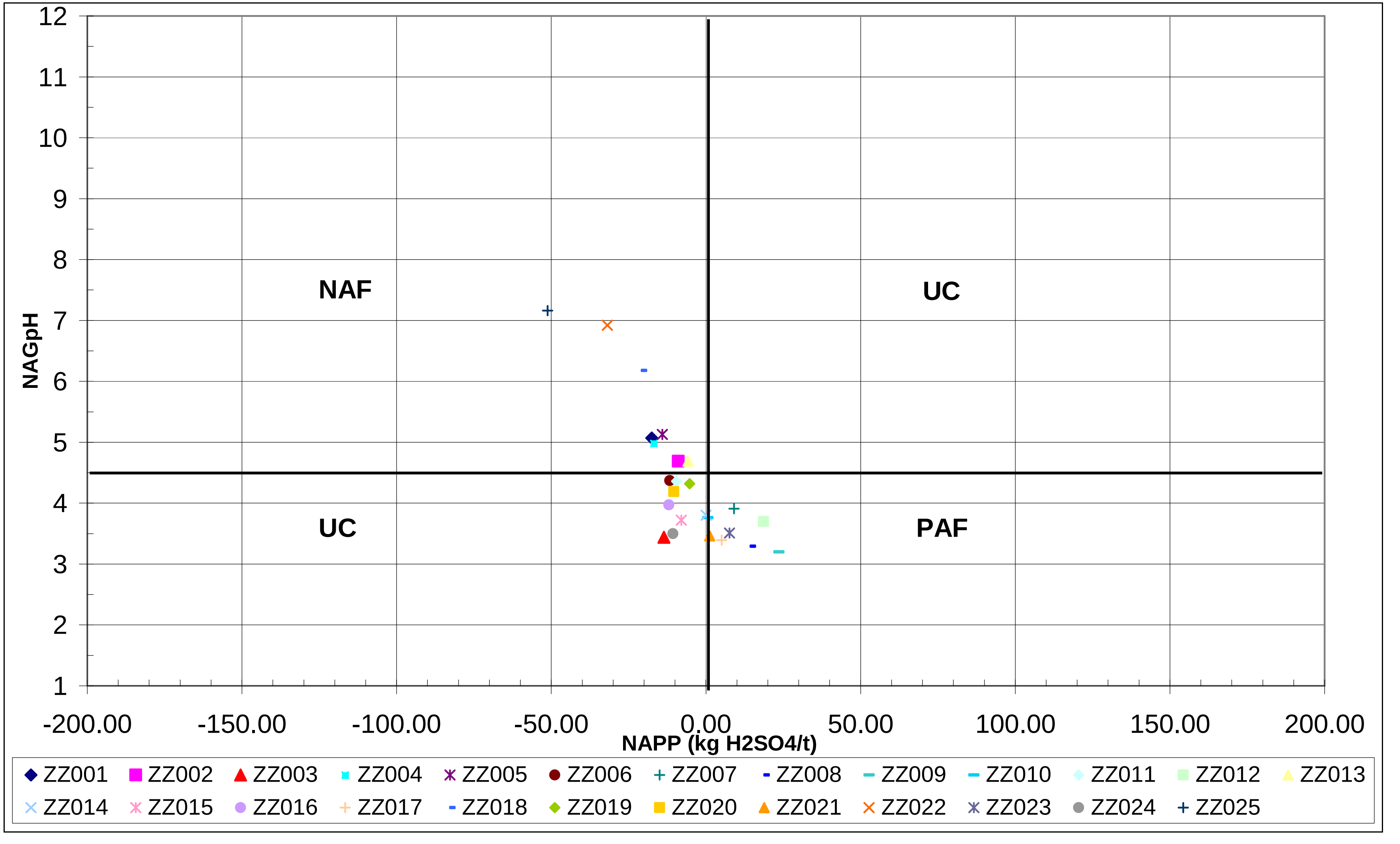
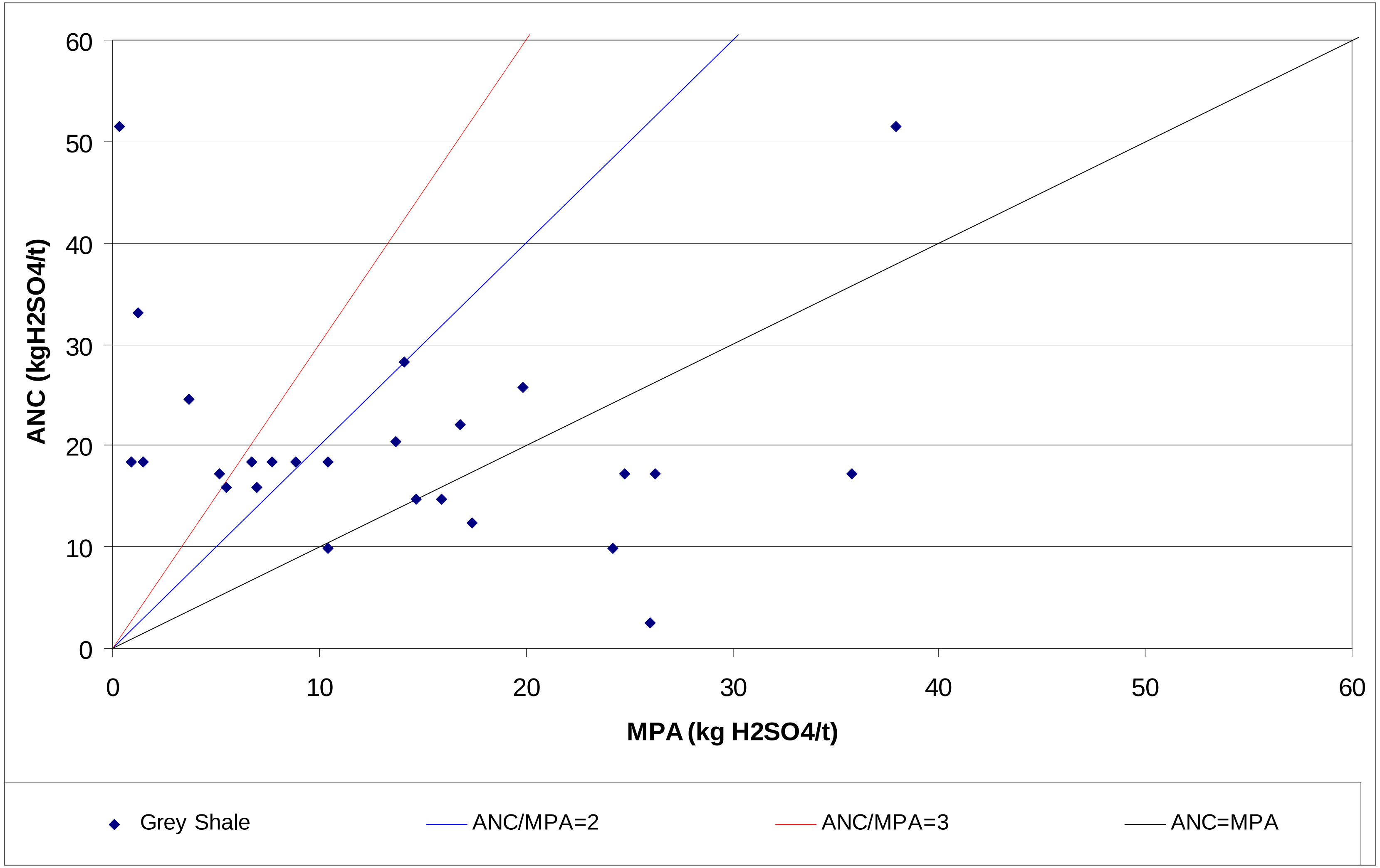


Figure 5 ARD Classification by ANC an MPA



3.3 Trace Metals

The NAG leachate for 3 samples was analysed for a range of trace metal toxicants. With the exception of manganese, the highest trace metal concentrations were in the NAF sample ZZ01 and the lowest were in the PAF sample ZZ09. This is contrary to what would be expected, given the usual association of metals with elevated sulfur and the typically higher mobility of the trace metals under acid conditions. Although the aggressive peroxide leaching procedure can yield exaggerated metal concentration, in comparison with leachate likely to be generated in the environment. NAG leachate analyses can be used to target metals for further assessment in additional tests such as column leach test. The results of these tests indicate that metals, especially Zn, Al and Fe, have potential to be concentrated in leachate from the grey shale and should be assessed further.

Table 4 Trace Metals in NAG Leachate

Sample	AMD Class	Al	As	Cd	Cr	Fe	Mn	Ni	Pb	Zn
		g/L	mg/L	mg/L	mg/L	g/L	mg/L	mg/L	mg/L	mg/L
ZZ001	NAF	13.2	89	2	223	51.1	1685	220	138	496
ZZ009	PAF	5.7	37	1	51	13.7	230	39	44	121
ZZ025	NAF	11.6	83	2	72	40.9	1831	52	96	193

3.3.1 Testing Method Validity

None of the samples had a sulfur content of greater than 2%, indicating that the sulfur is likely to have been fully oxidised with a single application of hydrogen peroxide solution. Consequently, only limited sequential NAG testing would be required to validate single-addition NAG testing.

4. Conclusions and Recommendations

4.1 ARD Classification

The grey shale used in Polishing Pond embankment and access road construction is generally NAF to PAF-LC – equivalent to "Low-NAG" material- and consequently represents relatively low risk of acid leachate generation. Some of the material within the Polishing Pond embankment is classed as PAF-HC if the sulfur-based NAPP values are used, but are classed as PAF-LC if the acid-derived NAG values are used.

As the total sulfur content of the material is generally below 2%, the static NAG and NAPP testing performed is appropriate.

Several metals, primarily Zn, Fe, Al were elevated in NAG leachate and consequently should be investigated further.

4.2 Recommended Additional Works

- Representative samples of grey shale should be assessed using free-draining leach column (FDLC) testing (AMIRA 2002), along with other waste and tailings materials to assess the potential changes of the leachate chemistry over time;
- As the PAF material identified within the Polishing Pond Embankment is classified as Low-Capacity , based on NAG at pH7, no remedial action is proposed at this stage. However, the pH and EC of runoff from the roads and downstream from the Polishing Pond should be monitored a part of the site environmental monitoring to confirm no significant acidity is being generated. If runoff is identified as being significantly acidic, the use of crushed limestone or dolomite in catch drains to neutralise runoff should be assessed;
- Areas on non-mineralised dolomite and other carbonates should be assessed as local sources for neutralising material if acid neutralisation of sulfidic waste rock or tailings is required. Testing should include assessment of metals released when reacted with acid leachate;
- Prior to further use of waste rock material for construction, NAG testing should be carried out to confirm it is NAF or PAF-LC.

5. Reference

AMIRA. 2002. *ARD Test handbook*. AMIRA International Limited, Melbourne VIC.

DME. 1995. *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Minerals and Energy. Brisbane.

GHD. 2007. *Waste Rock Management Plan - Placement and Sampling Plan*. Report for Zeehan Zinc Ltd October 2007 Ref # 32/13671/41489. GHD Pty Ltd, Hobart.

ITR. 2006. *Managing Acid and Metalliferous Drainage Handbook February 2007* Department of Industry Tourism and Resources. Canberra.

SEMF. 2007. *Comstock Mine Visual Waste Rock Characterisation Manual - August 2007 Revision 2*. Ref # 1292.001. SEMF Pty Ltd, Hobart.

Appendix A

AMD Test Summary Table

Construction Material Sample Results

Sample	$pH_{1:2}$	$EC_{1:2}$	MPA	ANC	NAG	NAG pH	NAPP	Class	Capacity
	pH units	uS/cm	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	pH units	kg H_2SO_4/t		
ZZ001	7.51	96	0.9	18.4	2.5	5.07	-17.5	NAF	
ZZ002	7.55	318	7.0	15.9	2.9	4.69	-8.9	NAF	
ZZ003	7.64	518	37.9	51.5	4.9	3.44	-13.6	UC	
ZZ004	8.59	186	1.5	18.4	2.5	4.98	-16.9	NAF	
ZZ005	8.63	581	14.1	28.2	2.9	5.13	-14.1	NAF	
ZZ006	8.19	334	6.7	18.4	3.9	4.37	-11.7	UC	
ZZ007	8.15	447	26.3	17.2	4.9	3.91	9.1	PAF	LC
ZZ008	5.70	856	24.2	9.80	3.4	3.29	14.4	PAF	HC
ZZ009	6.38	777	26.0	2.45	4.9	3.20	23.6	PAF	HC
ZZ010	7.51	399	10.4	9.80	3.4	3.76	0.6	PAF	LC
ZZ011	8.38	382	8.9	18.4	2.9	4.36	-9.5	UC	
ZZ012	7.60	940	35.8	17.2	3.4	3.70	18.6	PAF	HC
ZZ013	8.59	539	19.9	25.7	2.0	4.69	-5.8	NAF	
ZZ014	7.01	780	14.7	14.7	2.5	3.80	0.0	UC	
ZZ015	7.90	407	10.4	18.4	2.5	3.72	-8.0	UC	
ZZ016	8.37	130	5.2	17.2	2.5	3.97	-12.0	UC	
ZZ017	7.84	403	17.4	12.3	3.9	3.39	5.1	PAF	
ZZ018	9.19	258	3.7	24.5	0.7	6.18	-20.8	NAF	
ZZ019	8.73	526	16.8	22.1	2.2	4.32	-5.3	UC	
ZZ020	7.51	306	5.5	15.9	2.0	4.19	-10.4	UC	
ZZ021	7.97	422	15.9	14.7	3.4	3.46	1.2	PAF	
ZZ022	9.05	224	1.2	33.1	0.2	6.92	-31.9	NAF	
ZZ023	7.54	610	24.8	17.2	3.7	3.51	7.6	PAF	
ZZ024	8.81	240	7.7	18.4	3.4	3.50	-10.7	UC	
ZZ025	9.23	252	0.3	51.5	Nil	7.16	-51.2	NAF	

Mean	7.9828	437.24	13.728	20.454	2.9791667	4.3484	-6.724
Median	7.97	403	10.4	18.4	2.9	3.97	-8.9
Max	9.23	940	37.9	51.5	4.9	7.16	23.6
min	5.7	96	0.3	2.45	0.2	3.2	-51.2

Leachate Sample Results

Sample	Al	As	Cd	Cr	Fe	Mn	Ni	Pb	Zn
	g/L	mg/L	mg/L	mg/L	g/L	mg/L	mg/L	mg/L	mg/L
ZZ001	13.2	89	2	223	51.1	1685	220	138	496
ZZ009	5.7	37	1	51	13.7	230	39	44	121
ZZ025	11.6	83	2	72	40.9	1831	52	96	193

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