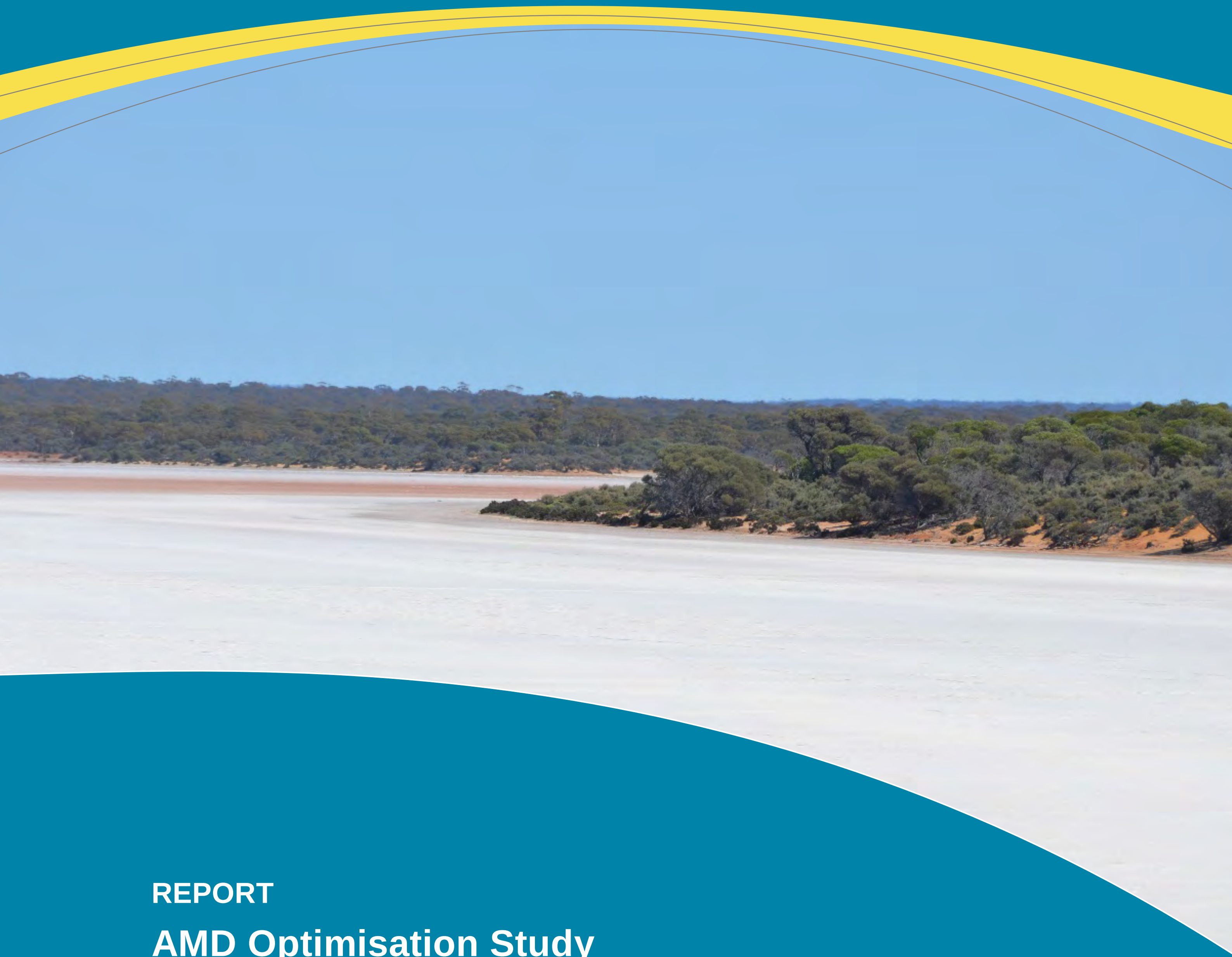
APPENDIX P: AMD OPTIMISATION STUDY (MWH)

MWH

BUILDING A BETTER WORLD



REPORT

AMD Optimisation Study

Prepared for St Ives Gold Mining Company Pty Ltd

June 2016

QUALITY STATEMENT

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Executive Summary

The purpose of this study was to assess the current knowledge and understanding of the potential for mined waste and tailings materials to generate acid metalliferous drainage (AMD) in order to identify data gaps and assess AMD risk at the St Ives Gold Mine (SIGM) site. Recommendations have been made with a focus on optimising the process of refining the risk assessment and providing information to assist with modifying current operational procedures as well as future closure planning.

This review consisted of analysis of acid base accounting (ABA) results for over 3000 samples. This data was collated and characterised using a site specific acid generation potential classification scheme. Data related to the assessment of impact from metals present in waste rock materials has been interpreted from a geographical information systems (GIS) data base of drillhole sample assays. The assessment of AMD risk was undertaken based on static geochemical testing, ABA and acid generation potential classification. Qualitative assessment of the reliability of data provided, as well as elevated metals content, was also considered in the assessment of overall AMD risk for each lithology.

The total number of samples assessed were distributed across the major lithologies represented at SIGM, and as such, results were considered to provide a good representation AMD characteristics for each lithology across all mine areas. The majority of samples were classified as non-acid-forming (NAF) – barren, NAF or potentially NAF, indicating that potentially-acid-forming (PAF) and potentially PAF materials make up a relatively small component of waste at SIGM (<11%). The majority of lithologies have therefore been assessed as having a low risk potential to generate acid, with the exception of Kapai Slate and Cave Rocks Sediments which have a high potential to generate acid. Other lithologies with a low to moderate risk potential to generate acid are the Tertiary sediment, Cave Rock Dolerite, Lunnon Basalt and Mafic Intrusion; although with these lithologies, the risk is likely to be confined to mineralised zones where sulfide concentrations tend to be higher in waste rock.

Regionally, basement rock materials have naturally elevated total concentrations of chromium, copper and zinc, and low concentrations of lead and selenium compared to nominated trigger values for potential impact to aquatic biota in Lake Lefroy. Total arsenic concentrations are elevated in basalt lithologies and tailings materials. Although the assessed metals are considered to be regionally elevated and dissolution of metals into the aquatic environment is considered to be limited by natural sorption processes, localised leaching of waste rock and tailings materials due to local runoff water chemistry, or lower pH associated with acid generation is possible.

The current management practices and procedures in place at SIGM are considered to be at a standard that is consistent with current industry practice, and appropriate for the management of AMD risk at the site. The key recommendations and outcomes from this assessment are summarised in the AMD risk framework (**Section 8.3**) and focus on optimisation of ongoing testwork to understand longer lag-time

AMD characteristics and the potential for AMD to cause impact to receptors. Recommendations have been made to focus any ongoing AMD assessment work on refining the AMD risk assessment and improving knowledge gaps identified in the AMD risk framework. Areas within the risk framework where recommendations have been made include:

- establishment of site specific baseline criteria;
- ongoing analysis of risk, using updated procedures for the identification and management of potential AMD sources, as well as adding to the understanding of metals leaching and longer lag-time properties of PAF and NAF materials associated with potential pathways between sources and receptors;
- ongoing assessment and prioritisation of risk with a focus on developing an understanding of the location and amount of available NAF and low metals risk material for use in closure; and
- review and monitoring of the effectiveness of current management strategies through the refinement of groundwater and surface water monitoring strategies to identify early signs of potential AMD generation.

St Ives Gold Mining Company Pty Ltd

AMD Optimisation Study

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ABBREVIATIONS

Abbreviation	Description
ABA	Acid base accounting
ABCC	Acid buffering characteristic curve
AC	Acid consuming
AMD	Acid metalliferous drainage
ANC	Acid neutralising capacity
AP	Acid potential
EC	Electrical conductivity
GARD Guide	Global Acid Rock Drainage Guide
GIS	Geographic information systems
Gold Fields	Gold Fields Australia Limited
kg	Kilograms
km	Kilometres
mg/kg	Milligrams per kilogram
mm	Millimetres
MPA	Maximum potential acidity
Mt	Million tonnes
MWH	MWH Global
NAF	Non-acid forming
NAG	Net acid generation
NAPP	Net acid production potential
NP	Neutralisation potential
P PAF	Potentially PAF
P NAF	Potentially NAF
PAF	Potentially acid forming
PER	Public Environment Review
ROM	Run of mine
%S	Percent sulfur
SIGM	St Ives Gold Mining Company Pty Ltd
TDS	Total dissolved solids
TSF	Tailings storage facility
UNC	Uncertain
uS/cm	Micro Siemens per centimetre
WRL	Waste rock landform

1 Introduction

St Ives Gold Mining Company Pty Ltd, a subsidiary of Gold Fields Australia Limited (Gold Fields), operates St Ives Gold Mine (SIGM), located approximately 60 kilometres (km) south of Kalgoorlie and approximately 7 km south east of Kambalda in Western Australia. Obligations under the Mining Act 1978 require SIGM to routinely assess and manage waste materials generated during mining, to prevent adverse impacts due to potentially acid generating material in the mined waste. SIGM have developed environmental procedures outlining sampling and analysis requirements for characterisation of acid metalliferous drainage (AMD) properties of waste materials, resulting in the collection of substantial amounts of data at the site.

Gold Fields have commissioned MWH Global (MWH) to undertake a review and assessment of the AMD data collected at SIGM and provide recommendations to update AMD sampling and analysis requirements at the site, to optimise the process and amount of sampling required, without impacting the quality of reporting or creating knowledge gaps relating the acid generation characteristics of materials on site.

Further to the original scope (outlined in MWH proposal dated March 2015), SIGM requested that MWH develop presentation media to allow effective communication of AMD issues both internally (e.g. SIGM staff education and training) and externally (e.g. regulatory inspections).

1.1 Scope and Objectives

The key objective of this report is to review the existing information relating to sampling and analysis of mined waste materials for AMD characterisation, and to provide guidance on the optimisation of the AMD sampling, analysis and management program at SIGM. Specific objectives for this optimisation study include the following:

- review available geological and geochemical data;
- review current SIGM standards and procedures for the assessment and management of mined waste materials with respect to AMD assessment;
- collate and review results of previously reported laboratory static test results;
- review available data against guidance outlined in the Global Acid Rock Drainage Guide (GARD Guide);
- provide recommendations for optimisation of future AMD sampling and analysis requirements; and
- produce a visual presentation on AMD issues specific to SIGM operations.

The scope of this report does not include review and analysis of the following materials:

- low grade ore stockpiles;
- materials used in the construction of on-site infrastructure; or
- materials contained within current and historic heap leach facilities.

A draft visual presentation is provided to SIGM (**Appendix D**) for review. MWH request input on the content from SIGM and once finalised, intend to present the information to SIGM during a future site visit. The information provided in the presentation is drawn from this report and utilises visual aids and photographs provided by SIGM personnel.

2 Background

2.1 Climate

The Kambalda area is classified as a semi-arid climate zone with hot, dry summers and cold winters. Using the Köppen system, the area is classified as a persistently dry desert climate. The closest registered weather station with long-term data available is the Kalgoorlie-Boulder Airport station (Station ID: 12038) located approximately 50 km from the township of Kambalda (Bureau of Meteorology, 2015). The climate statistic presented represent 74 to 77 years of recorded data between 1939 and 2015. Climate data is presented in **Figure 2-1**.

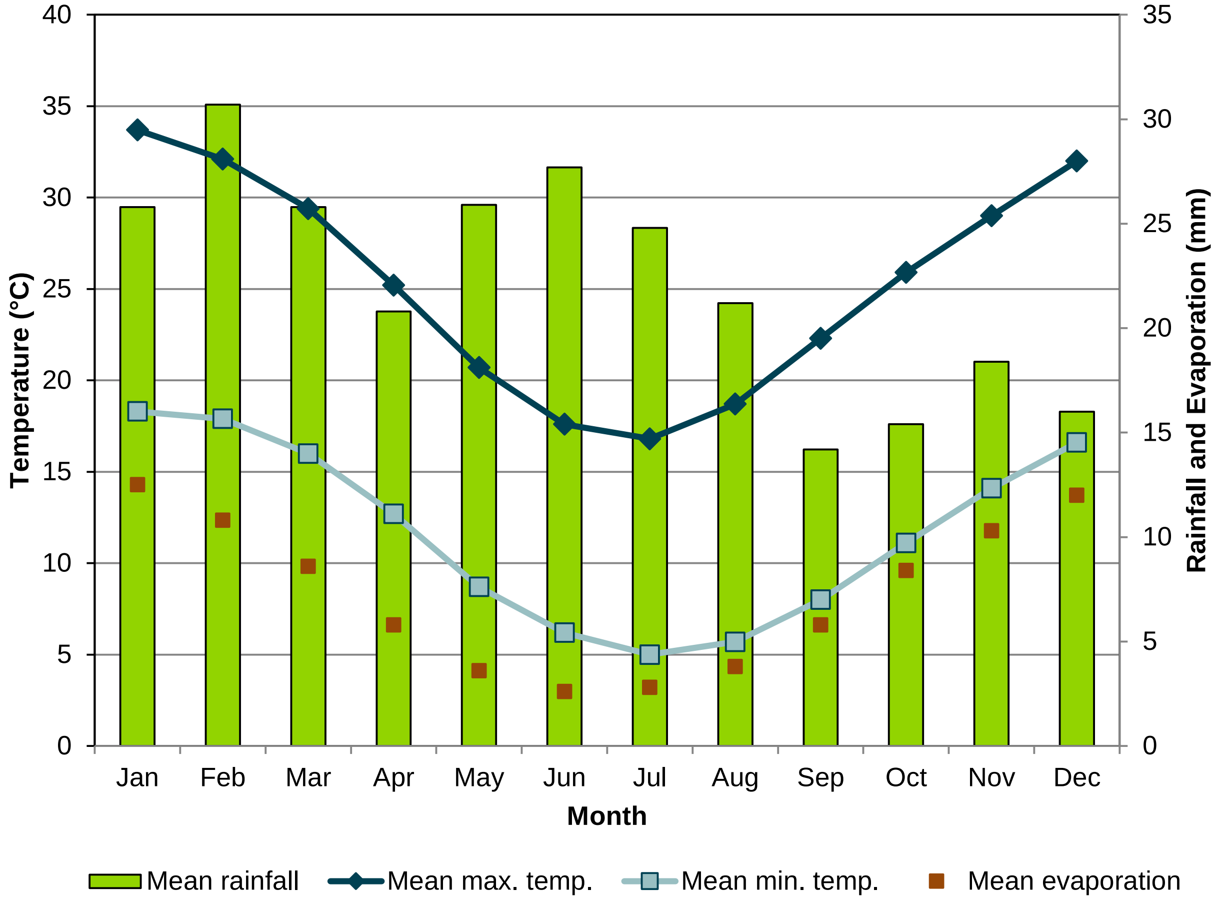


Figure 2-1: Climate Data for Kalgoorlie-Boulder Airport (Station ID: 12038) 1939-2015 (Bureau of Meteorology, 2015)

Annual precipitation averages at approximately 270 millimetres (mm), and rainfall is reasonably consistent between January and August, while September to December are generally drier. On average, precipitation falls over 68 days of the year, with the majority of rain days (90% of rain days) recording less than 10 mm of rainfall. In the region, precipitation can be highly variable spatially and from year to year, mostly due to large storm events associated with degrading cyclonic systems. These storm events are rare, but generally result in rainfall events greater than 90 mm (Gold Fields Ltd, 2013).

Annual average temperatures range between a minimum of 11.7 ºC to a maximum of 25.3 ºC. On average, the highest annual maximum and minimum temperatures occur in January, while the lowest annual maximum and minimum temperatures occur in July. Average annual evaporation rates have been recorded between 1966 and 2015. Average daily evaporation is 7.2 mm with the highest average daily evaporation rates occurring with highest maximum temperatures in January (12.5 mm). Lowest average daily evaporation occurs in June (2.6 mm).

Evaporation is generally lower than average rainfall, however as the majority of rainfall events are less than 10 mm, it is likely that infiltration is minimal and countered by the evaporation (which averages 7.2 mm). The majority of rainfall is associated with high intensity events. During these events, rainfall exceeds evaporation, resulting in infiltration; however, high intensity events also result in runoff, where rainfall exceeds infiltration rates. Runoff is likely to be the more dominant process during high intensity rainfall events at SIGM.

2.2 Regional Geology

The SIGM site is located within the south central part of the Archean Norseman-Wiluna Greenstone Belt, which comprises mafic and ultramafic rocks with minor felsic porphyry intrusions and meta-sediments, granites and cross-cutting Proterozoic dolerite dykes. **Figure 2-2** shows the stratigraphic column for the St Ives local geology. The basement geology is dominated by the Lunnon Basalt in the south or Paringa Basalt in the north. The area has been intruded by dolerite and porphyritic rhyolite swarms, during several intrusion events. Recent sediments comprise Tertiary lake and palaeochannel sediments overlain by transported Quaternary sediments.

Gold mineralisation is controlled by the Boulder-Lefroy Fault and is generally confined to structures associated with the fault such as mylonitic, breccia and shear zones associated with contact between the basement rocks, fault zones and intermediate and felsic intrusives. Minor mineralisation is associated within quartz veining and supergene sequences within the weathered profiles (Gold Fields Ltd, 2013).

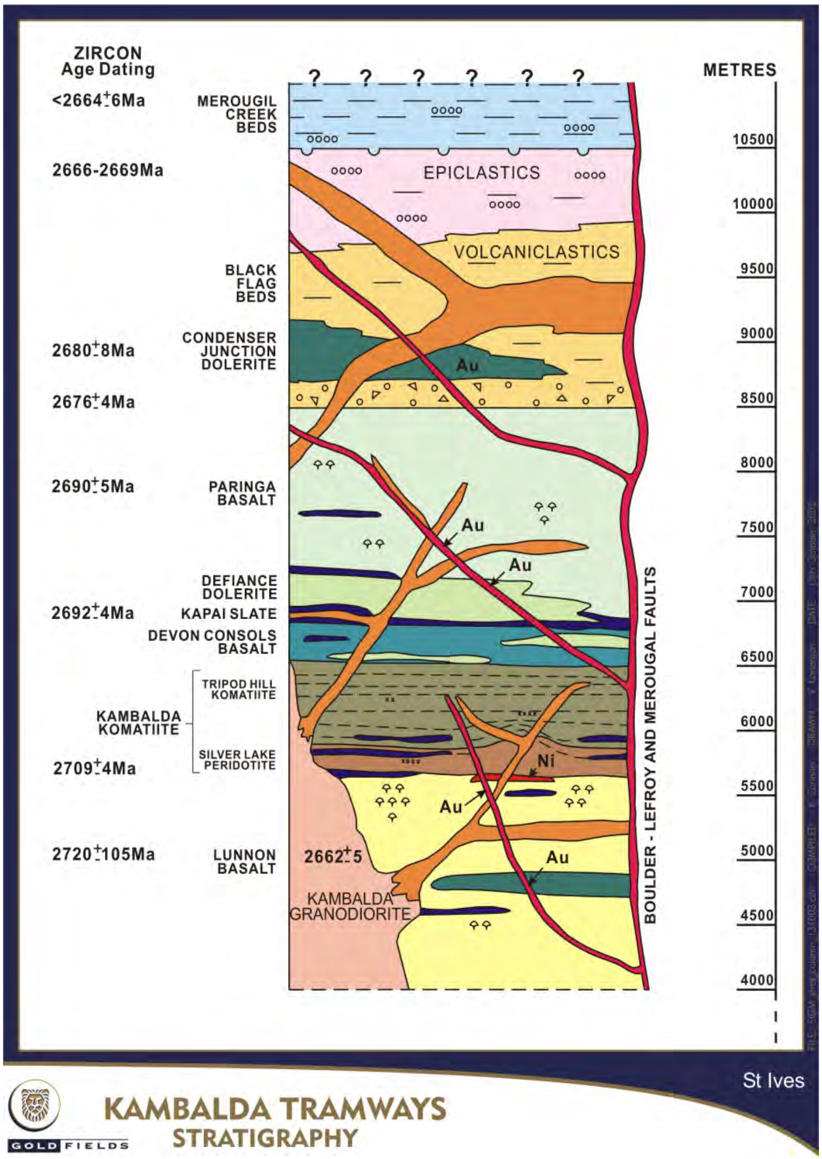


Figure 2-2: SIGM stratigraphic profile (Gold Fields Ltd, 2010)

2.3 Site History

Mining in the region began as early as 1896 when gold was discovered near Red Hill to the south east of Kambalda. Further interest in gold mining in the area developed with the discovery of the Ives Reward deposit in 1919. Mining continued until 1927, when the Ives Reward mine ceased production and the historic township of St Ives was abandoned. The area was predominantly explored and mined for nickel from the 1930s to the 1960s, although the presence of gold was noted in some of the nickel mining operations. In 1980, exploration on the eastern side of Lake Lefroy, revealed a substantial gold reserve, which lead to the development of the Victory mine (now referred to as the Leviathan Complex) in 1981. A carbon-in-pulp plant was commissioned later the same year, and the St Ives gold mine began expanding production. Gold Fields acquired the operation in December 2001 and by the end of 2009 the mine had produced 86.1 million tonnes (Mt) of ore at a grade of 3.3 grams/tonne from 40 open pits and six underground mining operations (Gold Fields Ltd, 2010). As of 2013, the SIGM mining operation comprised (Gold Fields Ltd, 2013):

- exploration disturbance on lake and land based areas;
- one active lake-based open pit;
- 13 inactive lake-based open pits;
- two active land-based open pits;
- 16 inactive land-based open pits;
- four active underground operations;
- four inactive underground operations;
- associated waste rock landforms (WRL), mining infrastructure and stockpiles;
- four tailings storage facilities (TSF);
- one in-pit TSF;
- one gold treatment plant;
- one inactive heap leach facility;
- historical mining operations and associated infrastructure; and
- administration facilities and other supporting infrastructure.

2.4 AMD Potential at St Ives

Acid and/or metalliferous drainage generally originates from the exposure of iron sulfide minerals (e.g. pyrite) to oxygen and water resulting in the production of sulphuric acid. The exposure of geological materials to oxygen and water can occur through microbial activity (which produces oxygen) in saturated conditions, or through the mechanical breakdown and sub aerial exposure of materials when disturbed during mining activities (either through mining and materials movement or through dewatering). As the resulting acidic drainage moves through surrounding soil and rock (in waste rock landforms, stockpiles and other mine features), it can react with other minerals to dissolve and liberate metals and salts. The acidic drainage may be neutralised if surrounding rocks contain carbonate materials or other minerals with natural acid buffering capacity, which can dissolve to consume acid. However, even if acid is neutralised, it is common for dissolved metals and salt to remain in solution in the form of metalliferous drainage. If the generation of either acidic, metalliferous, and/or acidic and metalliferous drainage is unmanaged, it has the potential to impact water quality and degrade habitat in the surrounding environment.

The rate of AMD generation and the potential for the AMD to impact the surrounding environment is dependent on numerous factors, including, but not limited to:

- the percentage and distribution of sulfide minerals in the material;
- the mineralogical form of sulfide present;
- the rate of oxygen supply;
- the composition of the pore water with which the sulfide minerals react;
- the absence or presence and availability of neutralising minerals;
- the microbial ecology;
- water flow rates; and
- water flow paths.

The potential for AMD to cause impact at a particular site can be assessed using a source-pathway-receptor model. For potential impact to occur, a potential AMD source must exist, there must be a potential flow path for the AMD to move into the environment, and there must be a sensitive receptor to be affected by the potential impact. The risk of the impact being realised may then be assessed by examining the properties of AMD that may be generated, along with the rate at which a receptor may be exposed to AMD impacted water. The potential sources, pathways and receptors identified at SIGM are discussed in the sections below.

2.4.1 Potential AMD Sources

The potential AMD sources present at SIGM are common to most mining operations. Primary sources, where sulfide minerals contained in materials have the potential to produce AMD, include:

- mined waste material stored in WRL and backfilled pits;
- ore and low-grade stockpiles;
- run of mine (ROM) pads;
- heap leach materials (spent or fresh);
- tailings;
- open pit walls;
- underground workings; and
- other supporting infrastructure (e.g. core yards and laboratories) that contain primary rock waste.

Secondary sources may also lead to generation of AMD. These are generally materials which may be impacted by AMD and contain readily soluble residual minerals or leachate containing elevated levels of metals and/or acid. At SIGM, these sources include:

- ore processing and heap leach infrastructure;
- sediments contained in water retention ponds and open pits containing water;
- surface water infrastructure; and
- seepage from WRL and open pit walls.

This study focuses on understanding the AMD characteristics of mined waste and tailings materials as they represent the dominant potential AMD sources on site. Previous test work and reporting has provided a large amount of information on these materials.

2.4.2 Potential Pathways

Potential pathways for AMD to move from sources to receptors usually involve movement of solid material, or water flow through primary or secondary source materials. Generalised pathways that exist at SIGM include:

- mass movement of waste rock and/or sediment through wind or water transport;
- groundwater flow through open pits or underground operations;
- groundwater dewatering and discharge;
- surface water runoff; and
- surface water infiltration and seepage through WRL, TSF and mine infrastructure.

As the purpose of this study is to assess the knowledge of source material AMD characteristics in order to identify data gaps and optimise the assessment of AMD risk for SIGM, it is assumed that all pathways may provide a link between sources and receptors; however, it is noted that runoff during large storm events presents a dominant process presenting a pathway from potential primary AMD sources such as WRL.

2.4.3 Potential Receptors

When released into the environment, AMD has the potential to impact water quality (groundwater and surface water), soil and sediment quality (through runoff and secondary precipitation of salts and minerals) and soil quality (through the mass movement of solid material). Identification of the ecological habitat and tolerance to impact is important to the development of screening criteria for the assessment of potential impact to flora and fauna receptors.

The environmental context of the SIGM site is outlined in the most current Public Environment Review (PER) (Gold Fields Ltd, 2010). The dominant habitat areas relevant to the site are identified as Lake Lefroy and the Great Western Woodlands. The Great Western Woodlands is one of the largest and most intact temperate woodland areas remaining on the Australian mainland. While the SIGM site is situated within the Great Western Woodlands region, the majority of the operations are located on and around Lake Lefroy.

Lake Lefroy is one of 30 major salt lakes in the Coolgardie bioregion. The Lake is grouped with 13 other lakes in the bioregion, as remnant lakes from palaeodrainage systems. The sub-group of 14 lakes are characterised by elevated calcium, lead, arsenic and potassium, and all tend to exhibit dominant diatom species. Lake Lefroy has a thick halite crust, which is not common to the other lakes, and is dry for the majority of the year. The water is neutral to weakly acidic, and hyper saline (up to 450,000 total dissolved solids (TDS)) and is dominated by sodium and chloride ions.

For the purposes of this study, screening criteria will consider biota populations in the Lake as the dominant receptor. Although other receptors (e.g. vegetation communities and fresh water areas in riparian zones (claypan lakes) are important, the objective of this study is to identify knowledge gaps and highlight areas of potential risk for the purposes of optimisation of AMD characterisation and risk assessments in the future. As the Lake is the dominant surface and groundwater receptor (from dewatering discharge points located on the lake), the assessment will focus on identification of areas of potential AMD generation that may impact biota living in the Lake.

3 Information Review

Existing information on characterisation of mine waste and tailings materials with respect to AMD was reviewed as part of this study. The review focussed on AMD characterisation information relating to waste rock and tailings materials only. This section provides a summary of the information reviewed and an assessment of relevance to ongoing optimisation of AMD practices at SIGM.

3.1 Previous Reports and Information

3.1.1 Waste rock and tailings

Numerous previous studies related to the AMD characterisation and assessment of risk related to AMD potential of mined waste materials and tailings have been undertaken at the SIGM. A complete list of previous reports containing data that was incorporated into this study is presented in **Appendix A**. Prior to 2000, few studies were conducted on the waste and tailings materials. Few samples were submitted for testwork as part of the PER published in 1999 (Dames & Moore, 1999); however, it was noted in the PER that geochemical and mineralogical analyses were routinely undertaken by SIGM. Pyrite occurrences were noted to be associated with zones of mineralisation and were volumetrically very small (Dames & Moore, 1999). Limited testwork (4 samples) is presented in the PER and comprises samples of Victory basalt (location unknown, although likely to be in the Leviathan Complex mine area) and waste and ore from the Intrepide Open Pit area. The limited presence of sulfide minerals, coupled with the presence of carbonate, or acid neutralising minerals was noted with reference to an AMD characterisation study conducted for Kambalda Nickel Mines (report not available for review as part of this study).

The only additional report available prior to 2000, comprised a study of Paris Legacy mine area in 1997, where tailings and miscellaneous samples were assessed for AMD properties and other contamination potential (including metals). Materials were found to be potentially acid forming (PAF), however, the static testwork included only total sulfur, so the acid generation capacity may have been over estimated in the absence of acid neutralising data. Samples were also found to be elevated with respect to heavy metals (arsenic, cadmium, copper, nickel, and zinc) (WMC Resources Limited, 1997).

In 2000, URS Australia Pty Ltd was commissioned by previous site operators WMC Resources Ltd to complete a review of potential AMD issues at SIGM. The review included a site visit to describe the environmental conditions of selected areas with respect to AMD potential. The site visit included the collection and analysis of waste and water samples from selected areas of the SIGM operations (URS, 2000). Criteria for AMD classification was not reported; however, it is interpreted that a combination of net acid production potential (NAPP), net acid generation (NAG) and sulfur percent (%S) were used to classify samples. Where sample lithologies were known (e.g. drillhole samples from the North Revenge Kapai Open Pit), Kapai Slate and one sample of oxide material was found to be PAF. Other materials tested (oxide, basalt and intermediate intrusion) were classified as either non-acid forming (NAF) or potentially acid consuming (AC). Water quality samples were described as similar to background concentrations with respect to pH and salinity; however, calcium-sulfate ratios were elevated with respect to sulfate, indicating that the pit water had been affected by sulfide oxidation. Metals and multi-element testwork was not reported for the waste rock samples.

Limited testwork and reports were available for the period between 2000 and 2005. In 2005, Mehling Environmental Management and O'Kane Consultants began a series of assessments and investigation into the AMD characterisation of waste rock and tailings materials at SIGM. A site wide study was conducted in 2005 (MEMi and O'Kane, 2005), and in the following years, specific studies focussed on the Leviathan Complex, tailings materials and heap leach materials. Several hundred samples were assessed, including historical data, for the Beta Hunt, northern lake-based, Greater Revenge area, northern land-based, Leviathan, southern land-based and underground mining operations, as well as limited mining infrastructure (ROM pad) areas. Classification of samples was conducted using primarily acid base accounting (ABA), using modified-NAPP which calculates acid neutralising capacity (ANC) using total inorganic carbon to avoid over estimation of neutralising potential. NAG testing was conducted for confirmatory purposes. The majority of samples were classified as NAF, with a subset classified as uncertain (UNC) and only a small number of samples classified as PAF. Metals analysis was also conducted, although the initial analysis was conducted at a high dilution ratio. Re-testing was conducted at a lower dilution ration (2:1). Results found consistently elevated levels of sulfate, as well as high levels of soluble alkalinity (in the form of carbonate) and elevated heavy metals (predominantly molybdenum). Elevated levels of other heavy metals (cadmium, cobalt, copper, nickel and zinc) were reported in samples with lower pH (MEMi and O'Kane, 2005).

In 2007, a study on tailings materials was conducted by Mesh Environmental and O'Kane Consultants (MESH and O'Kane, 2008). A similar classification scheme to the 2005 study was used to conduct a detailed characterisation of TSF 1 and a high level characterisation of TSF 2 and TSF 3. The tailings in TSF 1, 2 and 3 were produced from two carbon-in-leach plants, only one plant is currently in operation. The plants processed both primary and oxide ore from all active mining areas, resulting in a blended geology throughput to the plants. Both fresh and historical tailings were classified as predominantly NAF, with two samples classified as UNC and one sample classified as PAF. Total metals and leach extractions were conducted. Leaching found elevated levels of salts and metals (MESH and O'Kane, 2008).

From 2008, regular sample collection, static ABA analysis and classification of waste rock and tailings materials has been conducted at SIGM, generating data for between 100 and 200 waste rock samples per year. Results are available in primary laboratory reports, summary reports, specific mining operation approval documents and environmental compliance documents. The testwork has been conducted in accordance with SIGM environmental procedures (Gold Fields Ltd, 2009) and the majority has been classified using ABA using modified-NAPP which calculates ANC from total inorganic carbon. A lesser amount of NAG testing and metals testing has also been reported. To date, testwork has comprised only static geochemical test work; however, the majority of samples are classified as NAF or AC, with lesser numbers of samples classified as PAF (various references, refer to **Appendix A**).

3.1.2 Key Sulfide Mineralogy

Mineralogical testing conducted in several studies has provided some information on sulfur mineralogy present in the waste materials tested. Sulfide minerals identified in field descriptions and in x-ray diffraction testwork included pyrite, pyrrhotite and arsenopyrite. (MEMi and O'Kane, 2005; SIGM internal site note on Geology). Sulfide mineral occurrence at SIGM is closely realted to gold mineralisation, so varies in type and distribution depending on the host lithology. It has been observed that sulfide mineralogy displays a zonation from north to south along strike of the mineralised shear zone. Where mineralisaiton is hosted in the lower units of the stratographic sequence, pyrite is dominant mineralogy. Moving upwards through the sequence, host rocks in the central parts of the sequence are dominated by pyrite-magnetite, while sulfide mineralgoy in the sourthern mining areas, which are hosted in younger stratigraphies have higher proportions of pyrrhotite and arsenopyrite with pyrite (Connors *et al*., 2005; annotated in MEMi and O'Kane, 2005)

Mineralogical testwork conducted on various waste rock samples (geology not noted) found pyrite as a major sulfide mineral located in ore zones, with accessory amounts of pyrrhotite, chalcopyrite, marcasite, molybdenite, galena, and sphalerite. Secondary iron oxide and oxyhydroxide minerals were also detected (magnetite, ilmenite,goethite and heamatite) (AMMTEC, 2002). Carbonate mineralogy included calcite, dolomite as well as silicate minerals (including clay minerals and feldspars) that provide minor acid neutralising properites compared to carbonate minerals (AMMTEC, 2002). On this basis, the estimation of risk of AMD generated from oxidaiton of pyrite is considered to be a reasonable approach to the evaluation of previous data sources. Although other sulfide mienrals may be present, assessment based on the assumption that all sulfide minerals occur as pyrite is considered to be an appropriately conservative assumption.

3.2 Data Sources

A total of 3175 individual analysis relating to acid generation potential were collated from over 100 individual consultant or laboratory reports. A list of data sources is provided in **Appendix A**. Data mainly comprised paste pH and paste EC, ABA testwork (sulfur analyses, ANC, NAPP), carbon species analysis (as part of modified-NAPP procedures) NAG testwork and calculations to assist with classification of samples. A statement of data validation and the relevance of testwork is discussed in **Section 5.1**.

The raw database used to assess the distribution of selected metals across site was adapted from the drillhole database provided by SIGM (Drill Multi Elements ESRII layer, provided in August 2015). Data comprised geochemical assay results for exploration and ore definition drillholes, sampled for a typical XRF total metals suite (49 elements). The logged stratigraphy of the samples was also recorded.

3.3 SIGM Procedures and Standards

SIGM have several procedures and standards relating to the characterisation and management of potential AMD sources at the site. The procedures and standards reviewed as part of this study are:

- SIG-ENV-PR032 Identification and Management of Waste Rock Materials Characterisation (Gold Fields Ltd, 2005)
- SIG-ENV-PR030 Identification and Management of Acid Rock Drainage (Gold Fields Ltd, 2009);
- SIG-ENV-STD012 Waste Rock and Stockpile Management (Gold Fields Ltd, ver 6); and
- SIG-ENV-PR007 Waste Dump Design, Construction and Water Management (Gold Fields Ltd, 2005).

SIGM procedures for identification and management of acid drainage, and identification and management of waste rock materials characterisation, outline the process for sampling, testing and classification of waste materials during resource planning and operational phases of mining (Gold Fields Ltd, 2009; Gold Fields Ltd, 2005). While the former procedure relates mainly to the characterisation of acid generation potential and the latter procedures relate mainly to the characterisation of waste materials in order to determine placement and use in construction of WRL, there is considerable crossover, duplication and contradiction of the procedures with respect to characterisation of AMD properties of the mined waste material. It is noted however, that this has not impacted the continuation of waste rock sampling and classification at SIGM.

Review of the analytical requirements and classification criteria presented in the SIGM procedure for identification and management of acid drainage revealed some gaps in the prediction methods (related to NAG and total and leachable metals analysis) and use of a simplified method for classification which relies of acid base accounting (ABA) approaches only. The classification approach outlined in the procedure has been taken into account in the determination of ABA criteria outlined in **Section 5.2.4**.

While the current procedures are not incorrect, more complete testwork would provide a more comprehensive assessment of AMD characteristics. It is recommended that the SIGM procedures related to identification and classification of waste materials be reviewed to incorporate more comprehensive prediction testwork as well as a revised classification scheme. In addition, the procedure relates to testing of mine waste materials only. It is recommended that the procedure be reviewed to incorporate testing of other potential AMD source materials, such as tailings and stockpiled material.

The SIGM procedures discussed previously, along with the procedures for WRL design, construction and water management, and the standard for the management of waste rock and stockpiles, outline the procedures for characterisation, design and location of temporary and permanent landforms to prevent any adverse impact from AMD (Gold Fields Ltd, ver 6; Gold Fields Ltd, 2005). Management strategies described in the standard and the procedure identify the need to isolate materials that have the potential to generate AMD and manage them separately from other waste materials. The recommended management strategies detailed within the procedures are:

1. Selective handling and encapsulation of materials within benign, non-acid producing or acid consuming materials.
2. In-pit disposal.
3. Blending/co-disposal of materials with benign, non-acid producing or acid consuming materials.

These management measures are commonly employed in mining operations to limit the exposure to oxygen and water of potential AMD source materials and are considered to be appropriate. Further assessment of management measures should be considered in relation to the development of final landform designs to manage surface water and support rehabilitation activities as part of closure planning at the site. It is understood that current closure planning projects incorporate consideration of AMD risk in the development of WRL and TSF closure strategies.

4 Local Geology

The geology of the mining operations is focussed on the mineralised zone controlled by the Boulder-Lefroy Fault. Because the SIGM mining area covers a considerable distance from Caves Rocks to the north, along strike of the fault to Junction mine area in the south, host rock geology varies considerably. In general, the northern mining areas are dominated by older host rocks situated lower in the stratigraphic sequence (**Figure 2-2**). Moving south along strike of the fault, host lithologies generally move upward through the stratigraphic sequence, following the plunge of the anticline structure of the basement rocks.

For the purposes of this study, the assessment of AMD potential has been conducted by lithology in order to identify data gaps and opportunities for optimisation of AMD characterisation in the future. This provides a site-wide approach to the understanding of AMD characteristics for rock types that are mined across several mining areas. It will also assist in identifying the location of materials within WRL to assist in closure and rehabilitation studies in the future.

Lithologies were assigned based on the geological description of waste material sample logs. Confidence levels of 1 (high level of confidence) to 3 (low level of confidence, or unknown lithology) were assigned, based on the quality of logs provided. Rare, or undifferentiated rock types, along with samples of unknown lithology (confidence level of 3), topsoil, ore and miscellaneous materials were removed from the data set resulting in the review of 2996 samples for acid generation potential. The samples were grouped into 18 representative lithological units. Descriptions of the representative geology are provided in **Table 4-1** below.

Table 4-1: General Geological Descriptions

Lake sediment	Occur as an upper layer of saturated to semi-saturated sand and clay. The thickness of the unit varies up to 80 metres (m), but is generally around 10 m thick over lake-based open pits.
Tertiary sediment	Transported sand, silt and clay in consolidated and unconsolidated sequences up to 25 m thick. The sediments are generally associated with palaeochannels and for lake-based areas may be recorded as Lake sediments on logs. Rock types also include ferricrete duricrusts, laterite and minor calcrete.
Upper Saprolite	Included samples are logged as oxide, saprolite, saprolitic clay and saprock. The unit is characterised by a typical deep weathered regolith profile of saprolitic clays with laterite and minor sands.
Merougil Creek Beds	Pale grey to cream volcanic quartz wacke, sandstone, and minor conglomerate units.
Black Flag Beds	Epiclastic and volcaniclastic mudstone, siltstone, sandstone/quartz wacke, conglomerate and breccias.
Cave Rocks Sediment	Generally logged as siltstone and mudstone with minor sandstone and black shales.
Kapai Slate	Dark grey to black sulfidic volcaniclastic mudstone with cream-coloured siltstone.
Cave Rocks Dolerite	Cave Rock, Condenser and Defiance dolerites are similar, exhibiting a zonation from aphyric (lacking in phenocrysts) to coarse cumulate-type textures. Chemically they are iron-rich and have undergone amphibolite facies metamorphism.
Condenser Dolerite	
Defiance Dolerite	
Lunnon Basalt	Dark grey to dark green massive and pillow basalt with lesser shear-associated breccia and rare interflow siltstone. Visually the Lunnon basalt is very similar to the Paringa and Devon Consols basalt.
Devon Consols Basalt	Dark grey to dark green massive and pillow basalt with minor dolerite. Compared to the Lunnon and Paringa basalt, it has higher magnesium and epidote alteration associated with varioles.
Paringa Basalt	Dark grey to dark green massive and pillow basalt with rare interflow sediments.
Tripod Hill Komatiite	This unit includes samples logged as Silver Lake Peridotite (high-magnesium member) and ultramafic. The Tripod Hill Komatiite (also known as the Kambalda Komatiite) is a grey-green to grey-purple talc-rich komatiite. It is commonly zoned with a cumulate base and spinifex texture upper component.
Felsic intrusive	Dominated by quartz phenocrysts.
Intermediate intrusive	The units include in this lithology comprise Proterozoic dykes and flames porphyry. The intrusives generally cross cut the older stratigraphy and rock types vary from granodiorite to porphyritic units with large quartz phenocrysts in a mafic matrix.
Mafic intrusion	Comprise dolerite, lamprophyre and minor Proterozoic age dykes.
Tailings	Generally dark green to dark grey with minor brown layers with mafic minerals, quartz, feldspar, and trace sulphides ranging from clay to fine sand sized (MESH and O'Kane, 2008).

5 Data Analysis

A description of methodology and approach to interpretation and collation of the data for this study is described in this section. Tables containing the data results for acid generation potential assessment of each lithology are presented in **Appendix B**. The raw database used to assess the distribution of selected metals across site was adapted from the drillhole database provided by SIGM (Drill Multi Elements ESRII layer, provided in August 2015). Due to the size and complexity of the database, raw data is not presented with this report, but is available on request from SIGM.

5.1 Data Validation

Due to the large volume of data collated for this study, individual data validation assessments were not conducted on each consultant report and laboratory report. It is noted that quality assurance and quality control sampling was not reported in any of the reports reviewed. Given the large numbers of samples collated, the lack of duplicate sampling to provide assurance on repeatability of results is not considered to be important in the assessment of the data.

Data related to acid generation potential was provided in primary laboratory reports and consultant reports (as tabulated data). In most cases, data was able to be transposed directly into tables to minimise transcription errors. For tabulated data and manually entered data, transcription may have resulted in minor errors; however, they are not likely to have significantly affected the overall interpretation of the data. It is noted that, due to sample collection procedures and the distance of the site from laboratory facilities, there are likely to be non-compliances related to sample holding times and preservation techniques. The non-compliances are not likely to influence interpretation of the data as the samples generally would have been collected and stored out of weather prior to transport to laboratory facilities. Where possible, conservative approaches were used in the interpretation of data (refer to **Section 5.2**). Where results were questionable or unclearly reported in relation to units of measurement, or detection limit annotations, reasonable judgement was employed to modify data, or samples were omitted from statistical analysis. Some parameters that recorded values below detection limit were modified to zero values to allow calculation of ABA results (refer to **Appendix B**).

The purpose of this study is to assess the knowledge of source material AMD characteristics in order to identify data gaps and optimise the assessment of AMD risk for SIGM. On the basis of the assessment objectives and the quality and interpretation of the acid generation potential data provided, the overall quality of the analytical results is considered to be acceptable for interpretive use.

Data related to assessment of impact from metals present in waste rock materials has been interpreted from a geographical information systems (GIS) data base of drillhole sample assays provided to MWH by SIGM. Due to the volume of data provided it was decided that a high level overview of the distribution of selected metals would be assessed in order to highlight areas and geological units that may be of higher risk. The data was adapted in its raw, electronic form and was assumed to be acceptable for interpretive use.

5.2 Assessment of Acid Generation Potential

Two methods for prediction of net acid, or acid drainage potential are commonly used:

1. Acid base accounting (ABA) – which measures the likely acid generating potential and neutralising potential independently to determine net acid production; and
2. Net acid generation (NAG) – which measures net acid generated with neutralisation occurring simultaneously.

The ABA methodology calculates the acid generation capacity through separate testing of the acid generating and acid neutralising properties of the sample material. The maximum potential acidity (MPA) is a measurement of the acid that can be generated from the oxidation of sulfide minerals. The ANC is a measurement of the neutralisation properties of the material which is related to the presence of carbonate minerals and, to a lesser extent, silicate minerals. The NAPP is then calculated from the difference between the MPA and ANC values using the following formula.

$$NAPP = MPA - ANC$$

NAG methodology calculates the resulting acid generation capacity of a material during a single test, during which rapid oxidation of the sample allows acid generation and acid neutralisation reactions to occur simultaneously.

5.2.1 Statistical Analysis

Statistical summaries of the assessed data are provided in **Appendix C**. Statistical analysis of the data included calculation of maximum, minimum and mean values, as well as a record of the number of values reported for each parameter (n). The amount of variation in data was assessed using the standard deviation and boxplots. In general, a lower standard deviation (<2) indicates that the data is clustered more closely about the mean value, which indicates that the mean provides a reasonable estimate of the average data value recorded. Boxplots were plotted for each of the selected parameters. A boxplot shows the central tendency and variability of a data set. The interquartile range box (grey box) represents the middle 50% of data, while the upper and lower whiskers represent the 25^{th} and 75^{th} percentile distribution respectively. Outliers are shown by an asterisk beyond the upper or lower whisker. In general, the wider the distribution between the interquartile range and the upper and lower whiskers indicates a more variable data set. A larger number of outliers, also indicates a wide variation in the data and may indicate that separate populations of data may be present depending on the spread and grouping of outliers. A larger variation in the pH, EC, and sulfur values, means that the ABA characteristics may be more difficult to predict based on logged lithology alone; however, this would also depend on the overall classification results for each lithology.

5.2.2 Acid Base Accounting

The ABA methodology was used as the only basis for assessment of acid generation potential for the majority of samples reported in the data (72%). The ABA results of samples were assessed by graphical comparison of acid potential (AP) determined from MPA, against neutralisation potential (NP) determined from ANC. The charts are divided into areas that are NAPP negative, indicating that the sample is not likely to be acid generating, and NAPP positive, indicating that a sample is likely to generate acid. A NP/AP ratio line is depicted, where NP/AP is equal to two. Samples that plot above this line are generally considered to have a high enough NP that samples will not be at risk of generating acid. The approach used to determine the acid and neutralisation potential of the samples is described in the sections below.

5.2.2.1 Assessment of pH and EC

An assessment of physiochemical components, pH and electrical conductivity (EC), for each lithology was made using statistical analysis. The data was analysed statistically to obtain representative values, which were then compared to reference site values, to determine if waste materials and tailings exhibit characteristics that may indicate potential impact from generation of acid. Generally, waters and sediment impacted by AMD generation have a low pH (<4.5) and elevated salinity, due to release of sulfate during the oxidation reaction.

For the purposes of assessing the relationship between waste and tailings material chemistry, lake sediment physiochemical background values were chosen to represent the average characteristics of the receiving environment. As the physiochemical parameters (pH and EC) are assessed using a saturated paste consistency (one to one soil: water ratio), is it more appropriate to compare data to sediment quality parameters rather than water quality parameters.

Sediment pH was reported in 2010 for surficial lake sediments located at reference, interim and groundwater discharge sites on Lake Lefroy (Dalcon Environmental, 2010). The pH ranges for each site type is presented in **Table 5-1**.

Table 5-1: pH Ranges for Background Lake Sediment Samples on Lake Lefroy (Dalcon Environmental, 2010)

Reference sites	pH 4.4 to pH 8.5
Interim sites	pH 6.9 to pH 8.3
Discharge sites	pH 7.2 to pH 8.3

The EC of the lake sediments was not measured at each of the reference sites. The range in background EC of lake water quality was reported from historical fill events (117 mm and 35 mm fill events occurring in 2009). In the absence of sediment salinity values, EC was compared to background lake water quality which ranged between 123,000 and 243,000 micro-Siemens per centimetre (uS/cm) (Dalcon Environmental, 2010).

5.2.2.2 Assessment of Maximum Potential Acidity

Total sulfur content is commonly used to calculate MPA on the basis that all sulfur present in a sample is in the mineral form of pyrite (FeS_2). Where other forms of sulfur may be present in the sample (e.g. in sulfate minerals such as gypsum, secondary mineral precipitates such as jarosite, or other sulfide minerals forms such as arsenopyrite or pyrrhotite) this assumption can lead to the over-estimation of MPA. Where possible, it is preferred that sulfide sulfur is used to calculate MPA, as this value represents the sulfur content of the sample that is available for oxidation to form sulphuric acid which is usually in the form of sulfide minerals. Although the presence of sulfide minerals other than pyrite in a sample may still lead to an over estimation of MPA, this approach is considered to be a better method to estimate the acid generation potential of a sample compared to the use of total sulfur.

The collated data (**Appendix B**) included a combination of sulfur analyses including:

- total sulfur (%S);
- sulfate sulfur (sulfate as milligrams per kilogram (mg/kg) SO4);
- sulfate sulfur (as %S);
- sulfide sulfur (%S); and
- total oxidisable sulfur.

In most cases, either sulfide sulfur was reported, or a combination of total sulfur and sulfate sulfur results were reported enabling the calculation of sulfide sulfur content. Where sulfide sulfur results were available, MPA was calculated using this value. Where only total sulfur content was reported, MPA was calculated using the total sulfur value. It is noted that the latter calculation represents a conservative approach to the estimation of NAPP and in cases where sulfide minerals other than pyrite are present, may overestimate MPA produced from waste materials. The samples that were assessed using the conservative approach represent a minor portion of the total data assessed (2%).

The assumption that all sulfide is present as pyrite is used in the calculation of MPA as the oxidation of pyrite produces the largest amount of acid in its reaction products. This practice results in a conservative estimation of MPA as other non-pyritic sulfide minerals generally oxidise at lower rates and release less acid compared to pyrite. At SIGM, the presence of non-pyritic sulfide minerals, including pyrrhotite, arsenopyrite, chalcopyrite and galena, has been determined using field observations and XRD analysis (**Section 3.1.2**). Therefore, the estimation of MPA using the assumption that all sulfide is present as pyrite represents a conservative approach. The use of a conservative approach for the estimation of MPA enables this study to be undertaken as a reasonable, worst case scenario for the assessment of risk of acid generation at SIGM.

In addition to refining the method of calculation of MPA, the ratio of total sulfur to sulfide sulfur was examined graphically for each lithological unit. This approach gives and understanding of the dominance of sulfide species in different lithologies across the site in order to understand which units have a higher potential to generate acid.

The acid generation capacity was grouped into different categories using the reported sulfide value (or total sulfur value where relevant) according to the scheme described in **Table 5-2**.

Table 5-2: Acid Generation Capacity Grouping Scheme

Total Sulfide Value [1]	Grouping
<0.1%S	Barren[2]
>0.1%S and <0.3%S	Low acid generation capacity
>0.3%S	High acid generation capacity

Notes:

Criteria developed with reference to the GARD Guide (INAP, 2009) and the AMIRA International ARD Test Handbook (AMIRA, 2002).

[1] Where total sulfide values were not reported total sulfur values were used to determine acid generation capacity.

[2] Barren samples are considered to have minimal acid neutralising capacity and low sulfur content.

5.2.2.3 Assessment of Acid Neutralising Capacity

The method commonly used to determine ANC involves reacting (with heating) the sample with acid and determining the amount of acid consumed during neutralisation reactions (AMIRA, 2002). As this process does not distinguish between readily available neutralisation capacity and less available neutralisation capacity (which can vary depending on the acid-buffering mineralogy in the sample) the amount of ANC can be overestimated. In addition, the presence of organic compounds, and pyrrhotite in the samples can also lead to the overestimation of ANC.

An alternate method for the estimation of ANC involves calculating the available neutralising potential on the assumption that all inorganic carbon present in the sample is in the form of calcium carbonate. In reality, neutralisation potential is available from a variety of carbonate and silicate minerals including:

- calcium and magnesium carbonates (calcite, aragonite, magnesite);
- soluble clay-silicate minerals (chlorite, kaolinite);
- oxides and oxyhydroxides; and
- to a lesser extent, phosphate minerals.

In addition to calculated ANC, the acid buffering characteristic curve test (ABCC) can be undertaken. This test involves the slow reacting of a sample with acid to determine neutralisation potential. The ABCC data can provide a closer estimation of the portion of ANC that is readily available to neutralise acidic generated during the oxidation of sulfide minerals (AMIRA, 2002). MEMi and O'Kane (2005) conducted ABCC tests on a select number of samples and found agreement between calculated ANC (based on inorganic carbon content) and the effective ANC measured with the ABCC test. For this reason, neutralisation potential was determined using calculated ANC where total inorganic carbon results were reported. Where total inorganic carbon was not reported, measured ANC was used to determine neutralisation potential, which may result in an overestimation of ANC for some samples, although they represent a small portion of the total data assessed (9%).

5.2.3 Assessment of Net Acid Generation

Net acid generation (NAG) was reported for approximately one quarter of the data assessed (28%). The assessment of NAG is generally required to determine an accurate classification of acid generation potential. In general, a NAG pH of <4.5 pH units is considered to represent a sample that has the potential to generate acid. The NAG test has been known to overestimate acid generation capacity where organic acids may be present in a sample, and may underestimate acid generation potential where high sulfide values are recorded. In general, when used in combination with ABA, it improves the prediction of acid generation potential and reliability of interpretation of results (INAP, 2009).

5.2.4 Acid Drainage Potential Classification

The SIGM procedure for the identification and management of AMD classifies material into three categories based on modified acid base accounting and acid neutralising/acid producing ratio, based on guidance published by the Department of Mines and Petroleum – Environment (Gold Fields Ltd, 2009). The previous consultant reports provide varied classification criteria, closely related to criteria established in the AMIRA International ARD Test Handbook (AMIRA, 2002).

As this study is focussed assessment of potential AMD risk associated with waste rock and tailings materials for SIGM, a hierarchical and simplified classification scheme is proposed (Table 5-3) based on the GARD Guide (INAP, 2009) and the AMIRA International ARD Test Handbook (AMIRA, 2002). As the majority of samples provide assessment of ABA only (72%), the proposed scheme allows the assessment of potential AMD risk where NAG data is not provided, using the lower Hierarchy Two criteria. It is noted that this scheme does not aim to quantify acid generation capacity, or classify samples according to criteria, so should not be used for the quantitative classification of AMD potential. Hierarchy One results are assigned to traditional ABA classification groupings where ABA and NAG results are available. Hierarchy Two results are assigned to classification groupings with a prefix “potentially” denoted by a “P”, where ABA and NAG values were conflicting, or where only ABA results were available.

Where both ABA and NAG results were available (Hierarchy One classification), acid generation potential was assessed using charts where the ABA result (reported as NAPP) is plotted against the NAG pH result. The chart area is grouped into areas of PAF, NAF and UNC. An additional chart area is presented, where NAPP is < -20 kg H_2SO_4/t. This area indicates samples that are likely to have excess NP available, and exhibit acid consuming (AC) properties. Acid consuming potential is only indicated in the chart areas, as it is only indicative in the assessment of AMD risk undertaken in this study, and is only applicable to samples where both ABA and NAG results are available.

Table 5-3: Classification Scheme for Identification of Potential AMD Risk.

Hierarchy	ABA	NAG_{pH}	%S[1]	Classification
One	NAPP < 0 kg H_2SO_4/t	pH >4.5	<0.1	NAF - barren
			>0.1	NAF
		pH <4.5	<0.1	Potentially NAF
			>0.1	UNC
	NAPP > 0 kg H_2SO_4/t	pH >4.5	<0.1	Potentially NAF
			>0.1	UNC
		pH <4.5	>0.1 and <0.3	PAF – Low capacity
			>0.3	PAF – High capacity
Two	NAPP < -10 kg H_2SO_4/t	NA	>0.1	Potentially NAF
	NAPP between 0 and -10 kg H_2SO_4/t	NA	>0.1	UNC
	NAPP < 0 kg H_2SO_4/t	NA	<0.1	Potentially NAF
	NAPP > 0 kg H_2SO_4/t	NA	<0.1	Potentially NAF
		NA	>0.1	Potentially PAF

5.3 Assessment of Elevated Metals

The assessment of impact due to release of metals and metalloids is traditionally conducted through the comparison of levels of total metals in solid materials, and leachable or dissolved metals in liquid materials to published guideline criteria developed for the purposes of assessing risk to ecological receptors.

Over large parts of inland Australia, many water bodies, like Lake Lefroy, only contain water temporarily and have wet and dry periods that are driven by climatic controls which result in long periods of dryness, or drought, followed by prolonged, heavy rainfall (ANZECC, 2000). Ephemeral salt lake systems often display a large variability in water quality and water quality trends presenting issues in the assessment of impact due to the following factors:

- highly variable flow regimes are related to toxicant concentration, which leads to variable background levels depending on the current flow regime in the water body;
- wetting and drying cycles present pulsed exposures to receptors, whereas toxicant trigger values are determined on the basis of a chronic exposure to the receptor;
- current published guidelines do not account for modification of assessment criteria to account for periods where water flow is low of negligible; and

- the size and variability of wet and dry areas make sampling logistically difficult.

In the absence of reliable site specific background data, the guidelines generally recommend that impact to receptors in salt lake environments is assessed using marine water quality guidelines. The impact associated with solid components entering water bodies is assessed by comparison of total metals results to interim sediment quality guidelines (ISQG), which comprise two guideline values; low, and high. The low value indicates the concentration above which biological effects rarely occur, while the high value indicates the concentration above which biological effects would possible occur. The ISQG values are generally considered to be conservative estimation of potential impact, but provide an indication of the levels at which metals and metalloids may be bioavailable (ANZECC, 2000). ISQG values for selected metals are shown in **Table 5-4**.

Previous research on Lake Lefroy has identified preliminary site specific background values for lake sediments and water quality (Dalcon Environmental, 2010). Dissolved or leachable metals concentration data are reported in limited previous AMD reports (**Section 3.1.1**); however, variable leaching ratios were used and different metals are reported and analysed in each case. Due to this variability in the data, it was decided that the assessment of elevated metal potential would be assessed on a qualitative assessment of the total metals data provided in the SIGM drillhole database.

Research on aquatic biota in saline lake systems in inland Western Australia, including studies on Lake Lefroy, have identified a variety of aquatic invertebrate fauna inhabit the lake systems, which vary between dormancy and activity depending on the water flow regime, and salinity within the lake. Assessment of impact to the biota has focused on metals that are known to bioaccumulate in saline water species, including copper, lead, selenium, silver and zinc (MWH, 2015). Due to the large amount of metal data provided in the drillhole database, this study has focused on assessing the potential risk of elevated metals in sediments entering Lake Lefroy. The trigger levels are based on screening criteria developed using the reference sediment quality data and ISQG trigger values of those metal species that have the potential to accumulate in aquatic species, with a further limitation to metals that are likely to remain soluble at pH 6.0 to pH 8.0. This includes arsenic, chromium, copper, lead, selenium and zinc.

The lowest values from the three criteria was adopted as a trigger value. For copper and zinc, this value was the reference sediment quality value. For both lead and selenium, 95th percentile values (low and high) for reference sites were below detection limit. ISQG-Low value has been adopted for lead, while selenium has been assessed using the detection limit of 5 mg/kg for a worst case scenario approach.

The drillhole data was screened against the adopted trigger values, which are summarised in **Table 5-4**. Results exceeding the trigger value were plotted using GIS software enabling a spatial assessment of mine areas and lithologies where risk of elevated levels of metals are identified. It is noted that this approach presents a conservative high-level assessment of potential for elevated metals in waste rock and tailings to present a risk to receptors in Lake Lefroy; however, this approach is considered to be appropriate to highlight areas that may require further investigation to understand potential risks.

Table 5-4: Criteria for Assessment of Potenital risk Associated With Sediment

Element	Reference Sediment Data[1] (mg/kg)	ISQG-Low[2] (mg/kg)	ISQG – High[3] (mg/kg)	Adopted Trigger Value (mg/kg)
Arsenic	9.3	20	70	9
Chromium	195.6	80	370	80
Copper	16.2	65	270	16
Lead	<5	50	220	50
Selenium	<5	ND	ND	5
Zinc	29	200	410	29

Notes:

[1] Represents 95th percentile low value (Dalcon Environmental, 2010)

[2] ISQG – Low: concentrations above which biological effects rarely occur

[3] ISQG – High: concentrations above which biological effects would possible occur

ND = No trigger value data is published

5.4 Assessment of AMD Risk

Risk assessment provides a logical and comprehensive basis for decision making, provides process transparency, informs decision making and can provide input into prioritisation of future work. A framework for assessment of risk associated with AMD at SIGM is adapted from the GARD Guide (INAP, 2009). The risk framework Stages are outlined as follows:

1. Establish baseline environmental conditions and criteria against which to assess impact – soil, groundwater and surface water (saline and fresh sources).
2. Identify risks – define potential AMD source materials, pathways and receptor populations and sensitivities.
3. Analyse risk – conduct AMD characterisation (using static and kinetic tests) and evaluate risks with assigned certainty.
4. Assess and Prioritise risk – compare results with criteria and identify and prioritise gaps.
5. Manage/treat risks – apply management strategies to appropriately manage high risk and low risk areas, develop contingencies.
6. Review and monitor – monitor pathways and receptors to assess effectiveness of management and review risk assessment as required.

The results of this study aim to add to the current knowledge in Stages Two, Three and Four of the risk framework. The purpose of the overall risk assessment undertaken in this study is to highlight areas of the SIGM site, or particular lithologies where:

- there is less information on AMD characteristics;
- there is a high level of uncertainty around AMD characteristics;
- there is a high volume of PAF material or a high capacity for acid generation; and/or
- there may be elevated levels of metals in waste materials.

Recommendations for developing knowledge in other Stages of the risk assessment framework, to assist in developing a life of mine approach to the assessment and management of AMD risk at SIGM are discussed in **Section 8.3**.

5.4.1 Risk Matrix

An AMD risk matrix has been developed to assess overall AMD risk through examination of sample representation, pH, sulfide sulfur, ABA results, acid drainage potential classification (with a reliability assessment of the classification results) and elevated metals potential.

Sample representation is given a rating of 'Good' or 'Low'. 'Good' ratings represent lithologies where the percentage of samples in the assessed data correlate or exceed the estimated volumes of lithology mined. A 'Low' rating represents samples with less than 50 samples (denoted by a "1") or where the percentage of samples in the assessed data is significantly less than the estimated volumes of lithology mined (denoted by a "2").

The pH and sulfide sulfur risks are assessed using the statistical summary data. The average pH is described, and a higher risk may be present where pH is more acidic. The sulfide sulfur data is rated based on the percentage of sulfide in the majority (75^{th} percentile) of the samples for each lithology. 'Barren' represents samples where sulfide sulfur is near or less than 0.1 %S, 'Low Sulfur' represents samples where sulfide sulfur is less than 0.3%, 'Moderate' represents samples where sulfide sulfur is generally less than 1 %S, while 'High' represents samples where sulfide sulfur is higher than 1%.

The ABA risk is related to NAPP values, negative NAPP values are of lower risk than positive NAPP values. Samples with the majority of results reporting positive NAPP values are highest risk. Lithologies with a NP/AP of more than 2, have the lowest risk potential of generating acid. The potential acid generation risk is summarised by the classification (PAF or NAF) that the majority of sample results report. The reliability of the classification is a subjective rating, based on the sulfide sulfur percentage, the number of samples able to be classified using Hierarchy One classification groupings, and the number of samples classified as UNC. A rating of Low, Good or High is given in order of increasing reliability. Metals exceeding the nominated trigger values for each lithology are noted; however a risk factor is not assigned as an exceedance of total metal trigger value does not necessarily represent a potential impact to an aquatic environment. The overall AMD classification risk has been qualitatively assessed using a combination of all the data provided.

6 Acid Drainage Potential Results

Data tables providing raw data and acid generation potential classification are provided in **Appendix B**. Statistical summary tables are provided in **Appendix C**. Chart summaries of the data are provided in the attached **Figure 1** to **Figure 6**, which present charts for sulfide, ABA and classification assessments. Summaries of the results by lithology are provided in the sections below.

6.1 Lithological Representation of Data

From the 3175 available analyses, 2996 samples were able to be assigned into 18 major lithological units. Missing sample logs, and sample logs with minor or ambiguous geological descriptions were omitted from the dataset used for the assessment of AMD potential. Of the 2996 samples, approximately 93% (2777 samples) were assigned lithologies with a Confidence Level One, which provides a high degree of confidence that the AMD risk is able to be assessed by lithological unit. **Figure 6-1** presents the total sample numbers of each representative lithology for the 2996 samples that had Confidence Level One and Two lithological data.

The majority of assessed samples comprise basalt and dolerite units (Devon Consols Basalt, Paringa Basalt, Cave Rocks Dolerite, Defiance Dolerite and Condenser Dolerite) with over 200 individual samples reported for each lithology. Lithologies with less than 50 samples include; Merougil Creek Beds, Kapai Slate, Lunnon Basalt and mafic intrusion. A low number of samples may not impact overall AMD risk assessment, as it will depend on the variability of the reported data.

The volume of mined waste material is recorded monthly at SIGM. Analysis of this data was not carried out as part of this report; however, an estimated volume of mined material was made based on the recorded ore host rock which was provided by SIGM (Gold Fields Ltd, 2015). **Table 6-1** shows the percentage of each lithology represented in the data analysed, and the estimated percentage of the material mined over the last 20 years of mining. Tailings, sediment and dolerite from Cave Rocks is excluded from both percentage calculations as these were not included in the mined material record (Gold Fields Ltd, 2015).

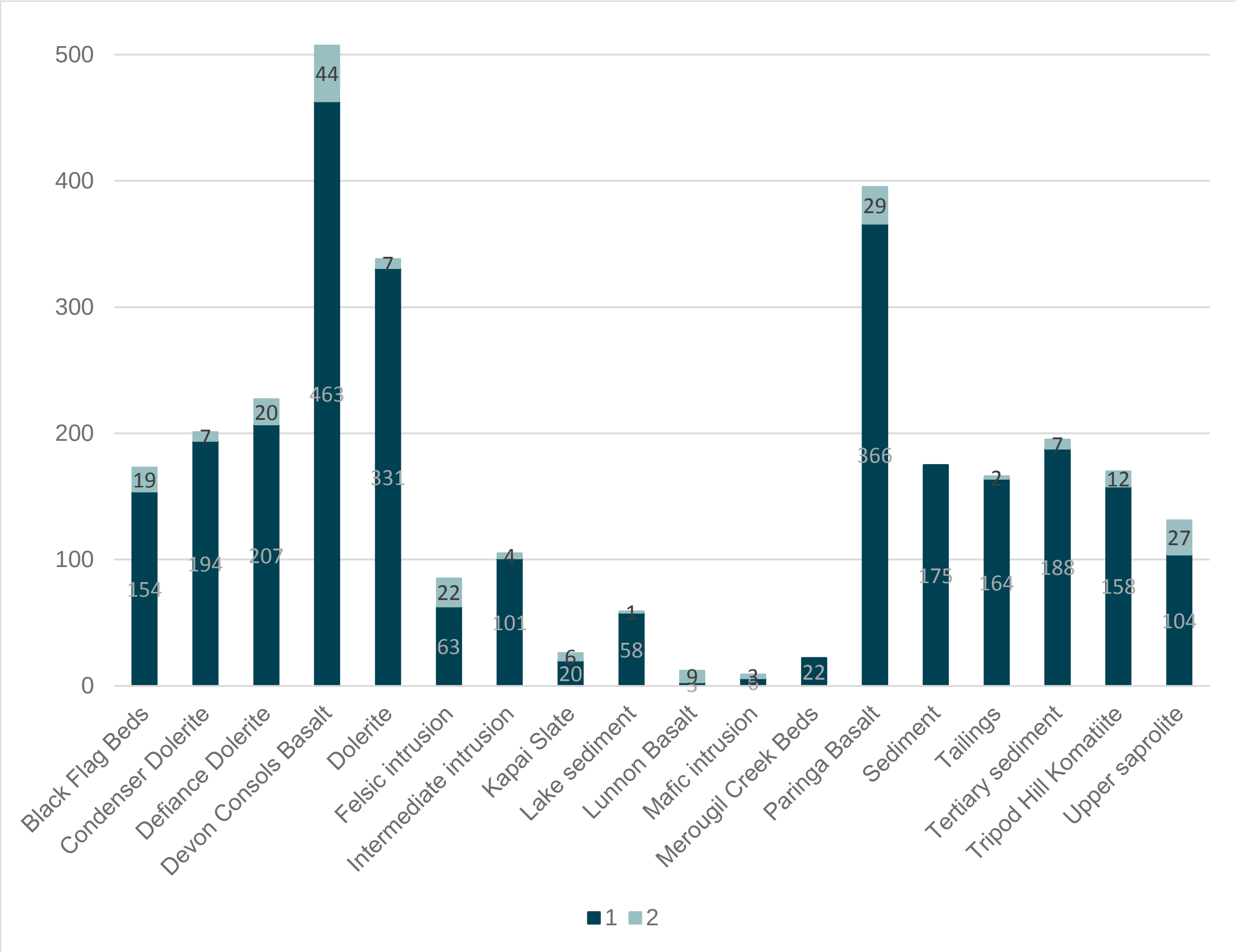


Figure 6-1: Data Numbers for Representative Lithologies Assessed for AMD Potential (Categories Represent Lithological Classification of Confidence Levels 1 and 2)

Notes:

“Dolerite” and “Sediment” lithologies refer to Cave Rocks dolerite and Cave Rocks sediment respectively.

Although not all separate representative lithologies are recorded (due to a difference between the recoded mine lithology and the logged waste rock lithology), the majority of mined material is recorded as dolerite and basalt (86%). In general, the dominant mined lithologies, are well represented by the data. Lithologies that have the potential to be underrepresented include: Kapai Slate, Condenser Dolerite and Paringa Basalt. Underrepresentation in sample numbers may not impact overall AMD risk assessment, as it will depend on the variability of the reported data. Other lithologies not recorded as part of the SIGM mined material database, which are also represented by the analysed data including Upper Saprolite, Cave Rocks Sediment, Cave Rocks Dolerite, Merougil Creek Beds and Tailings.

Table 6-1: Percentage Represetation of Each Lithology in the Assessed Data Compared to Estimated Mined Volumes of each Lithology

Lithology	Percentage of Data	Percentage of Mined Material
Lake sediment	3%	1%
Tertiary sediment	9%	
Upper Saprolite	5%	NR
Merougil Creek Beds	1%	NR
Black Flag Beds	7%	4%
Cave Rocks Sediment	NR	NR
Kapai Slate	1%	5%
Condenser Dolerite	9%	33%
Defiance Dolerite	10%	<1% (14%)
Cave Rocks Dolerite	NR	NR
Devon Consols Basalt	22%	5% (14%)
Lunnon Basalt	<1%	NR
Paringa Basalt	17%	34%
Tripod Hill Komatiite	8%	3%
Felsic intrusion	3%	1%
Intermediate intrusion	5%	
Mafic intrusion	<1%	
Tailings	NR	NR

Notes:

The value in brackets represents material recorded as "Leviathan Dolerite and Basalt", which is most likely a combination of Devon Consols Basalt and Defiance Dolerite.

6.2 Spatial Representation of Data

Figure 7 (attached) shows the spatial representation of the ABA data by mine area location In general, the samples are distributed across the majority of mine locations within the northern, central and southern mining areas. The mine locations not represented by the sample data include:

- Bahama Open Pit; and
- smaller historical satellite open pits (Pinnace, Orchin, Blue Lode and Clifton, as well as historical pits in the Leviathan and Greater Revenge complexes).

The areas not represented are not considered to be significant in the overall assessment of AMD risk for the site, as there are larger open pits located in close proximity, or that have been sampled more recently (in the case of historical mine pits), that have similar geology. Therefore the outcomes of the risk assessment may be extrapolated to apply to those areas where AMD samples have not been taken.

Figure 6-2 shows the sample numbers of data available for the various mine locations at SIGM. In general, the majority of mine areas are represented by the assessed data. Waste rock samples are represented across a range of lake and land based mining operations from the northern areas (including Cave Rocks, Formidable Open Pit, and Redoubtable Open Pit), through the Greater Revenge, Leviathan and other central mining areas, and to southern mining areas (including Diana Open Pit, Apollo Open Pit and Argo and Athena-Hamlet Underground mining areas). Areas with the highest number of waste rock samples are Cave Rocks (over 500 samples from open pit and underground operations), Athena-Hamlet Underground operations (just over 300 samples), Leviathan complex area (280 samples), Agamemnon South Open Pit (just under 200 samples, including Office, Delta Cutback Open Pits) and Argo Underground operations (176 samples). Collectively the areas with the five highest numbers of waste rock samples represent approximately half of the samples assessed.

Lake sediment sample distribution covers Formidable and Invincible Open Pit and Swiftsure exploration in the northern lake-base mine area, and Neptune Open Pit in the Central mine area. Other lake-base open pits would have included lake sediments in the mined waste (including Agamemnon and Delta area Open Pits, Grinder Open Pit, Revenge-Pluton Open Pit, Mars Open Pits, Intrepide Open Pit, Santa Ana and Bahama Open Pits, Redoubtable Open Pit, Temaraire Open Pit and Redback Open Pit), although it is likely that lake sediments would have been included in material logged as Tertiary sediment.

Tailings materials are described as Lefroy Monthly Composite. These samples represent monthly fresh tailings samples collected and analysed as part of environmental commitment requirements and reporting. Based on tailings deposition scheduling on site, these tailings are likely to have been deposited in TSF2, TSF3, North Orchin In-pit TSF and TSF4. Aged tailings samples were collected from TSF1, TSF2 and TSF3 as part of a study conducted by Mesh and O'Kane in 2008 (MESH and O'Kane, 2008). Tailings samples were also collected from the Paris legacy mine area in 1997.

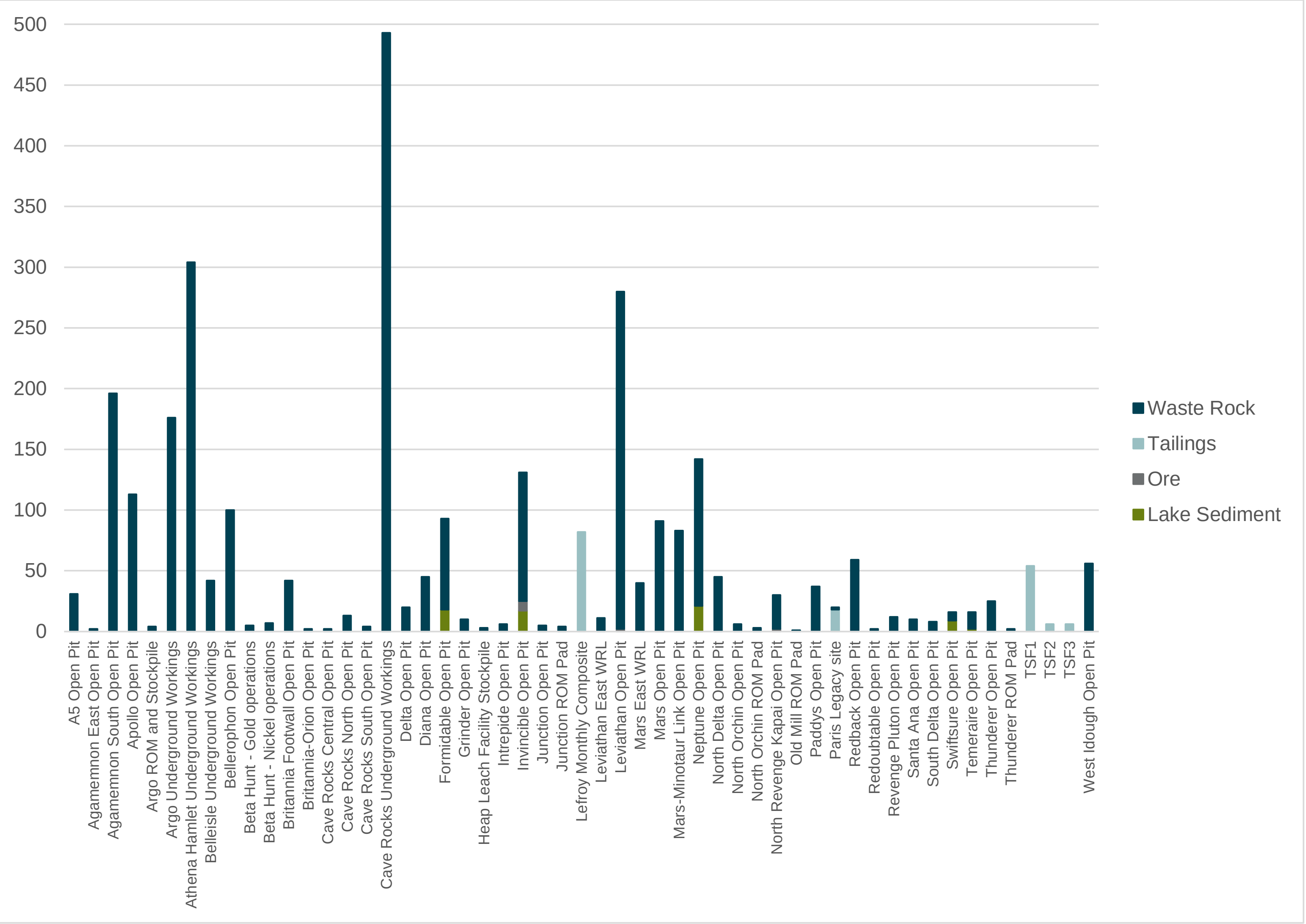


Figure 6-2: Number of Samples in the Assessed Data Summarised by Mine Area at SIGM

6.3 Analytical Data Results

The data analysed generally reported results for ABA parameters including:

- paste pH and paste EC;
- total sulfur, sulfate sulfur and sulfide sulfur;
- calculated MPA;
- measured ANC;
- total carbon, organic carbon and inorganic carbon;
- calculated ANC;
- calculated NAPP; and
- NAG.

Additional results were occasionally reported for alternative pH and EC measurements, and minor sulfur species. These results were omitted from the overall data analysis as they were not reported in large enough populations to enable a comparison of results. Selected parameters were analysed statistically (paste pH, paste EC, total sulfur and sulfide sulfur), to determine the variation of data within each representative lithology.

6.3.1 pH

The statistical analyses for saturated paste pH (based on a 1:1 ratio of soil to water) for each lithological unit is presented in **Figure 6-3**. A summary of the statistical data is provided in **Appendix C**.

In general, pH of waste materials at SIGM range from slightly acidic to alkaline (mean values range from pH 6.5 to pH 9.3) which is consistent with background surface water pH (**Section 5.2.2.1**) and groundwater pH, which ranges from pH 6.0 to pH 8.0 as measured from dewatering discharge points (URS Australia, 2004). This indicates that pH ranges of mined waste materials, are close to background values; therefore a decrease in pH may be used as an indicator for acid generation on site. It is noted that, some lithologies (Cave Rocks Sediment and Dolerite, Kapai Slate, Devon Consols Basalt and Tailings) contain isolated outliers that are acidic (< pH 4.5), which indicates that some waste samples analysed were acid generating when sampled. There is no related pattern between the locations of the waste rock samples that reported the low outlier results.

In general, variation in the pH data for each lithology is small (standard deviation <2.0), which indicates that the mean value is a reasonable representation of the reported data population. The Condenser Dolerite, Devon Consols Basalt and Paringa Basalt have large numbers of outliers, which indicates that there may be separate geochemical populations with respect to pH. However, this is likely to be related to variations in groundwater chemistry between sample locations.

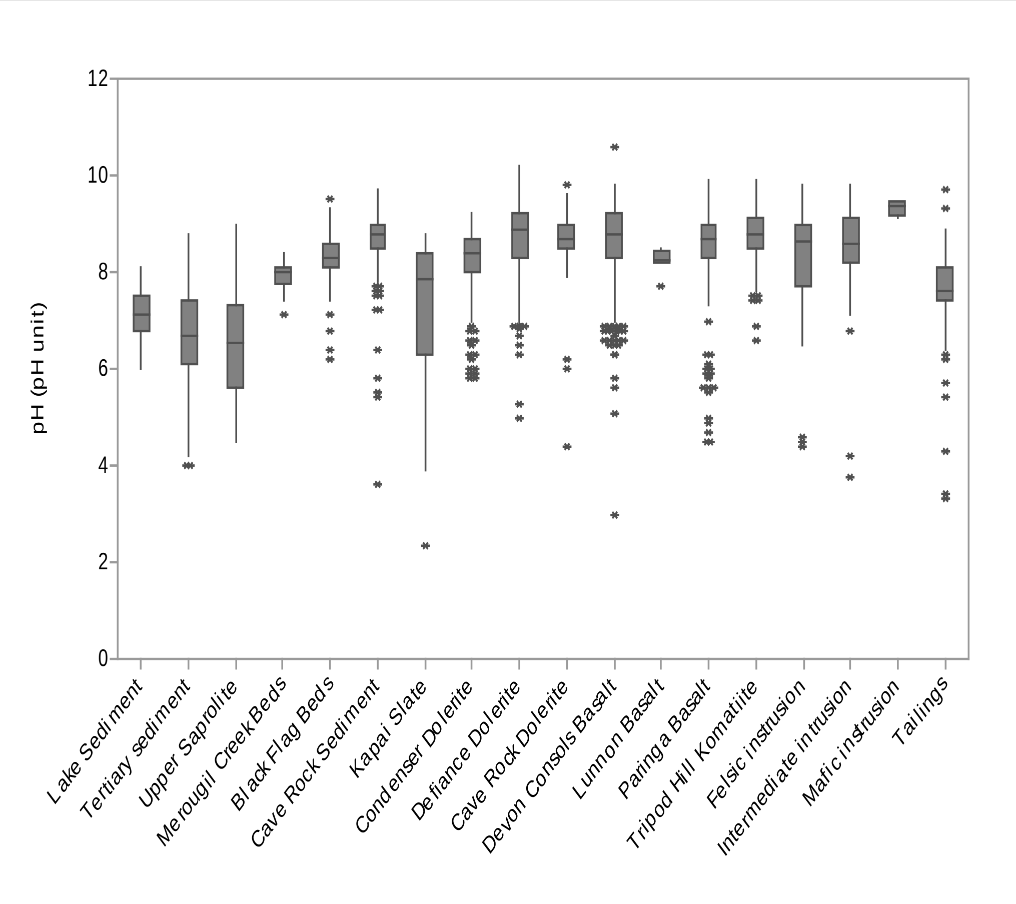
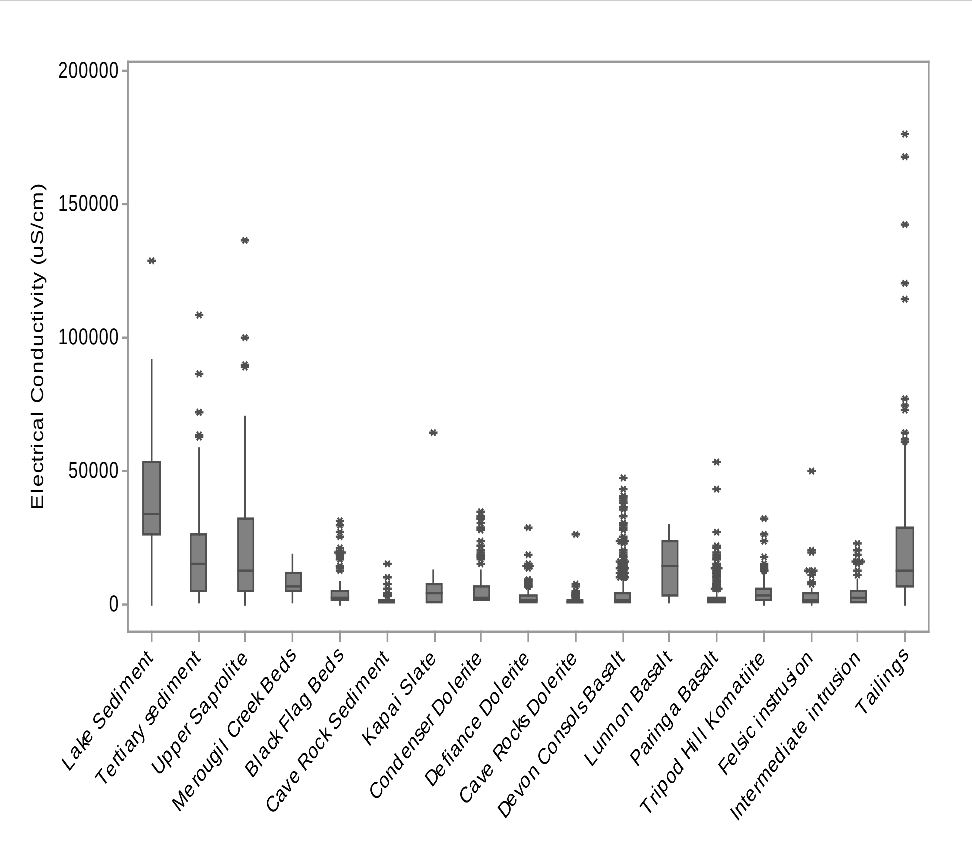


Figure 6-3: Box and Whisker Plot for Paste pH by Lithology

6.3.2 Electrical Conductivity

The saturated paste electrical conductivity (EC) (based on a 1:1 ratio of soil to water) for each lithological unit is presented in the box plots in **Figure 6-4**. A summary of the statistical data is provided in **Appendix C**.

In general, EC is highly variable, ranging from very low (<2000 uS/cm) to very high (>20,000 uS/cm), which is supported by very high standard deviation values. This indicates that mean values may not be representative for each lithological type. Similar to surface water salinity (**Section 5.2.2.1**), measured groundwater quality is typically hypersaline (150,000 to 360,000 mg/L TDS), and shows a high degree of variability depending on the rate of recharge and the aquifer (URS Australia, 2004). The EC of mined waste material is likely to be dependent on the EC of surface water recharge (for lake-based mine areas) and groundwater (for deeper, and land-based mine areas), and as such, any additional increase in salinity due to sulfide oxidation is unlikely to be noticeable.



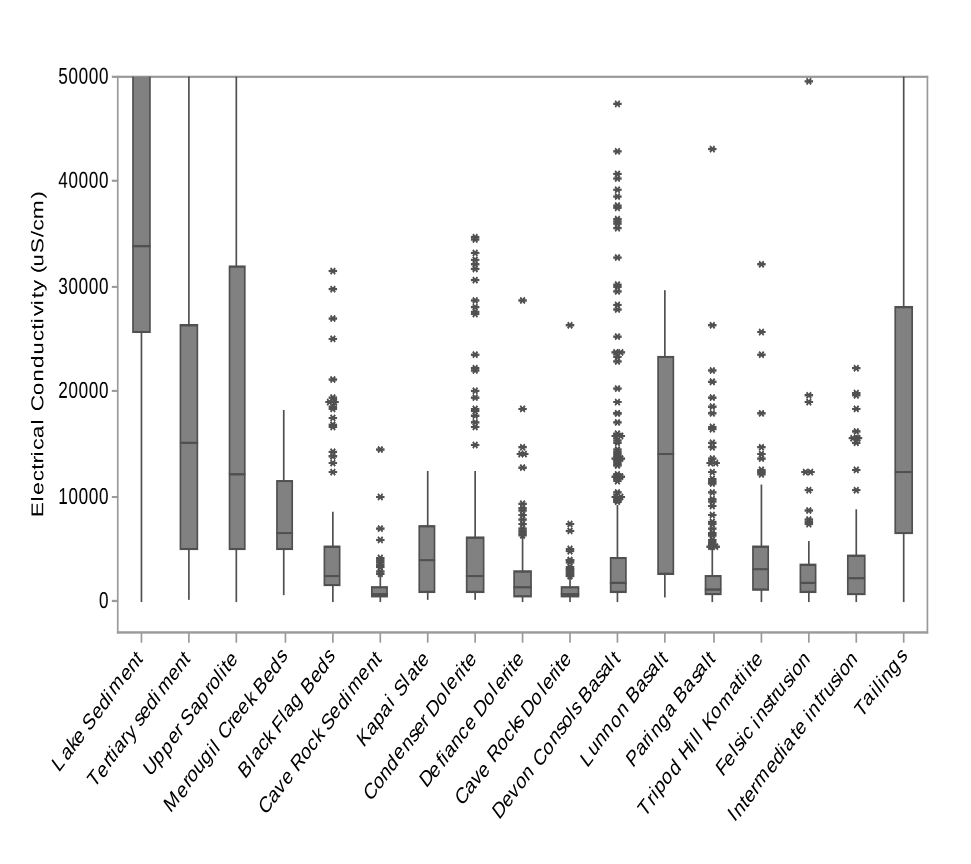


Figure 6-4: Box and Whisker Plot for Paste EC by Lithology (upper chart) with abridged scale (0 to 50,000 uS/cm - lower chart)

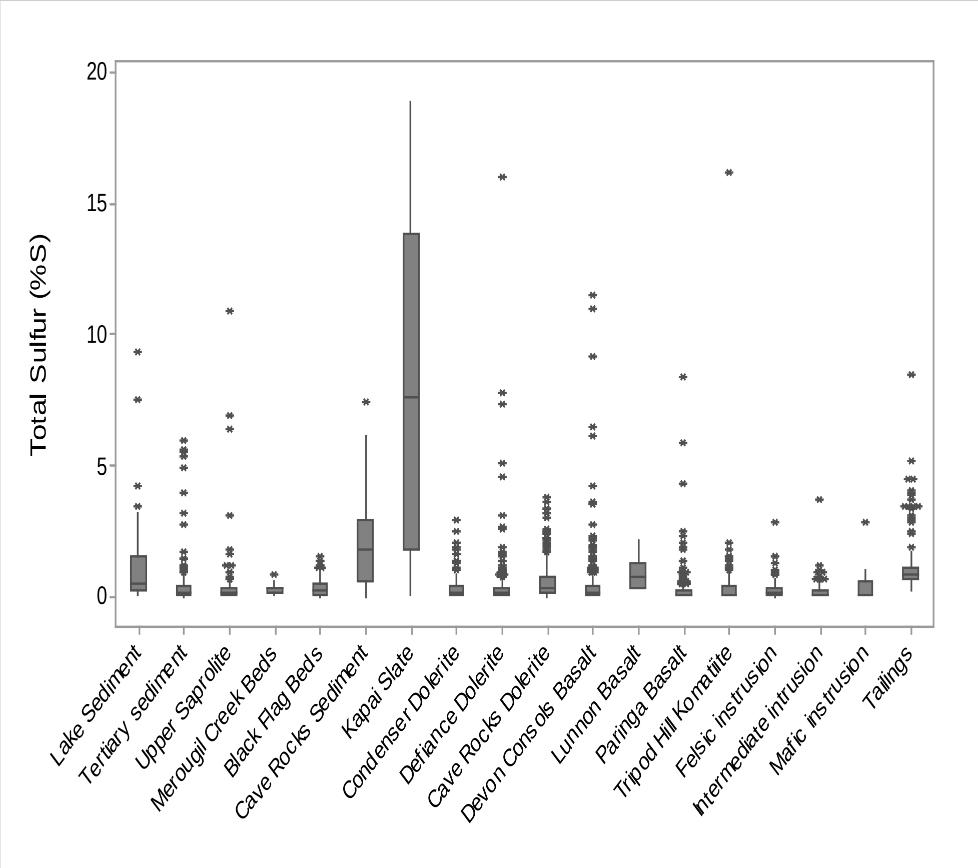
As is expected, lithologies located closer to the surface (Lake sediment, Tertiary sediment and Upper Saprolite) have higher EC than other deeper lithologies. These units are likely to be dominated by higher EC recharge from the salt lake, as well as a higher clay mineralogy content. Tailings and Lunnon basalt units also have a relatively higher EC compared to other units. Tailings EC is likely to be affected by process water salinity, which is typically hypersaline, while the Lunnon Basalt unit is logged only at the Beta Hunt site, which is located on the shore of Lake Lefroy so is likely to represent high salinities of groundwater in that area. Lithologies with lower EC (refer to **Figure 6-4** with abridged scale) generally have a large number of outliers, which is to be expected with a high variability in measured EC of both surface and groundwater on site. The high variability in data, coupled with hypersaline background characteristics of both surface water and groundwater means that EC is not likely to be a useful indicator of acid generation impact at SIGM.

6.3.3 Total sulfur

The total sulfur for each lithological unit is presented in the box plots in **Figure 6-5**. A summary of the statistical data is provided in **Appendix C**.

The lithologies with the highest total sulfur values include Kapai Slate, Cave Rocks Sediment and Lake sediment, with Kapai Slate having the largest range of total sulfur values across the site. Excluding the lithologies with notably high total sulfur, total sulfur values are generally low (refer to **Figure 6-5** with abridged scale) with the majority of interquartile ranges reporting values less than 0.5 %S. Lunnon basalt and tailings have slightly higher sulfur values compared to other lithologies. Higher sulphide in samples collected form Beta Hunt is likely to be associated with different ore mineralogy (where Lunnon Basalt samples are taken). Higher sulphide concentration in tailings is related the nature of sulphide minerals associated with the ore body (i.e. higher percentages of sulphide minerals are associated with ore compared to waste rock).

Outliers are common at total sulfur concentrations above 2 %S for most lithologies and outliers above 5 %S are recorded for Tertiary sediment, Upper Saprolite, Defiance Dolerite, Devon Consols Basalt and Paringa Basalt. These units also represent the main ore hosting lithologies (**Section 6.1**), illustrating the relationship between distribution of mineralisation across different lithologies in different mine areas, and the variability in total sulfur values. The lack of clear grouping in the outliers suggests that the groupings seen in the outlier data for pH (**Section 6.3.1**), are more likely to be influenced by groundwater chemistry, rather that sulfide oxidation.



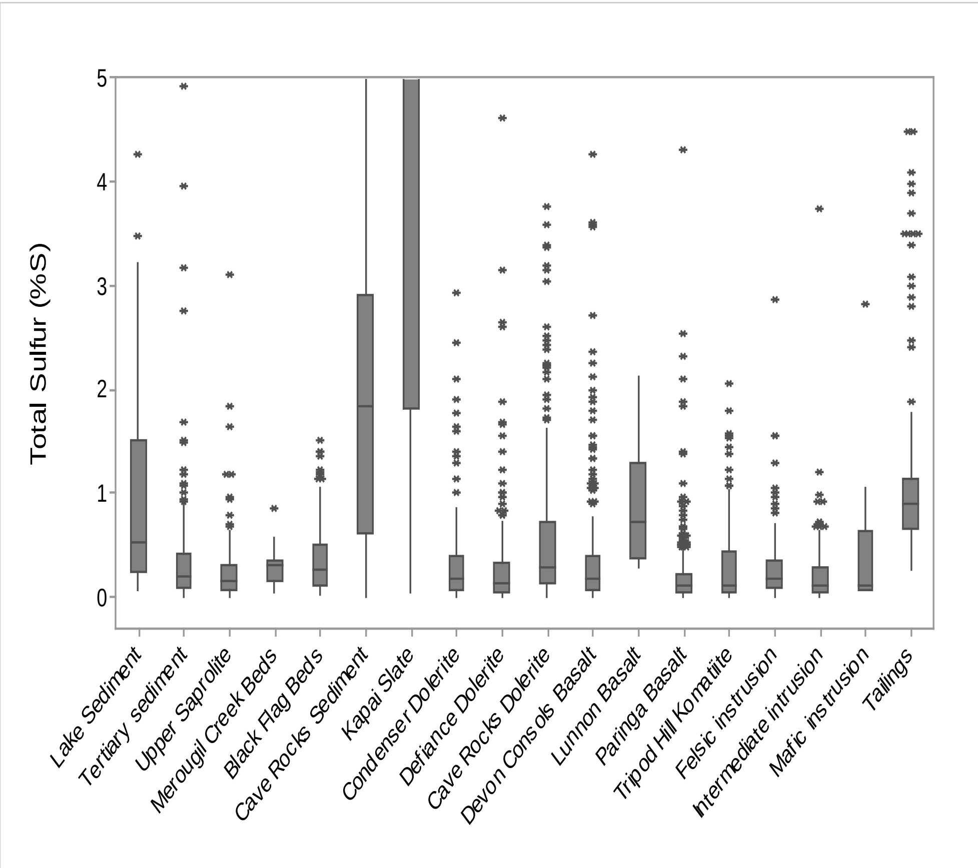


Figure 6-5: Box and Whisker Plot for Total Sulfur by Lithology (upper chart) with abridged scale (0 to 5 %S - lower chart)

6.3.4 Sulfide sulfur

The sulfide sulfur for each lithological unit is presented in the box plots in **Figure 6-6**. A summary of the statistical data is provided in **Appendix C**.

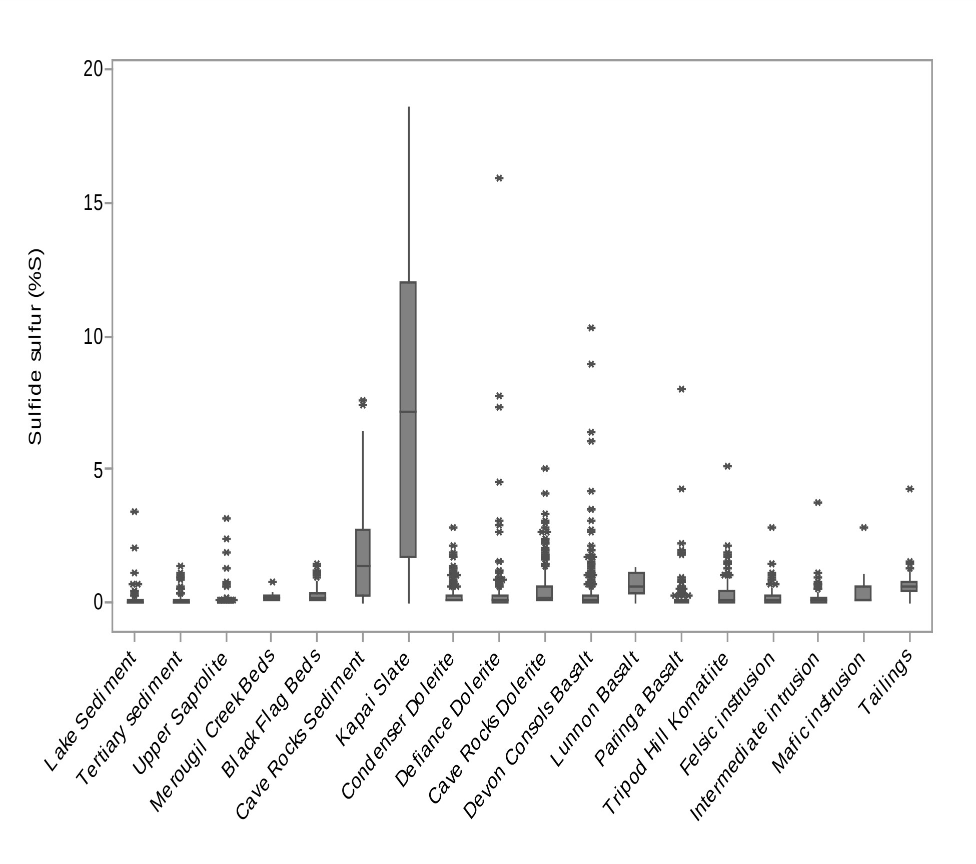
The sulfide sulfur data shows a similar distribution of range and variability to total sulfur indicating that for the majority of lithologies, sulfide sulfur is the dominant form of sulfur. The exceptions are Lake sediment, Tertiary sediment and Upper Saprolite, which have much lower concentrations of sulfide sulfur compared to total sulfur. This is to be expected as those lithologies are near surface and represent the oxidised zone of the stratigraphy. Lithologies with a high proportion (based on mean and 75th percentile values) of samples reporting sulfide sulfur concentrations near or less than 0.1 %S (considered to represent barren samples) are Lake sediment, Tertiary sediment, Upper Saprolite, Paringa Basalt and intermediate intrusion. Lithologies with low sulfide sulfur (75th percentile concentrations less than 0.3 %S) are Merougil Creek Beds, Black Flag Beds, Condenser Dolerite, Defiance Dolerite, Devon Consols Basalt and felsic intrusion.

Outliers are spread out indicating variability in sulfide sulfur concentrations within most of the lithologies. As with total sulfur, the variation in the interquartile range and outliers for sulfide sulfur data is likely to be associated with the distribution of mineralisation across different lithologies in different mine areas, rather than with any particular lithological unit.

6.3.5 Sulfur Species

The comparison of total sulfur to sulfide sulfur was assessed graphically for each lithology (**Figures 1a**, **2a**, **3a**, **4a**, **5a** and **6a** attached). Where all sulfur in the sample is in the form of sulfide minerals (e.g. pyrite), the sample will plot along the line representing a sulfide sulfur-total sulfur ratio of one. Samples that contain sulfur minerals other than sulfides, including sulfate minerals (e.g. gypsum, jarosite and barite), and native sulfur will plot above the line. A summary of the dominant sulfur species by lithology is presented in **Table 6-2**. The majority of samples contain both sulfide minerals and non-sulfide minerals. This indicates that analysis of total sulfur alone will over-estimate MPA if used for calculation. It is recommended that sulfide sulfur is included in all AMD assessments in the future, and that this value is used to calculate MPA, rather than total sulfur.

It is noted that sulfide minerals other than pyrite may also be present in the mined waste material at SIGM (**Section 3.1.2**). For further refinement of risk, sulfide mineral speciation may be undertaken to provide a better estimation of MPA; however, this information may not provide any additional value to the overall risk of AMD potential over the life of mining.



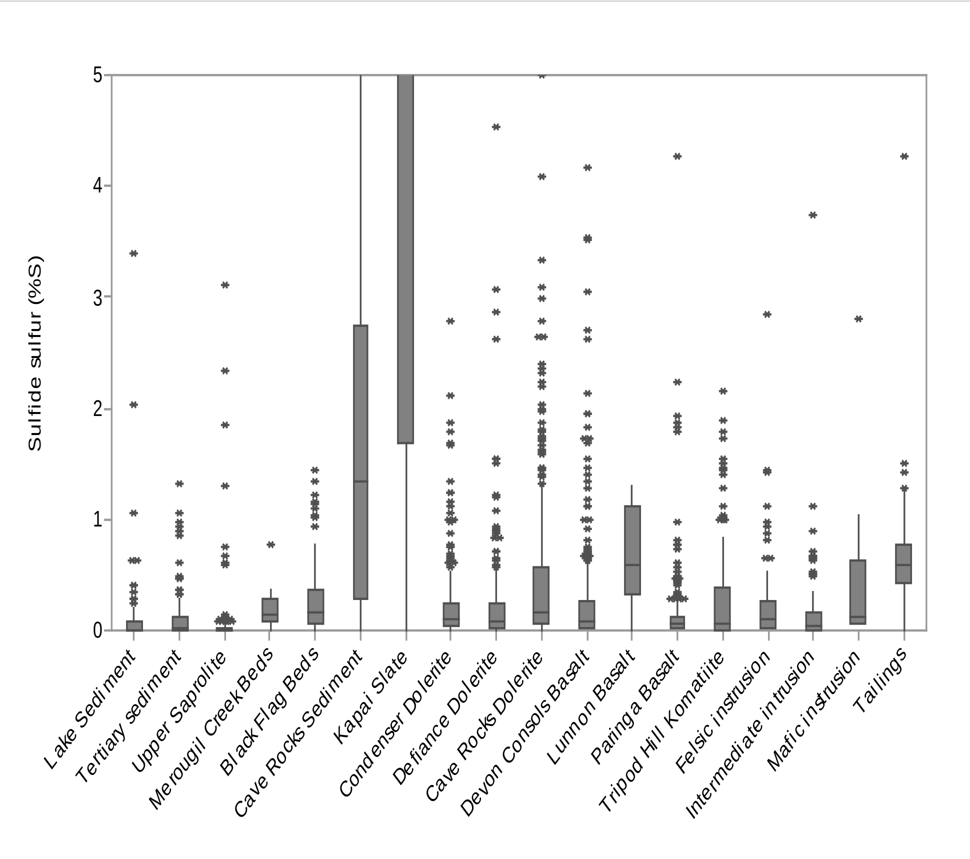


Figure 6-6: Box and Whisker Plot for Sulfide Sulfur by Lithology (upper chart) with abridged scale (0 to 5 %S - lower chart)

Table 6-2: Dominant Sulfur Species by Lithology

Lithology	Figure Ref.	Dominant Sulfur Species
Lake sediment	1a	Dominated non-sulfide minerals.
Tertiary sediment	1a	Combination of samples dominated by sulfide sulfur and non-sulfide minerals. In general the amount of sulfate (non-sulfide minerals) is related to salinity, so samples with lower salinity tend to have sulfide minerals as the dominant form of sulfur.
Upper saprolite	1a	Generally dominated by non-sulfide minerals. Occasional samples are dominated by sulfide minerals, but no clear relationship exists.
Merougil Creek Beds	2a	Generally dominated by sulfide minerals
Black Flag Beds	2a	Generally dominated by sulfide minerals
Caves Rocks Sediment	2a	Generally dominated by sulfide minerals. Some samples have a higher proportion of non-sulfide minerals (generally less than half the total sulfur concentration), these samples tend to have higher salinity.
Kapai Slate	2a	Generally dominated by sulfide minerals
Condenser Dolerite	3a	Generally dominated by sulfide minerals, non-sulfide minerals also present in lesser amounts.
Defiance Dolerite	3a	Generally dominated by sulfide minerals
Cave Rocks Dolerite	3a	Generally dominated by sulfide minerals, non-sulfide minerals also present in lesser amounts.
Devon Consols Basalt	4a	Generally dominated at sulfide minerals at higher total sulfur concentrations (>1 %S). Sulfide minerals still dominate at lower total sulfur concentrations, but there is a higher proportion of non-sulfide minerals.
Lunnon Basalt	4a	Generally dominated by sulfide minerals, non-sulfide minerals also present in lesser amounts.
Paringa Basalt	4a	Generally dominated at sulfide minerals at higher total sulfur concentrations (>1 %S). Sulfide minerals still dominate at lower total sulfur concentrations, but there is a higher proportion of non-sulfide minerals.
Tripod Hill Komatiite	4a	Generally dominated by sulfide minerals, non-sulfide minerals also present in lesser amounts (generally less than half the total sulfur concentration).
Felsic intrusion	5a	Samples contain both sulfide and non-sulfide minerals, no clear relationship exists.
Intermediate intrusion	5a	Samples contain by both sulfide and non-sulfide minerals, no clear relationship exists.
Mafic intrusion	5a	Generally dominated by sulfide minerals.
Tailings	6a	Fresh tailings are generally dominated by sulfide minerals, while aged tailings contain both sulfide and non-sulfide minerals.

6.3.6 Acid Base Accounting Results

Acid Base Accounting results are plotted on charts (**Figures 1b**, **2b**, **3b**, **4b**, **5b** and **6b** attached) showing the distribution of NAPP positive and NAPP negative data by lithology. The majority of samples tested plot on the NAPP negative portions of the ABA charts, with the exception of Kapai Slate (**Figure 2b**). Other lithologies with a relatively high proportion of samples that plot on the NAPP positive side of the ABA charts include Cave Rocks Sediment (**Figure 2b**) and Cave Rocks Dolerite (**Figure 3b**). These lithologies have a high risk potential to generate acid.

An NP/AP ratio of 2 or greater generally indicates that samples are likely to remain non-acid generating over long-lag times, and are generally considered to have a high enough NP that samples will not be at risk of generating acid. Lithologies that have the majority of samples that plot above the NP/AP = 2 line include Merougil Creek Beds and Black Flag Beds (**Figure 2b**); Condenser and Defiance Dolerites (**Figure 3b**); Lunnon Basalt, Devon Consols Basalt and Paringa Basalt (**Figure 4b**); and aged and fresh tailings (**Figure 6b**; excluding tailings sampled at Paris Legacy mine area, which are not represented on the chart due to lack of reported NP results).

6.4 Acid Drainage Potential Classification

The analysed data was classified for acid drainage generation potential based on the classification scheme described in **Section 5.2.4**.

A summary of the acid drainage potential classification for all 2996 samples is shown in **Figure 6-7**. The majority of samples are classified as NAF – barren, NAF or potentially NAF, indicating that PAF and potentially PAF materials make up a relatively small component of waste at SIGM (<11%). The majority of data was classified using the Hierarchy Two criteria (represented by the prefix "potentially" or "P") due to the lower number of NAG results reported in the data. A breakdown of the classification by lithology is presented in **Table 6-3**. **Figures 1c**, **2c**, **3c**, **4c**, **5c**, and **6c** (attached) show the classification groupings for samples able to be classified using the Hierarchy One scheme, and the proportion of each classification grouping for each lithology is shown in **Figure 6-8**. A summary of the classification groupings by rock type and lithology is provided in the following sections.

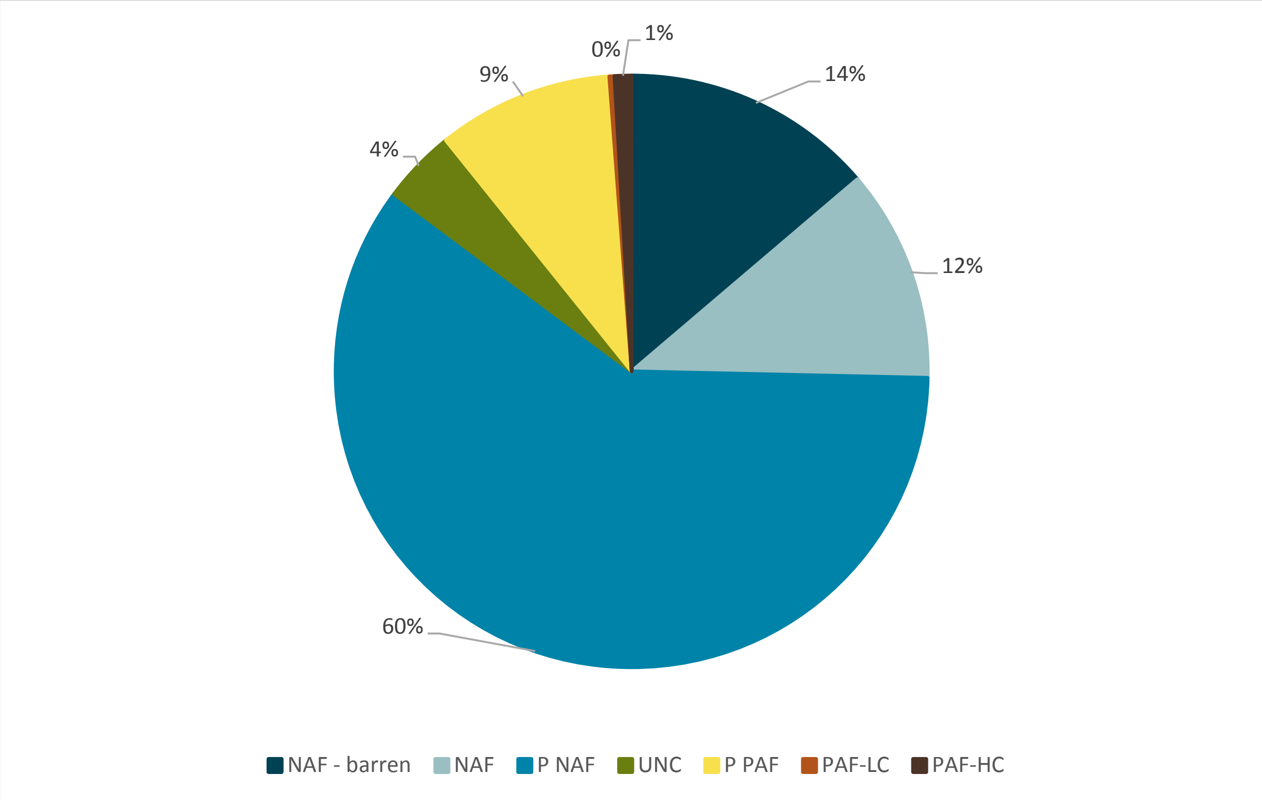


Figure 6-7: Summary of Acid Drainage Potential for the Total Number of Samples Assessed

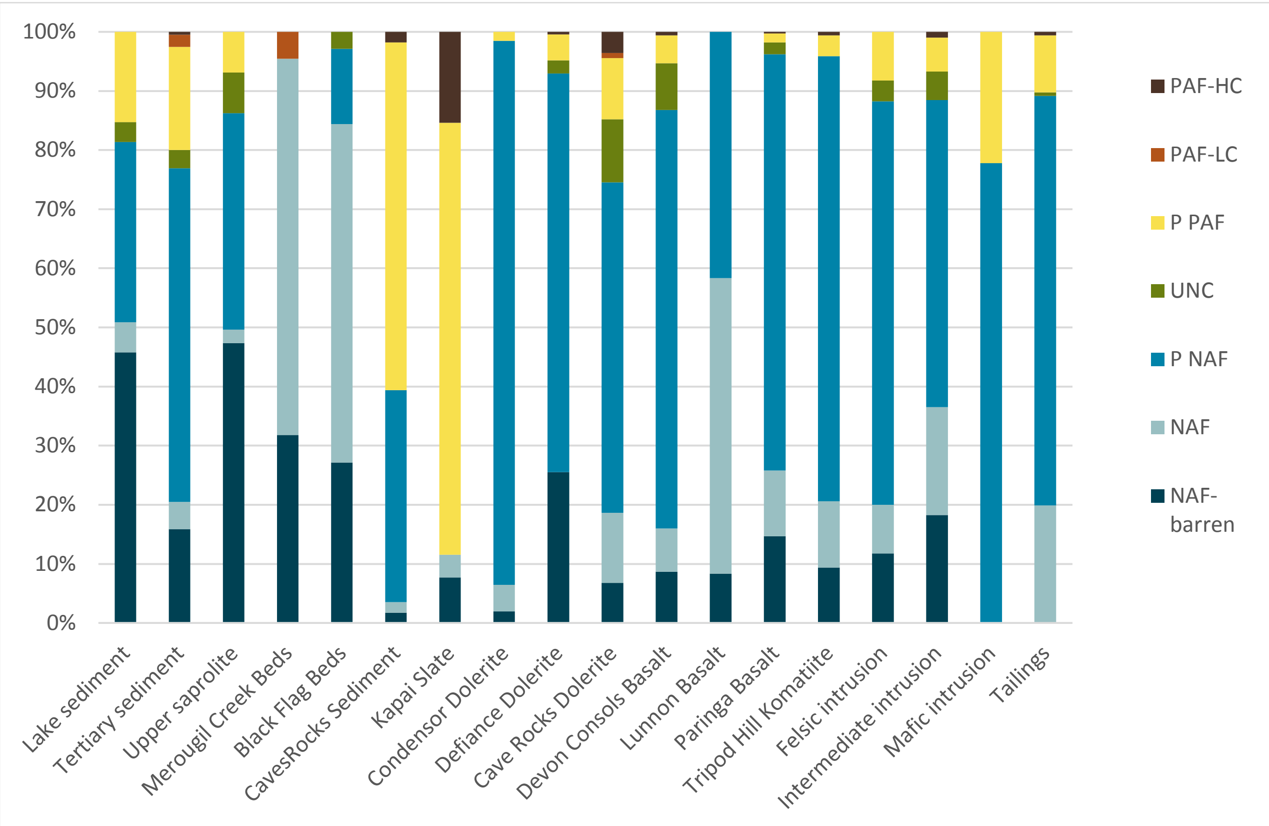


Figure 6-8: Proportion of Acid Drainage Potential Classification by Lithology

Table 6-3: Summary of Acid Drainage Potential of Representative Lithologies

Lithology	NAF - barren	NAF	P NAF	UNC	P PAF	PAF-LC	PAF-HC	TOTAL[1]
Lake sediment	27	3	18	2	9	-	-	59 (32)
Tertiary sediment	31	9	110	6	34	4	1	195 (51)
Upper saprolite	62	3	48	9	9	-	-	131 (71)
Merougil Creek Beds	7	14		-	-	1	-	22 (22)
Black Flag Beds	47	99	22	5	-	-	-	173 (151)
Cave Rocks Sediment	3	3	61	-	100	-	3	175 (12)
Kapai Slate	2	1	-	-	19	-	4	26 (6)
Condenser Dolerite	4	9	185	-	3	-	-	201 (13)
Defiance Dolerite	58	-	153	5	10	-	1	227 (64)
Cave Rocks Dolerite	23	40	189	36	35	3	12	338 (90)
Devon Consols Basalt	44	37	359	40	24	-	3	507 (96)
Lunnon Basalt	1	6	5	-	-	-	-	12 (7)
Paringa Basalt	58	44	278	8	6	-	1	395 (103)
Tripod Hill Komatiite	16	19	128	-	6	-	1	170 (36)
Felsic intrusion	10	7	58	3	7	-	-	85 (18)
Intermediate intrusion	19	19	54	5	6	-	1	105 (39)
Mafic intrusion	-	-	7	-	2	-	-	9 (0)
Tailings	-	33	115	1	16	-	1	166 (35)

Notes:

[1] Brackets represent the total number of samples able to be classified using Hierarchy One classification.

6.4.1 Recent and Oxide Sediments

The recent and oxidised sediments include Lake sediment, Tertiary sediment and Upper Saprolite. Based on the samples that were able to be classified using Hierarchy One classification, the majority of samples are classified as NAF (**Figure 1c**) with the majority of those further classified as NAF – barren, for all three lithologies (**Figure 6-8**). Minor samples plot in the UNC area of the chart (Lake sediment, Tertiary sediment and upper saprolite) and only Tertiary sediment samples are classified as PAF (five samples) with most (four samples) being further classified as PAF-LC.

Samples that are classified using the Hierarchy Two groupings are predominantly P NAF; however, some Lake sediment and Tertiary sediments are classified as P PAF (15 to 20% of samples tested), and a smaller proportion of Upper Saprolite samples are also classified as P PAF (7% or samples tested). The Lake sediment samples classified as P PAF are associated with Neptune and Formidable mine areas.

The Tertiary sediment samples that are classified as PAF and P PAF are predominantly located in the Neptune, Athena-Hamlet mine areas, with a smaller proportion of samples located in Bellerophon and Mars-Minotaur Link mine areas.

Overall, the majority of recent sediments are likely to be NAF based on predominantly low sulfide concentrations. Lake and Tertiary sediment samples that are classified as P PAF or PAF are likely to be associated with shallow supergene mineralisation located within and near the recent sedimentary units. Upper saprolite samples classified as P PAF are located in various mining areas and are likely to be isolated samples associated with mineralisation.

6.4.2 Interbedded and Older Sediments

Interbedded and Older Sediments comprise Merougil Creek Beds, Black Flag Beds, Cave Rocks Sediment, and Kapai Slate lithologies. Based on the samples that were able to be classified using Hierarchy One classification, the Merougil Creek Beds and Black Flag Beds are classified as NAF, with the exception of one Merougil Creek Beds sample that was classified as PAF-LC (with a very low NAPP value of 4.6 kg H_2SO_4/tonne), and a small proportion of Black Flag Beds (five samples) that were classified as UNC based on conflicting NAPP and NAG results. All of the Merougil Creek Bed samples (100%) and the majority of the Black Flag Beds samples (87%) were able to be classified using Hierarchy One classification groupings. Furthermore, the majority of the samples from these lithologies plot in the AC area of the chart (**Figure 2c**), meaning that the samples are likely to have excess available NP, and may exhibit acid consuming (AC) properties.

Based on samples able to be classified using the Hierarchy One classification, some Kapai Slate and Cave Rocks Sediment samples are classified as PAF-HC (**Figure 2c**). With the addition of the Hierarchy Two classification, Cave Rocks Sediment and Kapai Slate have the highest proportion of samples classified as P PAF, or PAF (Kapai Slate) at SIGM (**Figure 6-8**).

Overall, the Merougil Creek Beds and Black Flag Beds are likely to be NAF. The majority of these samples were taken from Invincible and Bellerophon mining areas. The Kapai Slate is mainly found in lake-based mine areas, but has also been mapped in the Leviathan Complex and surrounding Open Pits. Although the larger proportion of Kapai Slate samples are classified using the Hierarchy Two classification grouping, the high sulfide values, and the ABA properties indicate that waste rock from this lithology is likely to be high risk with respect to potential acid generation. The majority of Cave Rocks sediment samples were classified using Hierarchy Two classification, giving some uncertainty around the classification results. In addition, mineralogy noted in the logging includes pyrrhotite more commonly than pyrite, so the AP values may be overestimated. This means that with more detailed geochemical testing, the acid generation risk associated with the lithology may decrease.

6.4.3 Dolerites

The dolerite lithologies comprise Condenser Dolerite, Defiance Dolerite and Cave Rocks dolerite. The samples that were able to be classified using Hierarchy One classification represent a small proportion of the lithologies (**Table 6-3**). Based on that classification grouping, the Condenser Dolerite and Defiance Dolerite samples are mainly classified as NAF, with some Defiance Dolerite samples classified as UNC (five samples) or PAF-HC (one sample) (**Figure 3c**). All of the Defiance Dolerite samples that are classified as NAF, are further classified as NAF-barren. Cave Rock Dolerite samples are mainly classified as NAF; however a proportion of samples are also classified as UNC and PAF. The samples classified as PAF can be further classified as PAF-LC (three samples) and PAF-HC (12 samples). Some of the Condenser Dolerite and Defiance Dolerite samples also plot within the AC area of the chart (Figure 3c). The majority of the Condenser Dolerite samples that plot in this area were sampled from the Argo mine area, while the Defiance Dolerite samples that plot in this category are located around lake-based mine areas (e.g. the proposed A5 Open Pit, and Redback Open Pit).

Based on the samples that are classified using the Hierarchy Two classification, the majority of samples are classified as P NAF (**Figure 6-8**). Only a small proportion of Condenser Dolerite and Defiance Dolerite are classified as P PAF (<2% and 4% respectively), while a larger proportion of Cave Rocks Dolerite are classified as P PAF (10%).

Overall, the Condenser Dolerite and defiance Dolerite lithologies are likely to be NAF, with isolated areas that have the potential to generate acid, being confined to mineralised shear zones containing dolertitic material. The majority of Cave Rocks Dolerite samples were classified using Hierarchy Two classification, giving some uncertainty around the classification results. In addition, mineralogy noted in the logging includes pyrrhotite more commonly than pyrite, so the AP values may be overestimated. This means that with more detailed geochemical testing, the acid generation risk associated with the lithology may decrease.

6.4.4 Basalts and Ultramafic

The basalt lithologies comprise Lunnon Basalt (logged at Beta Hunt only), Devon Consols Basalt and Paringa Basalt. The Ultramafic lithology is represented by Tripod Hill Komatiite. Based on the samples that were able to be classified using the Hierarchy One classification (**Figure 4c**) the majority of basalt samples, and the Tripod Hill Komatiite samples are classified as NAF, with the exception of minor Devon Consols Basalt samples (three samples classified as PAF-HC) and one sample each of Paringa Basalt and Tripod Hill Komatiite (classified as PAF-HC). Approximately half of the samples from each lithology (**Table 6-3**) can be further classified as NAF – barren. Furthermore, a large proportion of Lunnon Basalt, Devon Consols Basalt and Paringa Basalt samples plot in the AC area of the chart (**Figure 4c**) meaning that the samples are likely to have excess available NP, and may exhibit acid consuming (AC) properties.

Based on the samples classified using the Hierarchy Two classification, all remaining Lunnon Basalt samples are classified as P NAF, while the majority of Devon Consols Basalt, Paringa Basalt and Tripod

Hill Komatiite are also classified as P NAF. Minor Devon Consols Basalt and Paringa Basalt samples are classified as P PAF. The majority of Devon Consols Basalt samples that are classified as P PAF are located within the Greater Revenge mining areas, where mineralisation is predominantly hosted in the Devon Consols Basalt lithology. The Paringa Basalt samples are located different mine areas, and are likely to be isolated, and related to samples located near mineralised zones.

Devon Consols Basalt and Paringa Basalt have a small proportion of samples classified as UNC (8% and 2% respectively) under the Hierarchy Two classification groupings, based on low negative NAPP values (between 0 and -10 kg H2SO4/tonne). This means that with more detailed geochemical testing, the acid generation risk associated with the lithology may decrease. Overall the Basalt and Tripod Hill Komatiite lithologies are likely to be NAF, with some P PAF materials confined to areas associated with shear-zone hosted mineralisation.

6.4.5 Intrusives

Intrusive lithologies comprise felsic, intermediate and mafic intrusions. Based on the samples that were able to be classified using the Hierarchy One classification (**Figure 5c**), the majority of felsic and intermediate intrusion samples are classified as NAF, with the exception of one intermediate intrusion sample (classified as PAF-HC) and two felsic intrusion samples (classified as UNC, based on conflicting NAPP and NAG results). A proportion of both lithologies may be further classified as NAF-barren (total of 12% of felsic intrusion samples and 18% of intermediate intrusion samples). Some intermediate intrusion samples plot in the AC area of the chart (**Figure 5c**) indicating that some samples are likely to have excess available NP, and may exhibit acid consuming (AC) properties.

The samples classified using the Hierarchy Two classification make up the majority of the samples, for felsic and intermediate intrusion lithologies, and all of the mafic intrusion samples (**Figure 6-8**). The majority of samples are classified as P NAF. A proportion of samples from each of the lithologies were also classified as P PAF (8%, 6% and 22% for felsic, intermediate and mafic intrusions respectively). In general the intrusive lithologies are likely to be NAF, which indicates that sulfide minerals are likely to be confined to areas where intrusions intersect mineralised zones.

6.4.6 Tailings

Both aged and fresh tailings samples are included in the assessed data. Based on the samples that were able to be classified using the Hierarchy One classification (**Figure 6c**), the majority of tailings samples (both aged and fresh) are classified as NAF, with one sample of fresh tailings classified as UNC, based on conflicting NAPP and NAG results, and one sample of aged tailings classified as PAF-HC. All samples classified as NAF plot in the AC area of the chart (**Figure 6c**) indicating that the samples are likely to have excess available NP, and may exhibit acid consuming (AC) properties.

The majority of samples can only be classified using Hierarchy Two classification. The majority of samples (69%) are classified as P NAF (**Table 6-3**). All 16 samples that are classified as P PAF were located in the Paris Legacy mine area. No ANC results were reported for these samples. In general tailings materials in the operational areas of the site are likely to be NAF, with excess NP, and are likely to remain NAF over long lag-times.

7 Elevated Metals Assessment Results

Figures 8 through **13** (attached) present the spatial distribution of drillhole sample data that exceed the nominated trigger values (**Table 5-4**) for arsenic, chromium, copper, lead, selenium, and zinc. Lithologies logged in the drillhole database differ slightly from the representative lithologies assessed in this report (**Section 4**); however most key lithologies are reported, with the exception of recent sediments (Lake and Tertiary sediment, and Upper Saprolite) and tailings.

Total arsenic values greater than 9 mg/kg are recorded for several lithologies across the SIGM mine areas (**Figure 8**). Compared to other metals, there are fewer samples with elevated arsenic, and the majority of samples are basalt lithologies (Devon Consols Basalt, Lunnon Basalt, and Paringa Basalt), with lesser samples of Felsic Porphyry and Sediment (Black Flag Beds). In oxidising and aerated conditions, arsenic is likely to sorb onto sediment particles (in particular iron-oxides and iron-oxyhydroxides). This process limits bioavailability in aquatic environments. So although total arsenic concentrations are likely to be elevated in some waste rock samples at SIGM, the potential for impact to the receptor is likely to be, low based on the chemistry of the receiving environment.

Total chromium values greater than 80 mg/kg are recorded for a larger number of samples across the SIGM mine areas (**Figure 9**) compared to arsenic. The majority of samples with elevated chromium are basalt lithologies (Devon Consols Basalt, Lunnon Basalt, and Paringa Basalt), with lesser ultramafic and intrusive lithologies (felsic and intermediate). Like arsenic, chromium is likely to sorb onto sediment particles in oxidised, aerated aquatic environments, meaning the potential for chromium to be soluble and bioavailable in the receiving environment is likely to be low.

Total copper values greater than 16 mg/kg are recorded for the majority of samples across the SIGM mine area (**Figure 10**). The majority of samples with elevated copper are basalt lithologies (Devon Consols Basalt, Lunnon Basalt, and Paringa Basalt) and Sediments (Black Flag Beds), with lesser ultramafic and intrusive lithologies (felsic and intermediate). It is likely that elevated copper is associated with the basement rocks in the region and therefore it may be considered to be ubiquitous in the environment regionally The solubility of copper in aquatic environments is affected by the water properties, including pH, dissolved oxygen, suspended solids, hardness and salinity. Most copper present in soil tends to be strongly bound to soil particles; however, copper leaching may be higher in sandy, acidic soils. Bioavailability of copper in the aquatic receiving environment is likely to be limited by the properties of the water (neutral to alkaline pH and high salinity); however localised leaching of waste rock materials due to lower pH associated with acid generation is possible.

Total lead values greater than 50 mg/kg and total selenium values greater than 5 mg/kg are recorded for a minor number of samples across the SIGM mine area (**Figures 11** and **12**). Samples with elevated lead and selenium area sparsely distributed, and not confined to a single lithology or mine area. Based on the reported values, it is not likely that elevated concentrations of lead or selenium will be a major risk to aquatic receptors at SIGM.

Total zinc concentrations greater than 29 mg/kg are recorded for the majority of samples across the SIGM mine area (**Figure 13**). From comparison of the distribution of elevated metals, it appears that zinc is elevated in all key lithologies in the majority of samples represented by the data. It is likely that elevated zinc is associated with the basement rocks in the region and therefore it may be considered to be ubiquitous in the environment regionally. Toxicity of zinc to aquatic biota decreases with increasing hardness and salinity. Bioavailability of zinc in the aquatic receiving environment is likely to be limited by the properties of the water (high salinity); however localised leaching of waste rock materials due to lower pH associated with acid generation is possible.

Table 7-1: Summary of Qualitatve Risk of Elevated Metals in Representative Lithologies

Header	Qualitative Assessment of Elevated Metal Risk	Key High Risk Lithologies	Minor High Risk Lithologies
Arsenic	Moderate	Devon Consols Basalt, Lunnon Basalt, Paringa Basalt	Felsic Porphyry, Black Flags Group
Chromium	High	Devon Consols Basalt, Lunnon Basalt, Paringa Basalt	Felsic and intermediate intrusives, and Ultramafic
Copper	High	Devon Consols Basalt, Lunnon Basalt, Paringa Basalt, Black Flag Beds.	Felsic and intermediate intrusives, and Ultramafic
Lead	Low	None identified as high risk	None identified as high risk
Selenium	Low	None identified as high risk	None identified as high risk
Zinc	High	All	None identified as high risk

Table 7-1 presents a summary of the assessed total metals concentrations and distribution of elevated levels in key lithologies. In general, elevated metals concentrations are not confined to any particular mine area or lithology; with the exception of basalt lithologies (Devon Consols Basalt, Lunnon Basalt, and Paringa Basalt) which have higher levels of arsenic and chromium compared to other lithologies. Regionally, the basement rock is likely to have elevated concentrations of chromium, copper and zinc, so these metals may be considered to be ubiquitous in the environment.

Tailings samples have historically been assessed for total metals concentration (a total of 92 samples). A high level assessment of the results shows that the majority of tailings samples tested have total metal values exceeding the nominated trigger values for arsenic, chromium (only 25 samples reported), copper, and zinc. Total concentrations of lead and selenium were less than the nominated trigger value for all samples reported.

Although the assessed metals are considered to be regionally elevated and dissolution of metals into the aquatic environment is considered to be limited by natural sorption processes, localised leaching of waste rock and tailings materials due to local runoff water chemistry, or lower pH associated with acid generation is possible. Therefore, it is recommended that ongoing work consider assessment of potential solubility of metals in primary AMD sources and the potential for dissolved metal concentrations to cause impact to receiving environments.

8 Risk Assessment and Management Strategy

8.1 Risk Assessment

An overall assessment of AMD risk has been determined through examination of sample representation, pH, sulfide sulfur, ABA results, acid drainage potential classification (with a reliability assessment of the classification results) and elevated metals potential (**Table 8-1**).

In general, waste rock located near the mineralised zone is likely to have a higher risk of generating acid independent of the lithology. This is due to sulfide mineral distribution. It is recommended that sulfide mineral distribution is assessed when ore definition drilling takes place, in order to understand the spatial extent of the mineralised and alteration zone, where sulfide minerals would be in highest concentrations.

Specific lithologies that are identified as high risk are Kapai Slate and Cave Rocks Sediment. Lithologies that are identified as moderate risk are Cave Rocks Dolerite. The lithologies with low reliability in the potential acid drainage classification are:

- Tertiary sediment;
- Cave Rocks Sediment;
- Cave Rock Dolerite; and
- Mafic intrusion.

Table 8-1: Summary of Acid Drainage Potential and Metals Risk Potential Results and Overall Assessment of AMD Risk by Lithology

Lithology	Sample representation	pH	Sulfide sulfur	ABA	Potential Acid Drainage Classification	Reliability in Classification	Elevated Metals Present	Overall AMD Risk
Lake sediment	Good	Neutral	Barren	Negative	NAF	Good	Not determined	Low
Tertiary sediment	Good	Neutral	Barren	Negative	NAF	Low	Not determined	Low-Moderate
Upper Saprolite	Good	Neutral to Slightly acidic	Barren	Negative	NAF	Good	Not determined	Low
Merougil Creek Beds	Low (1)	Alkaline	Low	NP/AP >2	NAF	High	Chromium, copper and zinc	Low
Black Flag Beds	Good	Alkaline	Low	NP/AP >2	NAF	High	Chromium, copper and zinc	Low
Cave Rocks Sediment	Good	Alkaline	High	Majority Positive	PAF	Low	Chromium, copper and zinc	High
Kapai Slate	Low (2)	Neutral to Slightly alkaline	High	Majority Positive	PAF	Good	Chromium, copper and zinc	High
Condenser Dolerite	Low (2)	Alkaline	Low	NP/AP >2	NAF	Good	Not significant in reported data	Low
Defiance Dolerite	Good	Alkaline	Low	NP/AP >2	NAF	Good	Not significant in reported data	Low
Cave Rocks Dolerite	Good	Alkaline	Mod	Positive	NAF	Low	Not significant in reported data	Moderate
Devon Consols Basalt	Good	Alkaline	Low	NP/AP >2	NAF	Good	Arsenic, chromium, copper and zinc	Low
Lunnon Basalt	Low (1)	Alkaline	Moderate	NP/AP >2	NAF	High	Arsenic, chromium, copper and zinc	Low-Moderate
Paringa Basalt	Low (2)	Alkaline	Low -Barren	NP/AP >2	NAF	Good	Arsenic, chromium, copper and zinc	Low
Tripod Hill Komatiite	Good	Alkaline	Moderate	Negative	NAF	Good	Chromium, copper and zinc	Low
Felsic Intrusion	Good	Neutral to Slightly alkaline	Low	Negative	NAF	Good	Chromium, copper and zinc	Low
Intermediate Intrusion	Good	Alkaline	Low - Barren	Negative	NAF	Good	Chromium, copper and zinc	Low
Mafic Intrusion	Low (1)	Alkaline	Moderate	Negative	NAF	Low	Chromium, copper and zinc	Low-Moderate
Tailings	Good	Neutral to Slightly alkaline	Moderate	NP/AP >2	NAF	Good	Arsenic, chromium, copper and zinc	Low

8.1.1 Overall Risk Assessment

Although Kapai Slate is identified as a high risk lithology, it has been known to have a potentially high risk with respect to AMD potential since 2000 (**Section 3.1.1**), and therefore, current site management practices have prioritised selective handling of the waste materials to be placed within open pit voids, or in core areas of WRL. It also represents a small proportion of the mined materials at the site (5%). Statistical analysis of the data reveals that the lithology is the more normally distributed, so although sulfide sulfur has a wide range (<0.01 %S to 18.6 %S) the data has a low number of outliers, indicating that where the unit occurs, it has a high likelihood of containing sulfide sulfur. On this basis, the lithology is well understood and may continue to be managed as a high risk waste material with respect to potential acid generation.

Sediment and dolerite from Cave Rocks is highlighted in the risk assessment as having moderate to high potential to generate acid, and also as having low reliability in classification, due to a high proportion of samples with a positive ABA, moderate to high sulfide sulfur and samples classified as PAF and UNC. The risk associated with potential acid generation in these lithologies is not well understood; therefore, it is recommended that more detailed assessment of risk (incorporating assessment of current and potential impact, as well as kinetic testing of waste rock materials) be considered as part of ongoing operations at Cave Rocks.

Tertiary sediment is rated as low to moderate risk. The reliability of the data is low, due to the low proportion of NAG results reported. Some samples are classified as PAF, and although majority of samples have sulfide sulfur (majority of samples are classified as Barren), there is uncertainty around the acid generating characteristics of the samples with respect to sulfur mineralogy, nature of existing acid (where PAF samples have low NAG) and samples with conflicting NAPP and NAG results. Therefore, it is recommended that more detailed assessment of risk (incorporating assessment of current and potential impact, as well as kinetic testing of waste rock materials) be considered as part of ongoing sampling and characterisation programs.

Mafic intrusion samples were logged in the Leviathan Complex mine area in 2006 (**Appendix B**). The lithology has not been logged in waste samples since then and is likely to represent a very small portion of waste rock at SIGM. It is not considered to be a high priority for ongoing sampling, unless it is encountered in a new mining proposal mine area.

8.1.2 General Knowledge Gaps

Other potential AMD risk may be associated with samples classified as UNC, and with samples that are classified utilising the Hierarchy Two classification groupings. It is recommended that ongoing sample static analysis suites be modified to incorporate NAG testing as well as sulfide sulfur analysis, to ensure that a complete set of data is used for future classification of samples. In addition, SIGM may consider undertaking kinetic testwork, in the form of kinetic acid generation tests, ABCC tests and/or kinetic leaching tests to help understand the lag times of potential acid generation and potential risks under longer time scales (e.g. for closure).

8.2 Optimisation of AMD practices

Based on the outcomes of the overall risk assessment, the AMD risk is considered low and well understood for the majority of the lithologies on the site. In addition, where PAF material does exist, it is likely to be related to mineralised areas and therefore is able to be predicted in mapping, sample collection and analysis that is required to be conducted at the resource definition stage of mine area planning. Until Early 2015 SIGM collected between 100 and 200 samples of waste rock a year for AMD static testing. Current practice involves collection and analysis of samples for AMD analysis as part of new mining proposals). Tailings samples are regularly collected and analysed for static testing. In addition, all new mining proposals include sampling and static analysis of representative waste rock types. The risk assessment has identified a high degree of confidence in potential acid generation characteristics of representative lithologies at SIGM, enabling SIGM to review their procedures to focus on collection and analysis of samples located in less well understood lithologies and areas of site. It is proposed that the ongoing AMD program at SIGM focus on new mine areas, and understanding knowledge gaps and high risk lithologies in existing mine areas.

8.2.1 New Mine Areas

It is recommended that SIGM continue to sample and analyse materials to understand AMD characteristics for new mine areas to meet the regulatory requirements for environmental approval assessments. Sampling should aim to collect samples of each representative lithology, focussing on mineralised and non-mineralised zones to determine the extent of sulfide distribution. Total sample numbers may differ depending on the size of the deposit, but it is recommended that at least five to eight samples of each lithology that may be higher risk (i.e. located within mineralised zone) are included, depending on the estimated volume of material mined. It is also recommended that samples of each lithology be taken from mineralised areas and non-mineralised areas to validate the presence and absence of sulfide minerals. Selective handling and waste rock placement may then be managed within the mine plan. Testwork should comprise:

- static ABA and NAG testing including paste pH, EC, total sulfur and sulfide sulfur;
- total metals analysis; and
- leachable metals analysis.

8.2.2 Existing Mine Areas

The risk assessment has highlighted data and knowledge gaps associated with existing mine areas including the Cave Rock mine area, and some lithologies where acid generation potential classification is UNC or has low reliability. As there are a large number of samples for which characterisation has been undertaken, it is considered that additional sampling for static characterisation testing is unlikely to add any additional value to the current knowledge and risk associated with the majority of lithologies at SIGM. In addition, the current active mine areas are not necessarily in areas where additional characterisation work may add to the knowledge of those lithologies with samples classified as UNC, or with low reliability classification data.

It is recommended that ongoing AMD assessment work focus on identifying potential impacts associated with WRL and TSF, rather than ongoing characterisation of mined waste and tailings materials. With the exception of regulatory requirements for reporting AMD characteristics of waste and tailings materials, annual AMD characterisation testing may be modified to focus on assessing the potential pathways for AMD impact to reach receptors. Major pathways that have been identified as being potential conduits for leachate generated during oxidation of pyrite include:

- infiltration of rainfall into WRL and TSF;
- seepage from WRL and TSF into groundwater; and
- surface water and sediment runoff during rainfall events.

A monitoring strategy may be developed to assess potential for AMD impacts leachate to move along these pathways and to reach receptors in land and lake-based mine areas. The assessment should incorporate investigation of potential for pathways to exist (through groundwater and surface water characteristics and interaction assessment) as well as the chemistry of water and some waste material existing in those pathways to determine the potential for release of AMD during different water flow regimes. In addition, the potential for the resulting water to cause impact should also be considered. Given the nature of the Lake Lefroy receiving environment, as well as the known high salinity of groundwater, and inferred variability in sediment and soil chemistry, it is recommended that site specific baseline criteria be established for assessment of potential impact to surface water (both lake freshwater land-based receiving environments), groundwater and soils.

For mine areas that are less well understood, and for assessment of current risk associate with specific WRL, itis recommended that WRL be characterised according to the dominant lithologies and potential sulfide mineral concentration of waste materials contained within them. The purpose of this recommendation is to understand if any additional amelioration would assist in closure and rehabilitation of the WRL in the future. The results of this assessment have highlighted that sulfide concentration, and waste materials classified as PAF are likely to be related to the distribution of sulfide minerals within mineralised and alteration zones targeted for mining. The scope of understanding the location of waste materials may include:

- examination of historical mine plans to understand mine scheduling and waste rock placement;
- interviewing staff who have worked at the site over longer time periods;
- examination of sample logging sheets, reports, approval documents and waste tracking information (Some of this information is contained in the tables in **Appendix B**); and
- examination of historical aerial photographs to determine active mine areas and waste placement areas.

An understanding of the location and placement of waste materials in WRL would also assist in identifying areas where NAF and potentially AC waste may be located for use in undertaking closure and rehabilitation of higher risk areas. A summary of these and additional recommendations in the context of the whole of site AMD risk framework is provided in **Section 8.3**.

8.3 Risk Framework Summary

An AMD risk framework has been drafted, incorporating the results of the data analysis, and highlighting gaps and a summary of recommendations for ongoing work. The framework (**Table 8-2**) is based on a generalised framework provided in the GARD Guide (**Section 5.4**). The purpose of a framework is to aid in the understanding the current status of knowledge on elements that make up the overall AMD risk assessment at SIGM, and to highlight areas that may require additional knowledge to refine the risk assessment and add value to management practices at the site.

The assessment conducted in this study has added to the current understanding on Stages 2, 3 and 4 of the framework, and has highlighted areas to assist SIGM in the prioritisation of ongoing work required to further refine the risk assessment (**Section 8.1**). In addition, as SIGM is well into the operational phase of mining, and has begun to plan for closure, the risk framework also outlines the next steps for addressing knowledge gaps associated with the need to understand AMD characteristics for the purposes of developing closure completion criteria and rehabilitation prescriptions. This includes the assessment of materials that are NAF for potential reuse in rehabilitation applications.

Table 8-2: AMD Risk Management Framework for SIGM

Framework Stage	Description	Current Status	Summary of Recommendations	Priority
1	Establish baseline environmental conditions and criteria against which to assess impact – soil, groundwater and surface water (saline and fresh sources)	Current impact assessment for AMD adopts published regulatory guidelines for assessment of elevated metals in groundwater and baseline soils (land-based mining areas). Limited data is available for assessment of site specific background values for surface water and lake sediments (lake-based mine areas)	Development of site specific background values for assessing AMD impacts in groundwater and soils.	1
			Refinement of site specific background values for surface water and lake sediments.	1
2	Identify risks – define potential AMD source materials, pathways and receptor populations and sensitivities.	The AMD risk of representative primary source materials well understood. Risks due to secondary sources and some primary sources are yet to be assessed (e.g. heap leach facility). Potential pathways are known. Potential for impact to be present in pathways is not well understood. There is a limited understanding of receptor species and populations associated with Lake Lefroy (e.g. aquatic biota and riparian zone vegetation); however, some species populations and sensitivities of receptor species is not well understood (e.g. vegetation communities freshwater aquatic fauna, terrestrial fauna and riparian zone fauna and vegetation).	Undertake work to assess risks associated with other primary sources (e.g. heap leach facility).	2
			Understand background concentrations and variability, as well as receptor density and health to determine current tolerance to baseline water and sediment quality parameters. Increase knowledge on receptor populations and sensitivities within receiving environments of potential pathways to better understand which populations may be at greater risk. Refine risk assessment to focus on constituents that receptor populations are likely to be more sensitive to (related to site specific background values).	2
			Assess risks associated with secondary sources (may be undertaken closer to closure and decommissioning of relevant mine and infrastructure areas).	3
3	Analyse risk – conduct AMD characterisation (using static and kinetic tests) and evaluate risks with assigned certainty.	Risk of potential acid generation is generally well understood. Refinement of acid generation risk associated with some mine areas (Cave Rocks) and lithologies (Tertiary sediment) could be undertaken to better understand acid generation properties. Available acid consuming potential has been identified in certain lithologies (Condenser Dolerite, Defiance Dolerite and Paringa Basalt); however, the location and specific characteristics of acid neutralising availability are not well understood. Elevated metals that may be bioavailable are likely to be present in waste rock and tailings; however the potential for those metals to be leached at concentrations that may cause impact to receptors is not well understood.	Current SIGM procedures for the identification and management of potential AMD sources to be reviewed to capture more complete data from which to assess AMD risks for new mine areas and for any ongoing characterisation work.	1
			Investigate information available on mining and placement of waste materials with focus on sulfur (sulfide) concentrations to understand the distribution of PAF and NAF materials in WRLs.	1
			Ongoing testwork should focus on understanding the metals leaching and longer lag-time AMD properties of PAF and NAF materials as well as the sampling and investigation of potential for AMD leachate to travel along potential pathways to reach receptors. The development of a specific approach to refinement of AMD risk at Cave Rocks mine area is recommended.	1
4	Assess and Prioritise risk – compare results with criteria and identify and prioritise gaps.	The risk assessment should be regularly reviewed with additional data from new mine areas, and any ongoing testwork conducted to further refine the acid generation potential classification and elevated metals solubility in each lithology	Ongoing refinement of risk assessment and framework based on additional work.	Ongoing
			Consideration of availability of NAF and low metals risk material for use in closure to be undertaken through development of materials inventories of WRLs	1

Framework Stage	Description	Current Status	Summary of Recommendations	Priority
5	Manage/treat risks – apply management strategies to appropriately manage high risk and low risk areas, develop contingencies.	Current site management practices identify practical and appropriate waste material handling measures to reduce potential for acid generation. They include: 1. Specialised handling of high risk materials 2. Segregation of high risk materials 3. Encapsulation of high risk materials within lower risk materials 4. Blending and co-disposal of high and low risk materials 5. Sub aqueous and in-pit disposal of high risk materials to remain in a low oxygen environment These practices are considered to be acceptable for ongoing management of high risk lithologies.	Identify closure completion criteria (including requirement for validation sampling and assessment prior to material reuse) for use of available materials to assist in rehabilitation of outer surface of WRL and TSF to manage high risk areas. Identify closure and management approaches for other primary sources and for secondary sources.	3
			Develop contingencies for short and long-term management in the event that of areas of AMD impact are identified. These should focus on prevention of impacted water reaching receptors, and may include: • Seepage interception; • Stormwater retention; • Sediment capture; and • Surface water management to divert and direct runoff.	2
6	Review and monitor – monitor pathways and receptors to assess effectiveness of management and review risk assessment as required.	Monitoring plans for sampling and analysis of surface water and groundwater are focused on meeting regulatory requirements and currently incorporate limited information relevant to the assessment of AMD impacts.	Review and refine groundwater and surface water monitoring strategies to identify early signs of potential AMD generation, focussing on identified pathways for AMD-receptor interaction including: • Infiltration into WRL and TSF/seepage to groundwater; • Surface water runoff; and • Sediment mobilisation during rainfall events.	1

8.4 Summary

A review of all available geological and geochemical data relevant to the assessment of AMD risk associated with mined waste and tailings materials at SIGM was undertaken. The purpose of the review was to assess the current knowledge and understanding of the potential for materials generation of AMD in order to identify data gaps and assess AMD risk at the site. Recommendations have been made with a focus on optimising the process of refining the risk assessment and providing information to assist with modifying current operational procedures as well as future closure planning.

The majority of samples are classified as NAF – barren, NAF or potentially NAF, indicating that PAF and potentially PAF materials make up a relatively small component of waste at SIGM (<11%). The distribution of PAF materials is likely to be related to mineralisation and alteration zones near target ore deposits. The majority of lithologies therefore have been assessed as having a low risk potential to generate acid, with the exception of Kapai Slate and Cave Rocks Sediments, which have a high potential to generate acid. Other lithologies with a low to moderate risk potential to generate acid are Tertiary sediment, Cave Rock Dolerite, Lunnon Basalt and Mafic Intrusion; although with these lithologies, the risk is likely to be confined to mineralised areas where sulfide concentrations tend to be higher in the waste rock.

A high level assessment of the potential for mined waste and tailings material to be elevated in selected metals was undertaken. Regionally, basement rock materials have naturally elevated total concentrations of chromium, copper and zinc, and low concentrations of lead and selenium compared to nominated trigger values related to potential impact to aquatic biota in Lake Lefroy. Total arsenic concentrations are elevated in basalt lithologies and tailings materials. Although the assessed metals are considered to be regionally elevated and dissolution of metals into the aquatic environment is considered to be limited by natural sorption processes, localised leaching of waste rock and tailings materials due to local runoff water chemistry, or lower pH associated with acid generation is possible. Therefore, it is recommended that ongoing work considers assessment of potential solubility of metals in primary AMD sources and the potential for dissolved metal concentrations to cause impact to receiving environments.

The current management practices and procedures in place at SIGM are considered to be appropriate for the management of AMD risk at the site. The key recommendations and outcomes from this assessment are summarised in the AMD risk framework (**Section 8.3**) and focus on optimisation of ongoing testwork to understand longer lag-time AMD characteristics and the potential for AMD to cause impact to receptors. Recommendations that have been highlighted as having a higher priority are summarised by risk framework stage below:

- Establishment of baseline criteria:
  - Development of site specific background values for assessing AMD impacts in groundwater and soils and refinement of site specific background values for surface water and lake sediments to understand sensitivities and tolerance of receptor population to natural background variability in chemistry.
- Analysis of risk:

  - Update current SIGM procedures for the identification and management of potential AMD sources to capture more complete data from which to assess AMD risks for new mine areas and for any ongoing characterisation work.
  - Investigate information available on mining and placement of waste materials with focus on sulfur (sulfide) concentrations to understand the distribution of PAF and NAF materials in WRLs.
  - Understanding the metals leaching and longer lag-time AMD properties of PAF and NAF materials as well as the sampling and investigation of potential for AMD leachate to travel along potential pathways to reach receptors.
- Assessment and prioritisation of risk:
  - Development of an understanding of the location and amount of available NAF and low metals risk material for use in closure.
- Review and monitor to assess effectiveness of management:
  - Review and refinement of groundwater and surface water monitoring strategies to identify early signs of potential AMD generation, focussing on identified pathways for AMD-receptor interaction.

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Figures (attached)

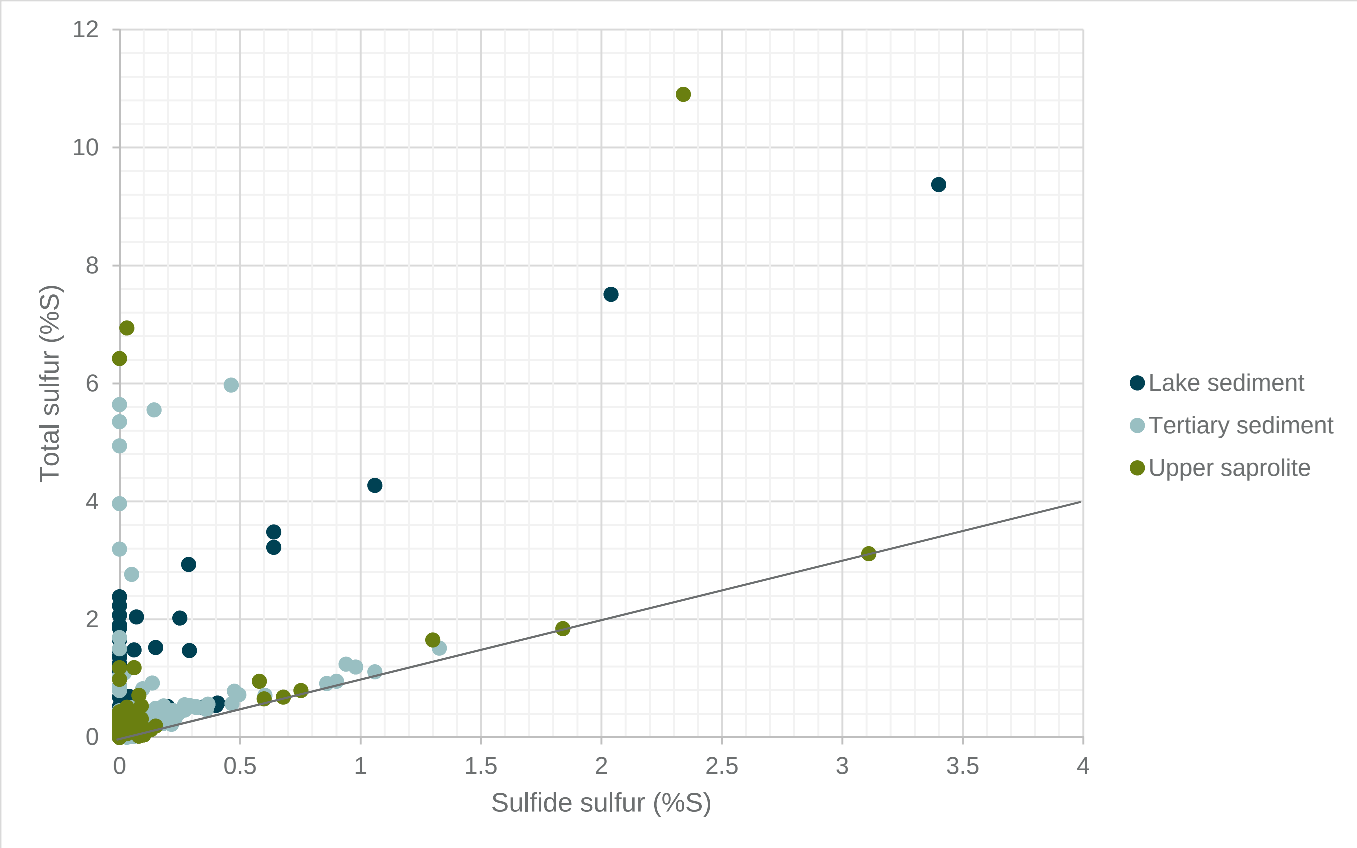


Figure 1a: Comparison of Total Sulfur and Sulfide Sulfur for Recent Sediments

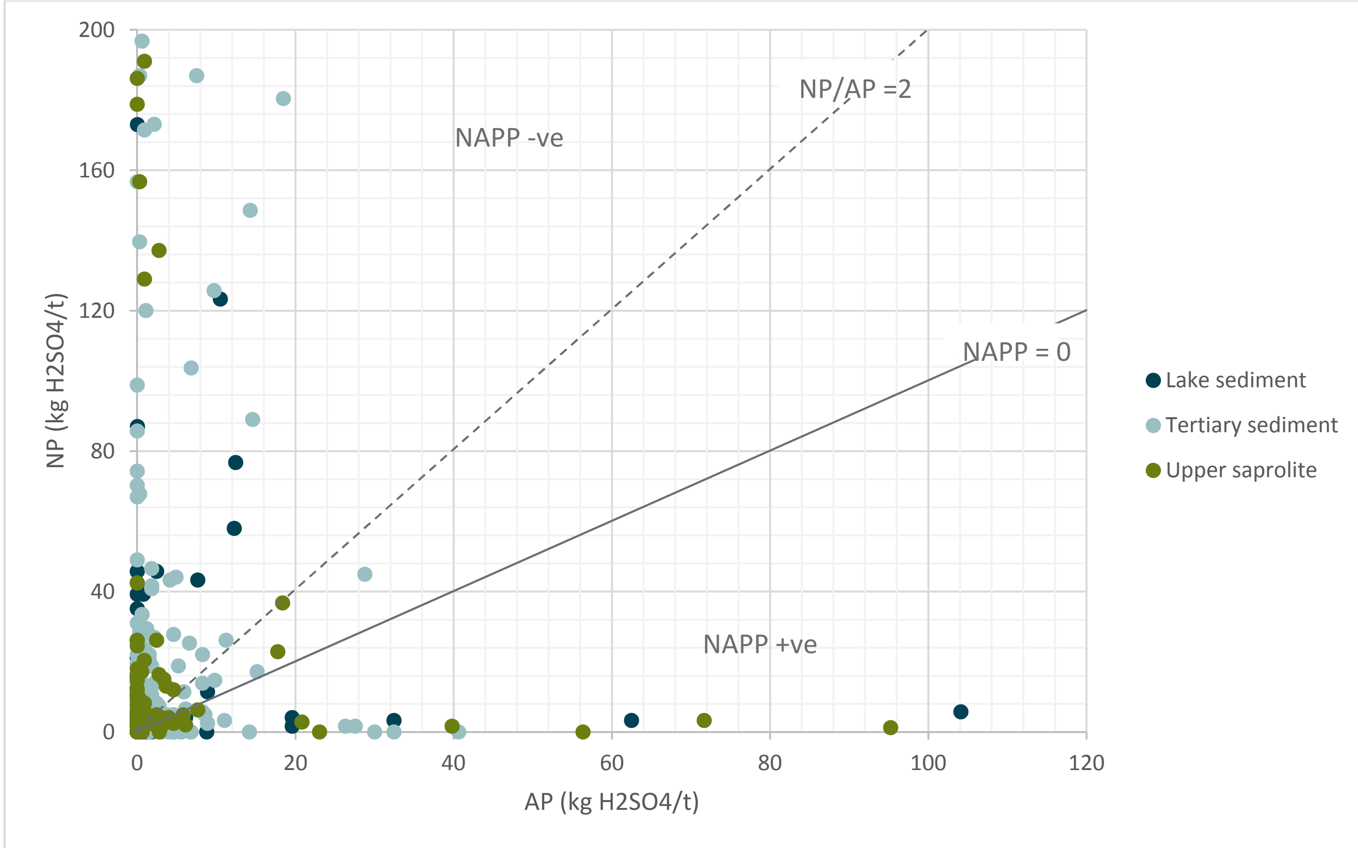


Figure 1b: ABA Plot for Recent Sediments

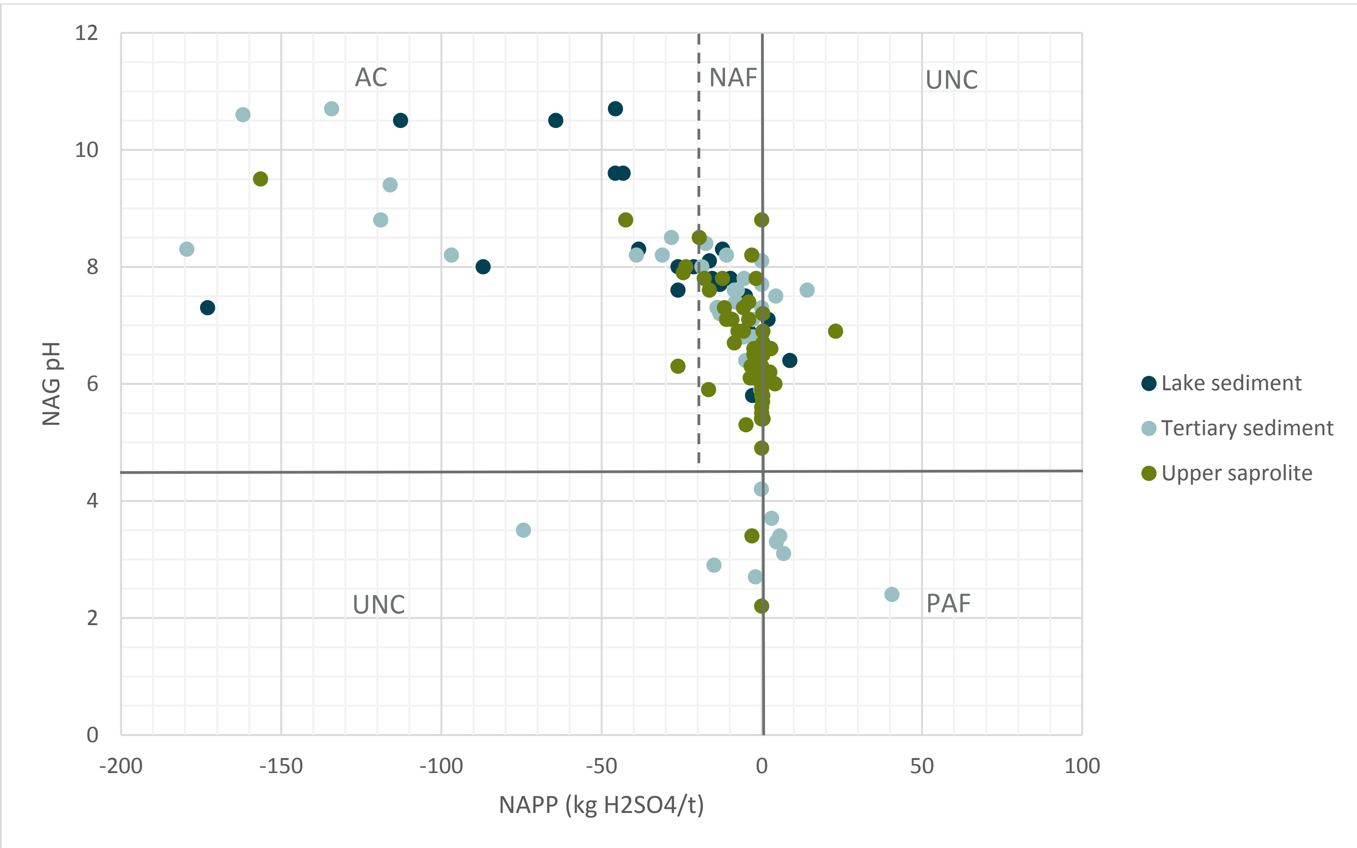


Figure 1c: Acid Drainage Potential Classification for Recent Sediments (Hierarchy One Classification Only)

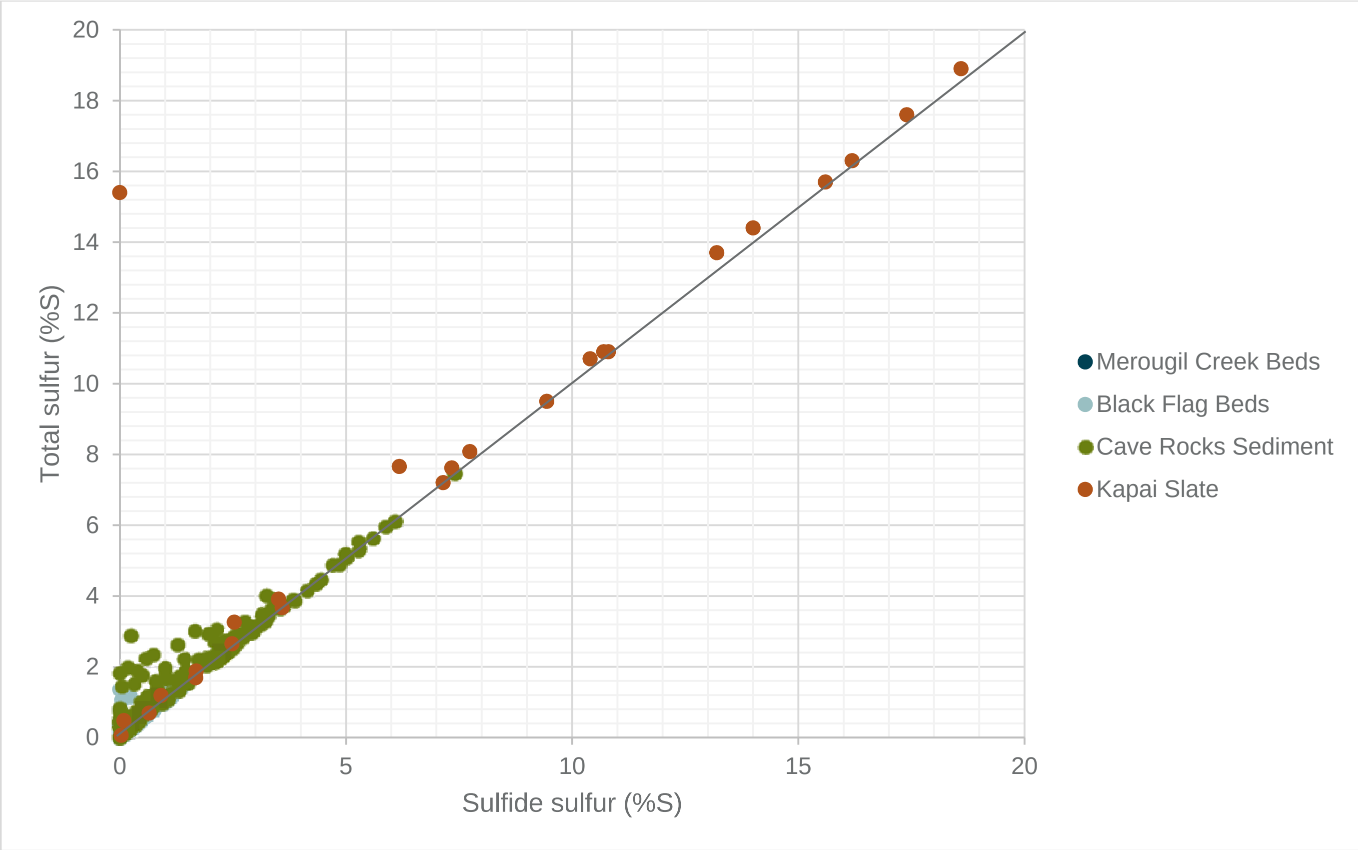


Figure 2a: Comparison of Total Sulfur and Sulfide Sulfur for Interbedded and Older Sediments

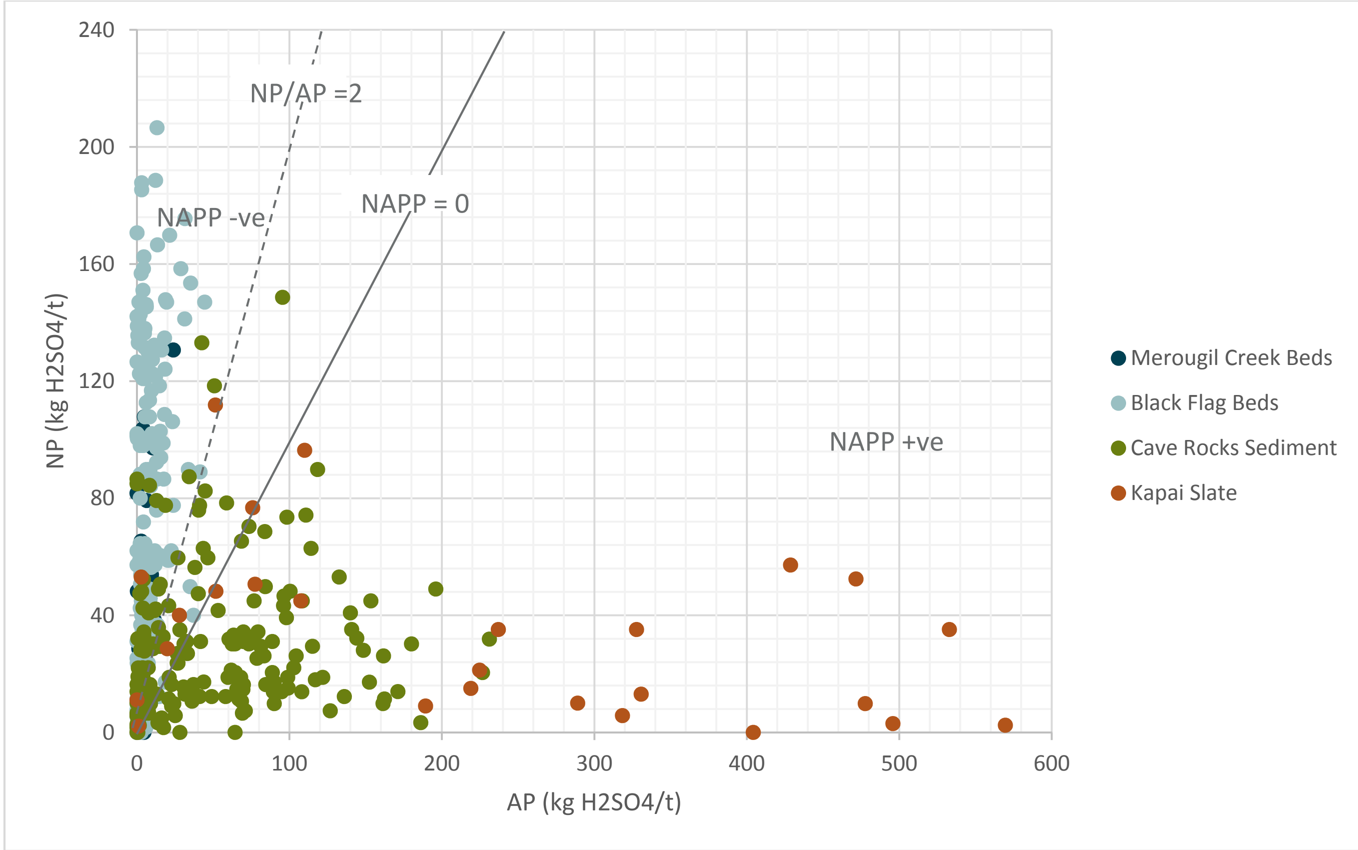


Figure 2b: ABA Plot for Interbedded and Older Sediments

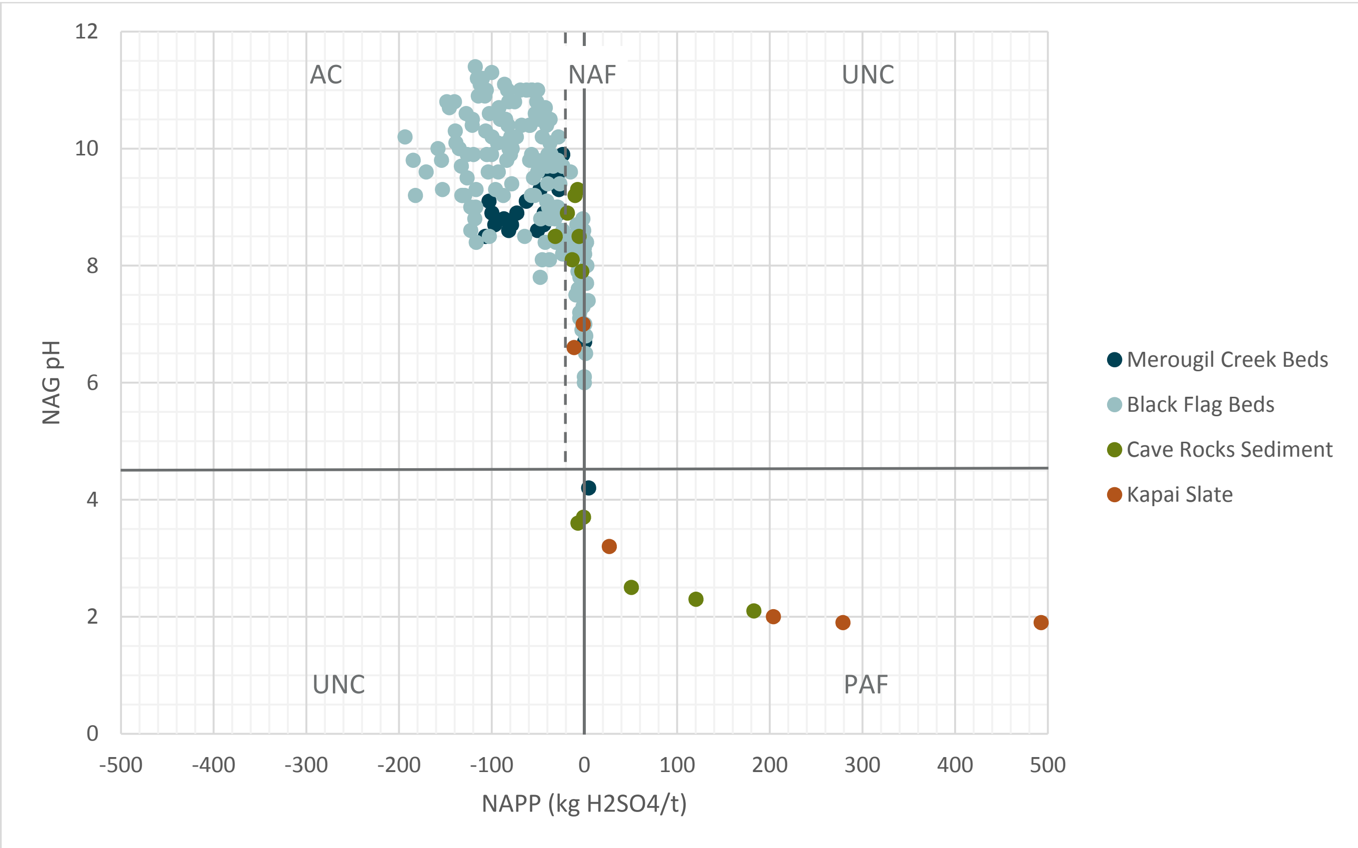


Figure 2c: Acid Drainage Potential Classification for Interbedded and Older Sediments (Hierarchy One Classification Only)

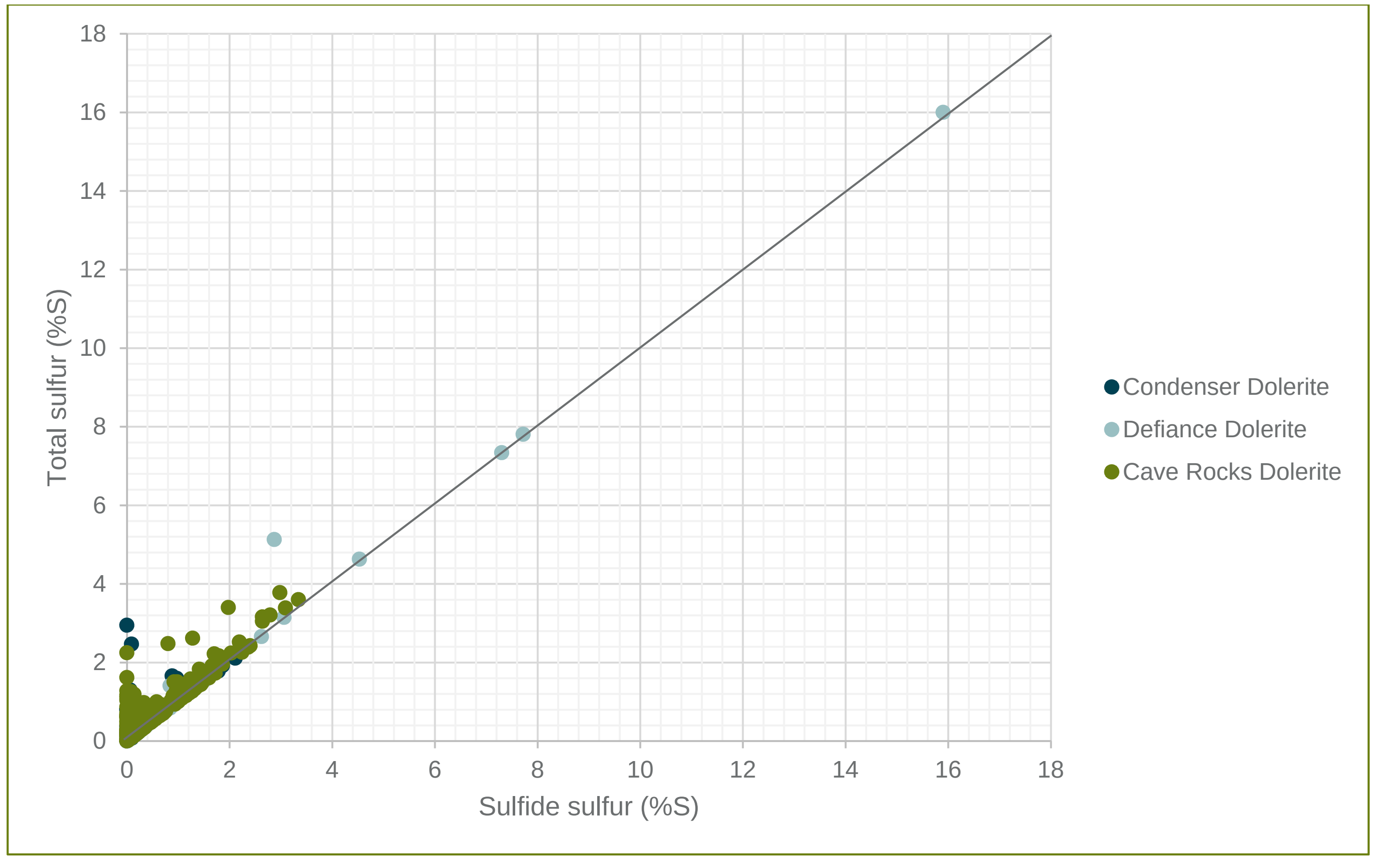


Figure 3a: Comparison of Total Sulfur and Sulfide Sulfur for Dolerites

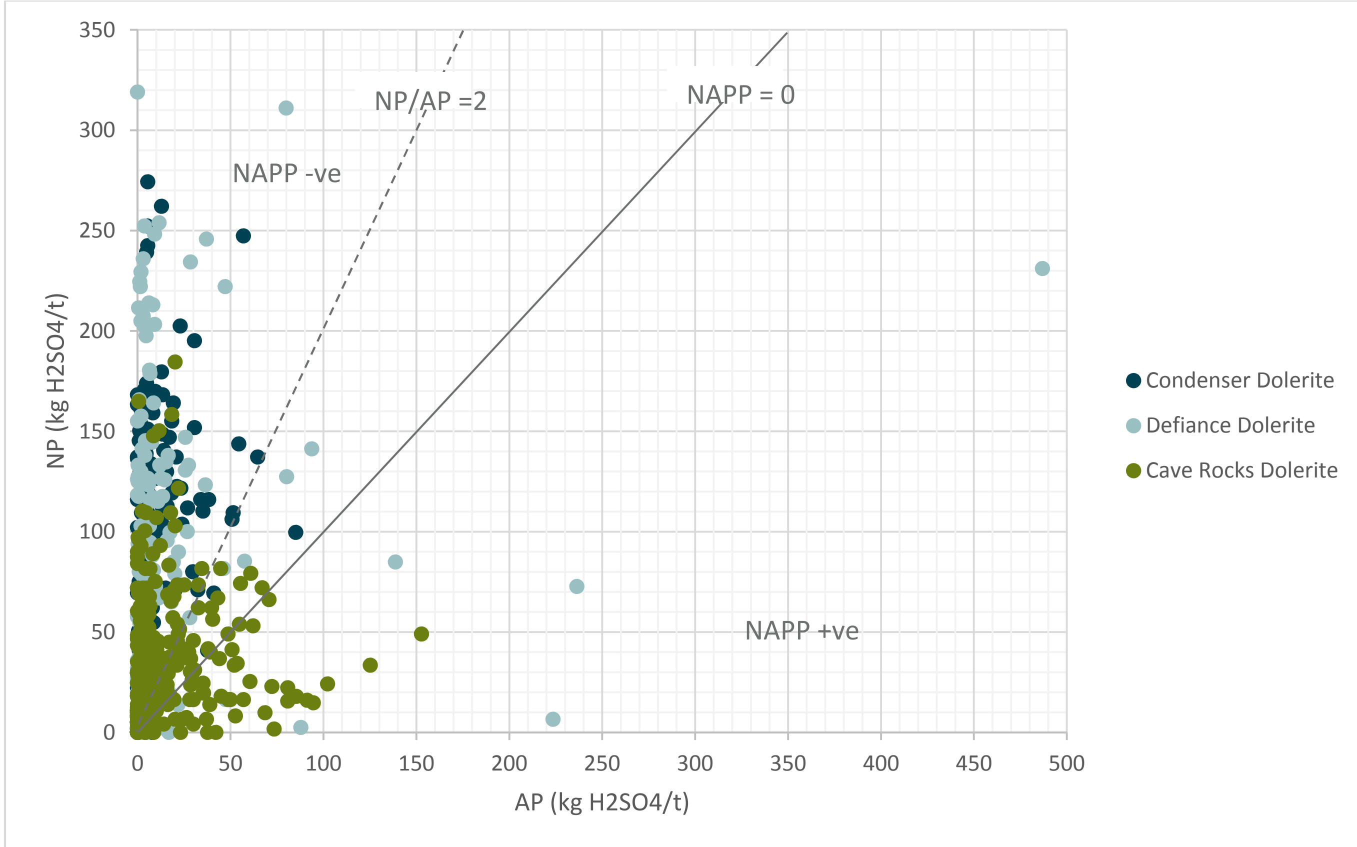


Figure 3b: ABA Plot for Dolerites

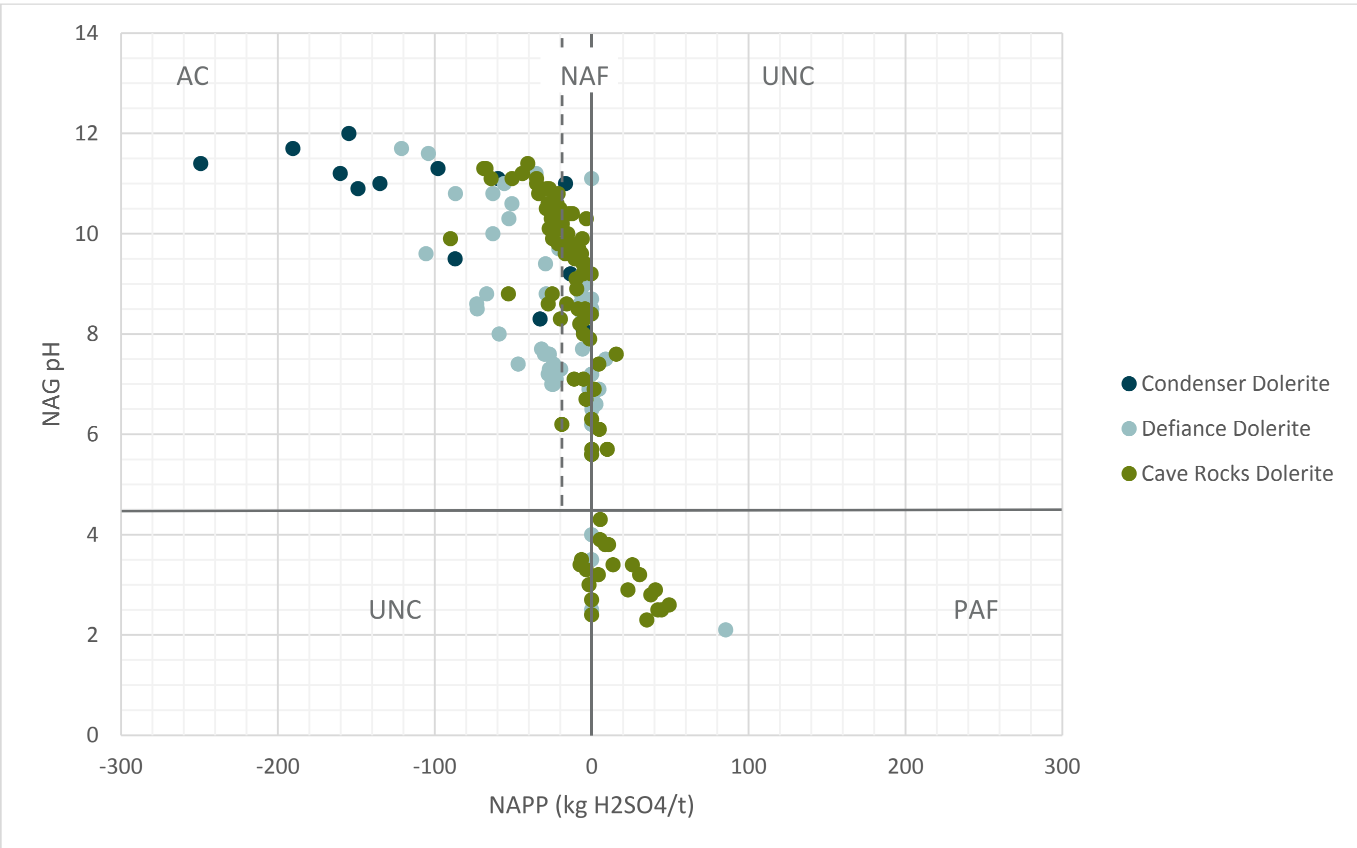
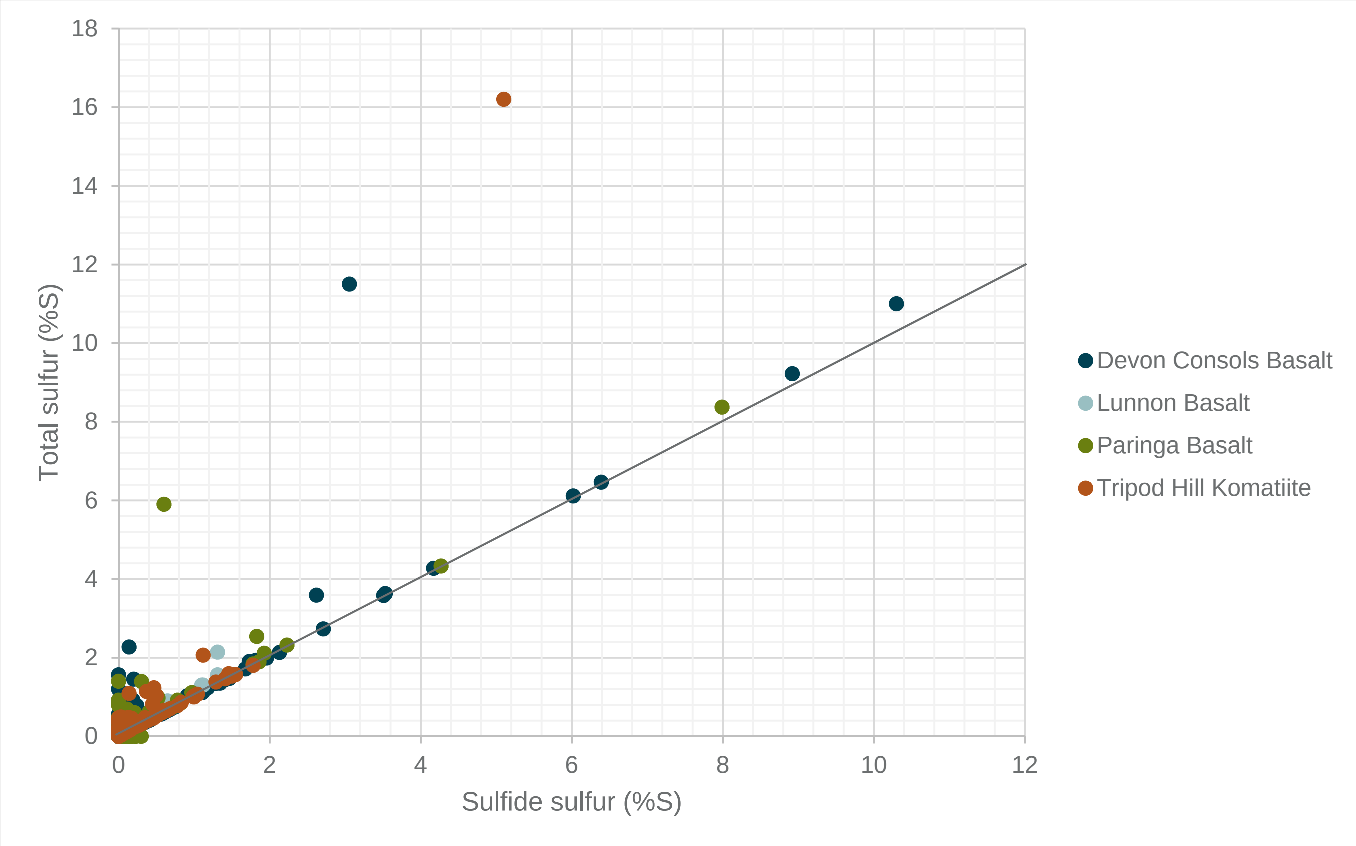


Figure 3c: Acid Drainage Potential Classification for Dolerites (Hierarchy One Classification Only)



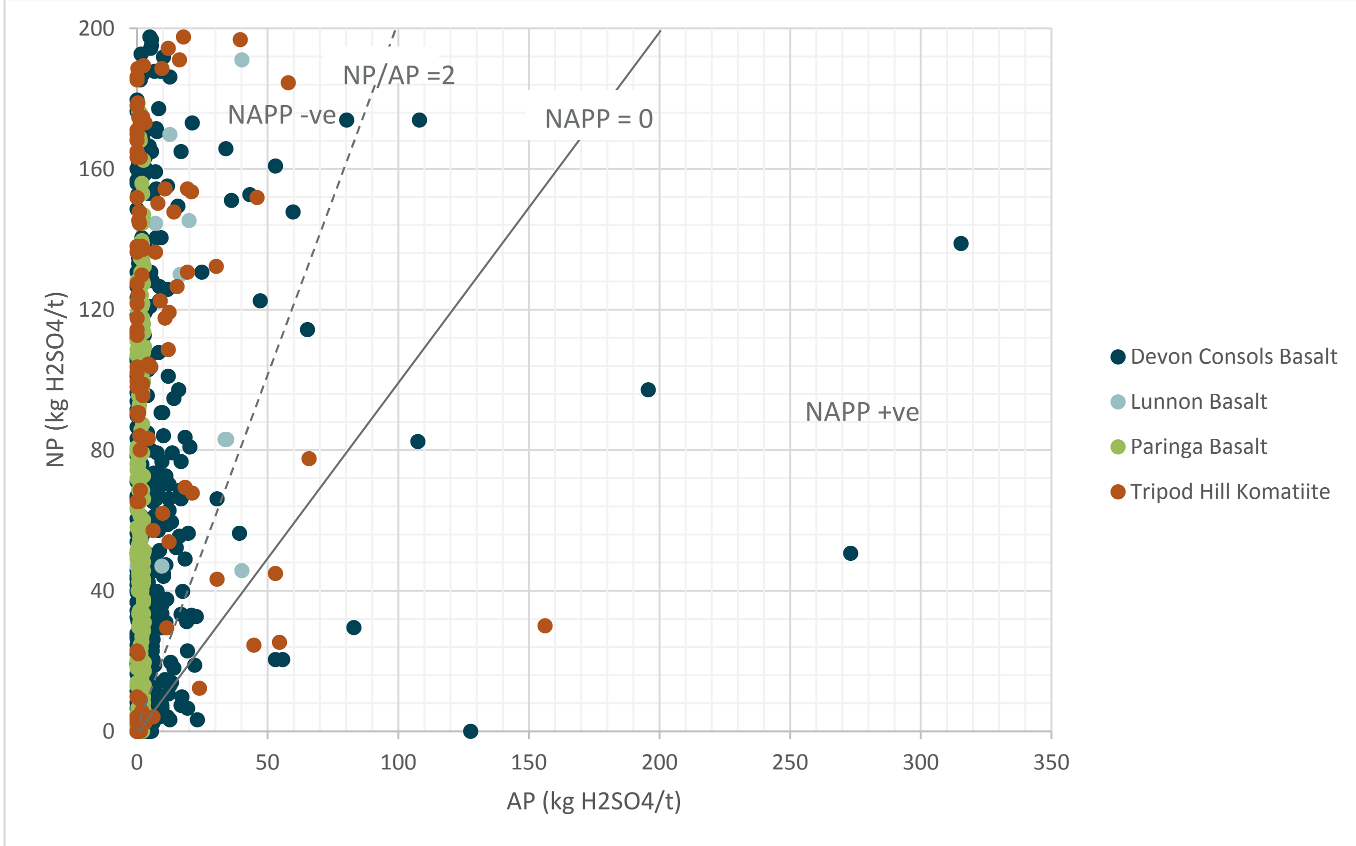


Figure 4a: Comparison of Total Sulfur and Sulfide Sulfur for Basalts and Ultramafic

Figure 4b: ABA Plot for Basalts and Ultramafic

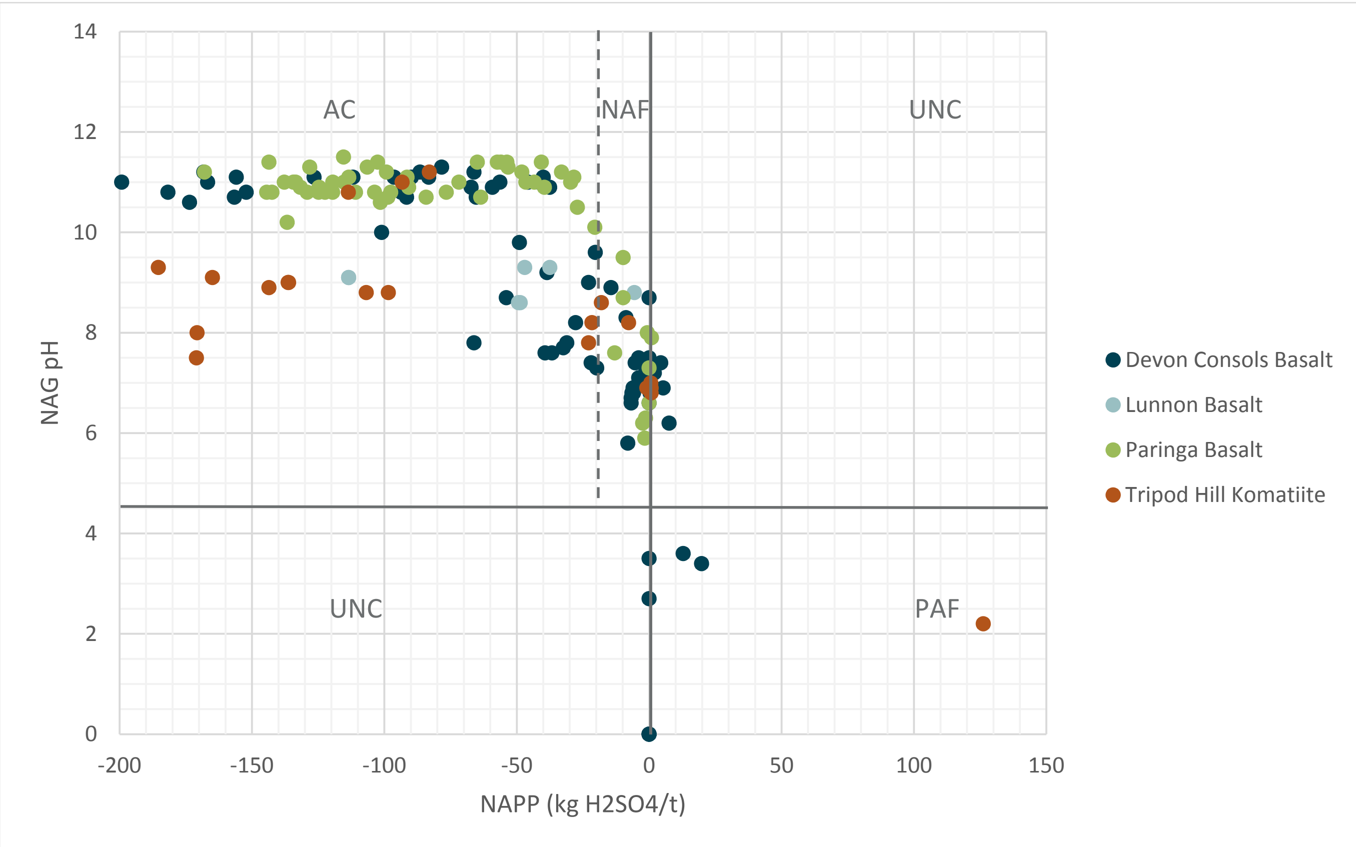


Figure 4c: Acid Drainage Potential Classification for Basalts and Ultramafic (Hierarchy One Classification Only)

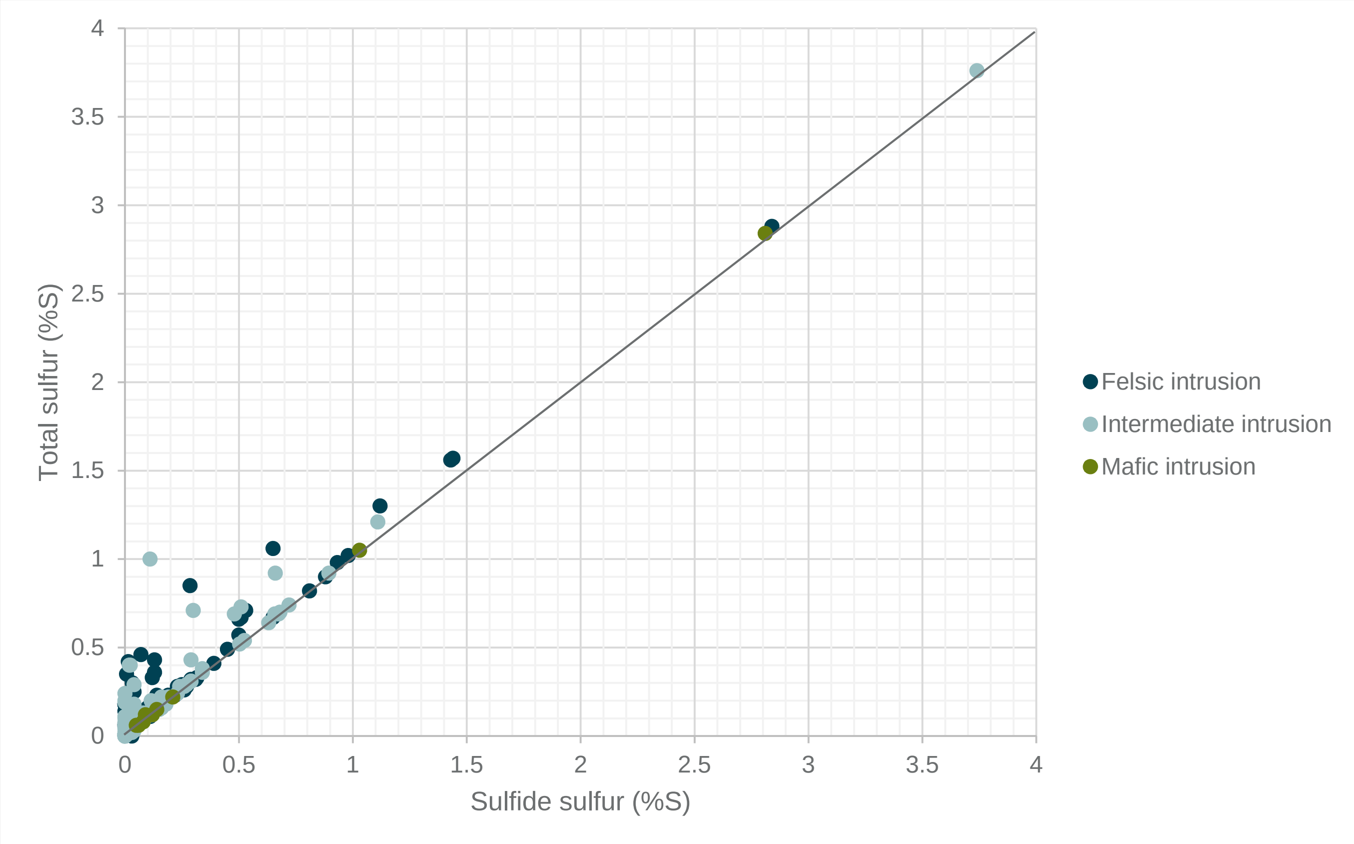


Figure 5a: Comparison of Total Sulfur and Sulfide Sulfur for Intrusives

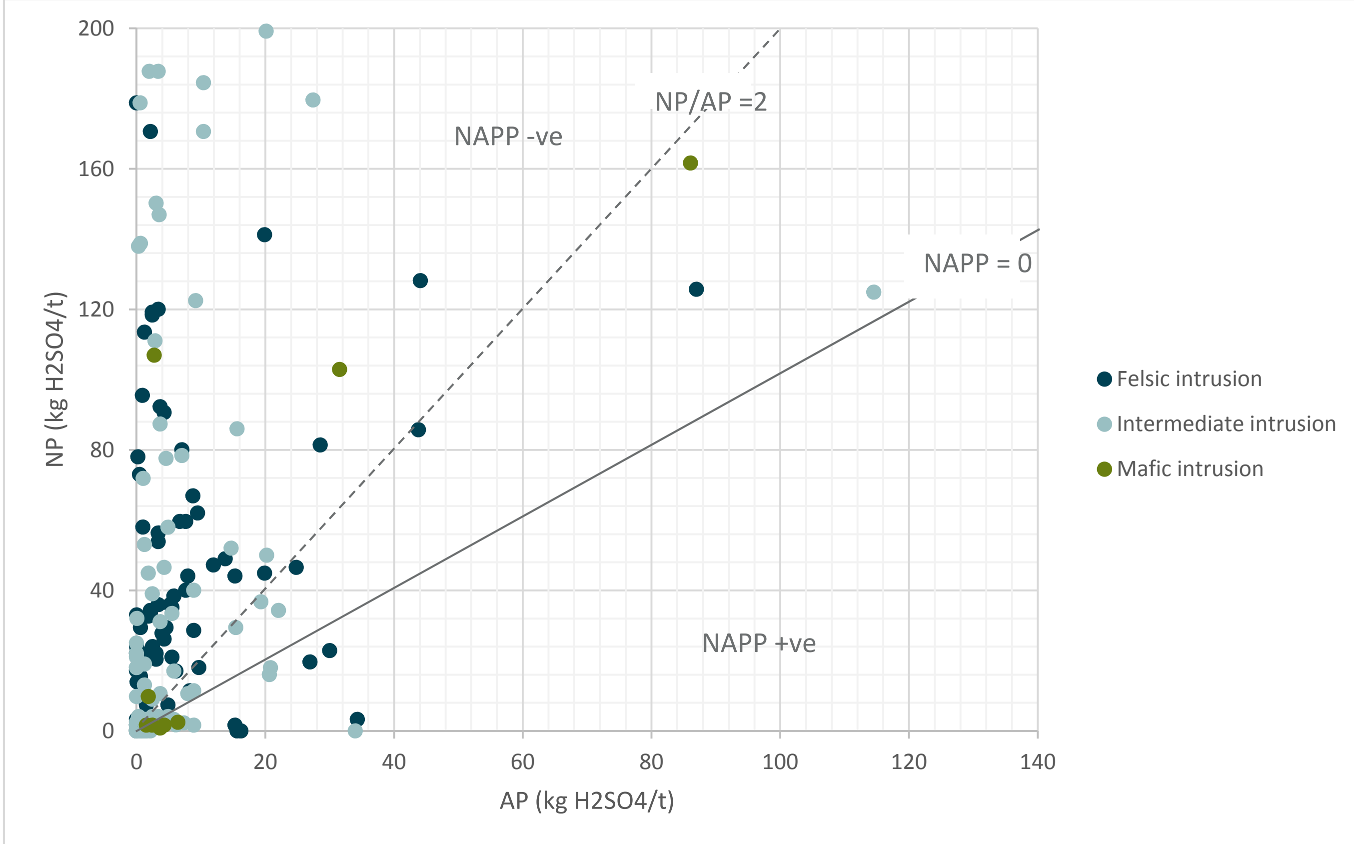


Figure 5b: ABA Plot for Intrusives

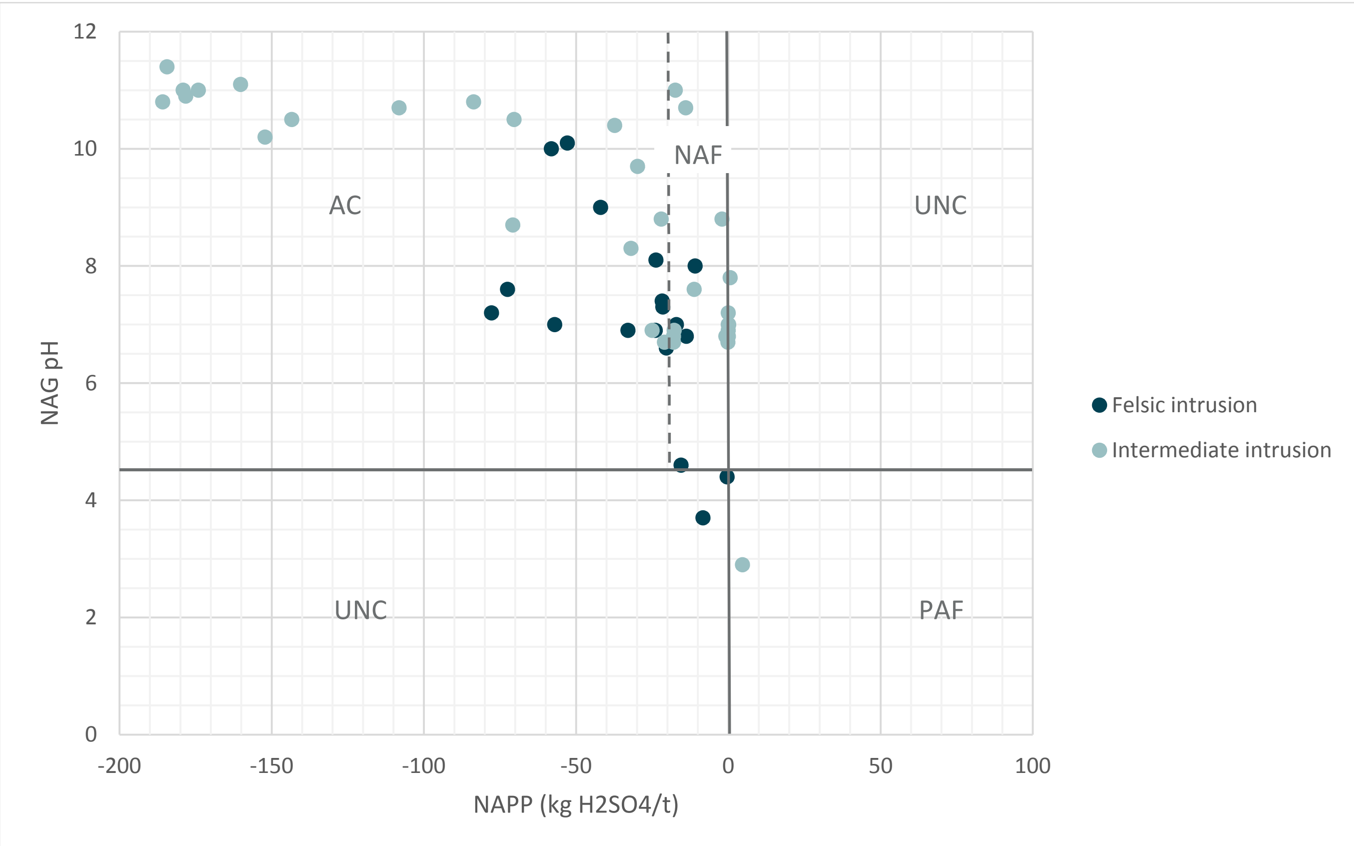


Figure 5c: Acid Drainage Potential Classification for Intrusives (Hierarchy One Classification Only)

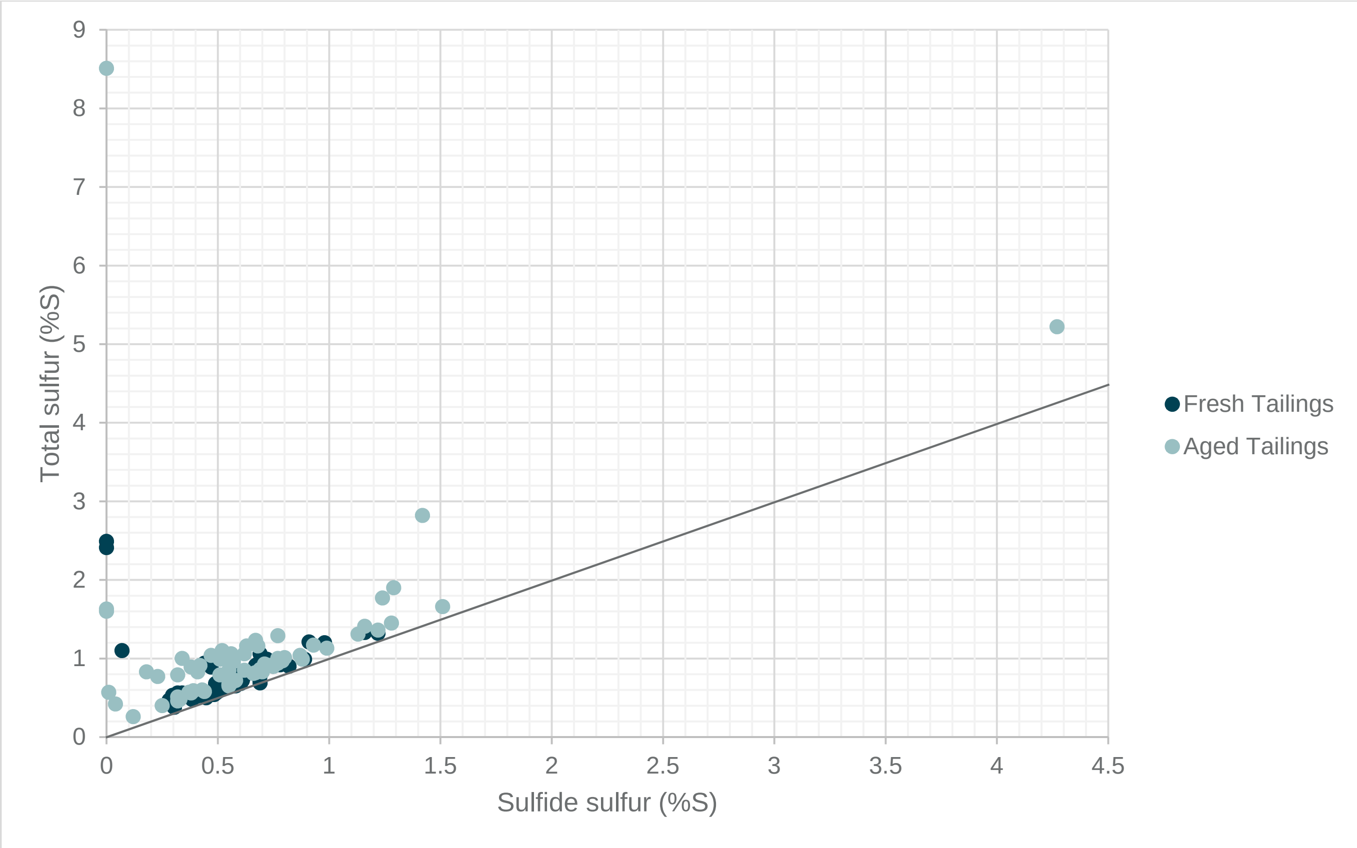


Figure 6a: Comparison of Total Sulfur and Sulfide Sulfur for Tailings

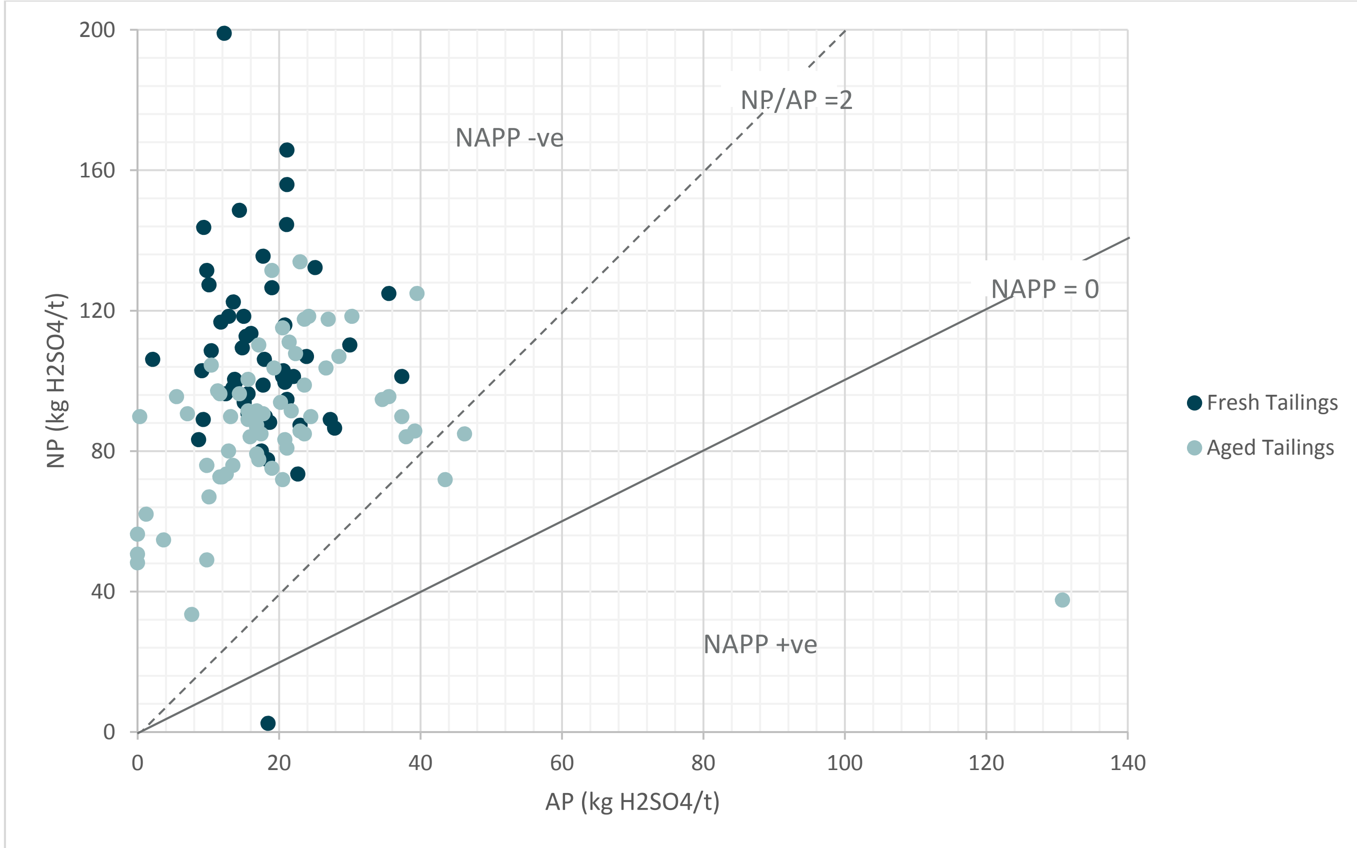


Figure 6b: ABA Plot for Tailings

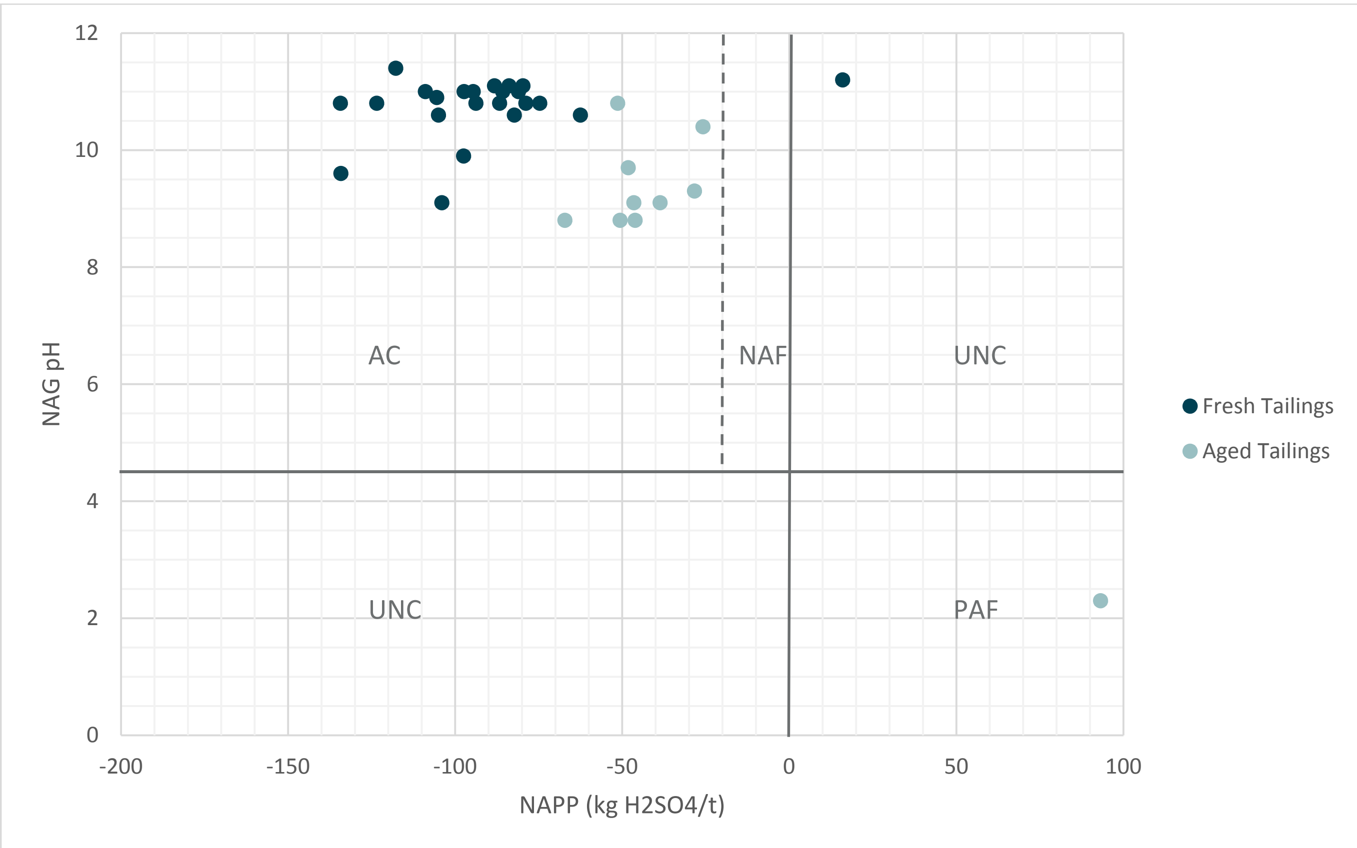
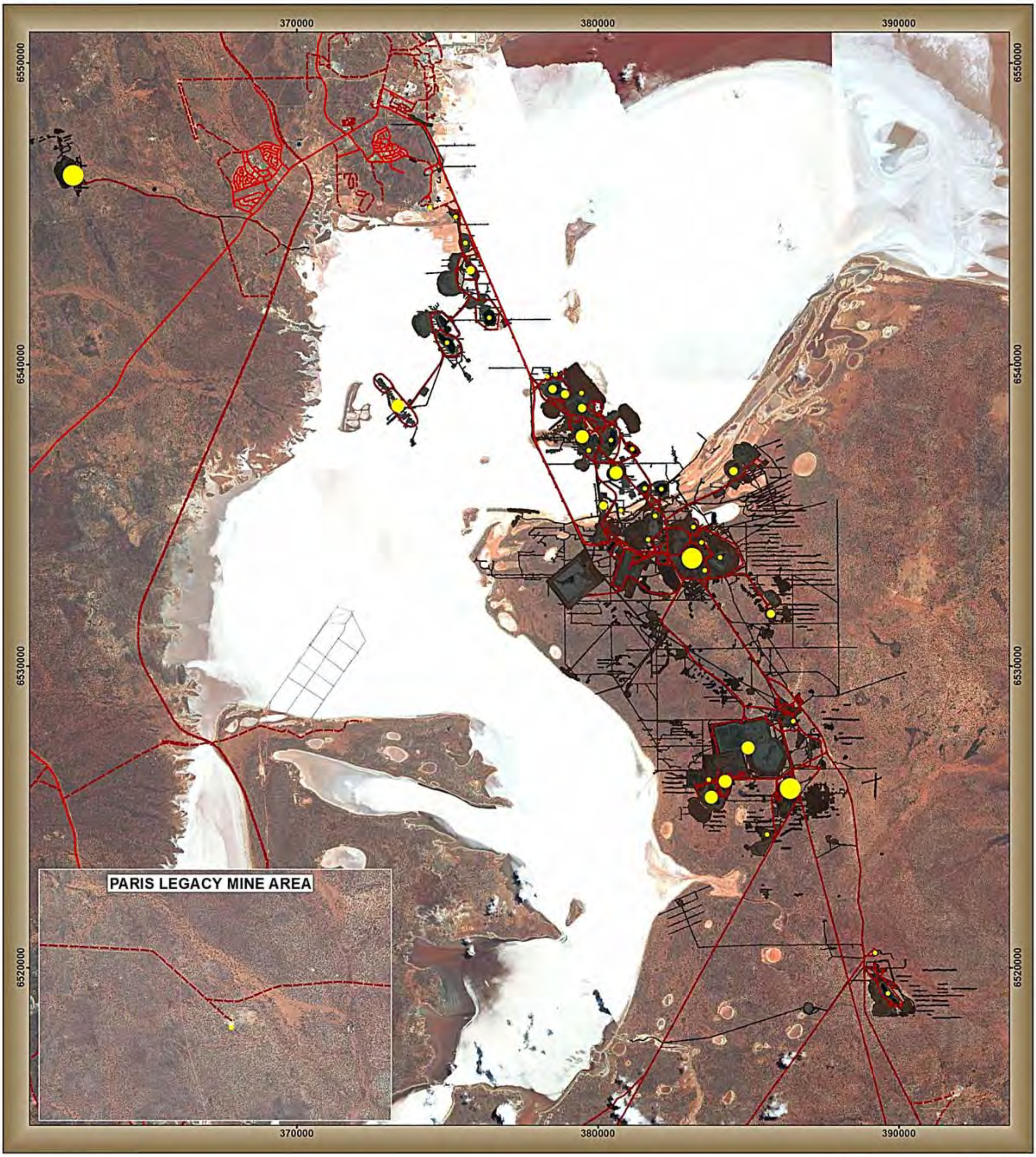


Figure 6c: Acid Drainage Potential Classification for Tailings (Hierarchy One Classification Only)

Sample Results - Total ABA



LEGEND

Total ABA 2015
- 1 - 50
- 51 - 100
- 101 - 200
- 201 - 550

Domains and Features

Main Roads
- Sealed Road
- Unsealed Road

0 2.5 5 7.5 10

Kilometres

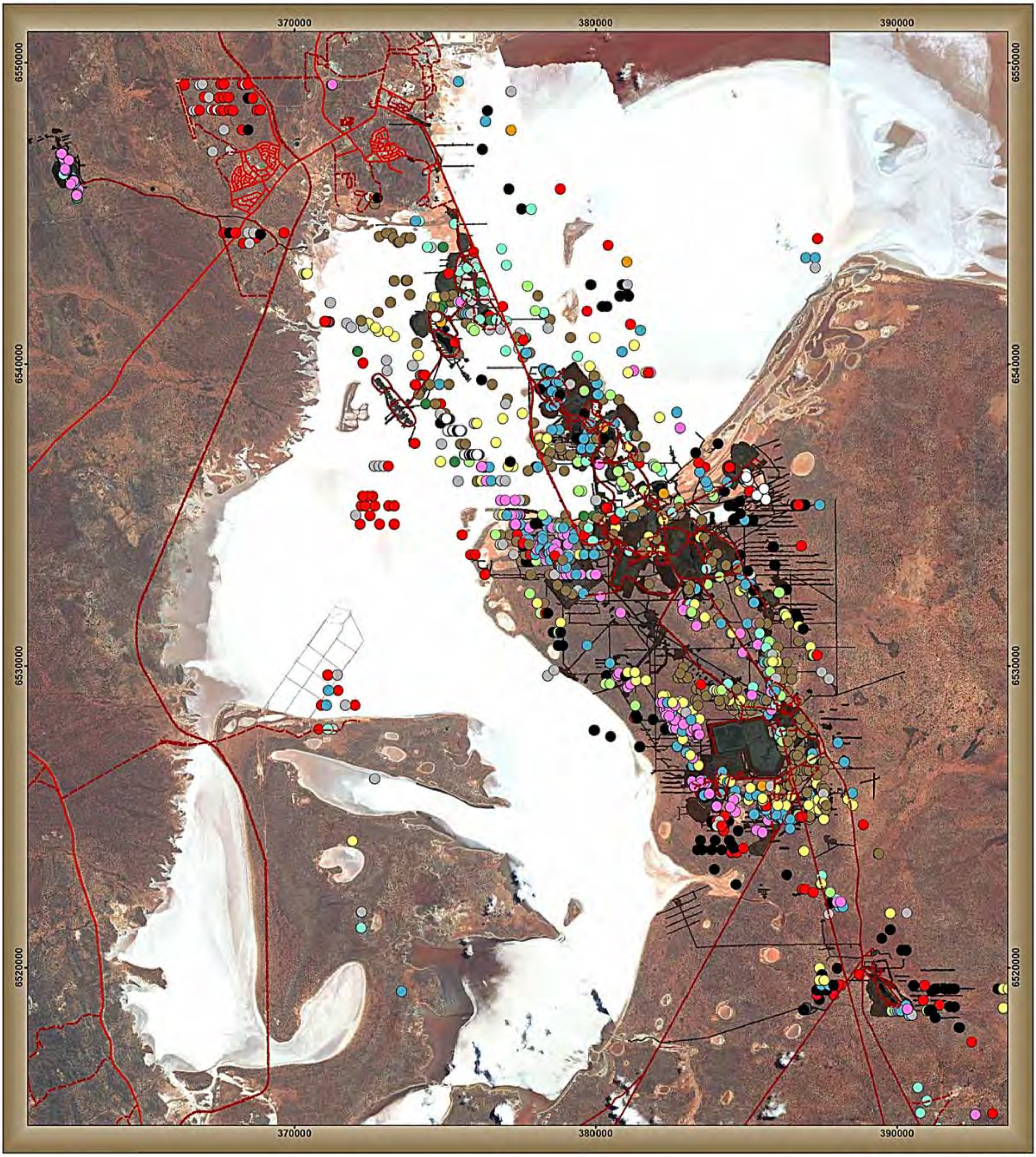
N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_ABA_Results_2015

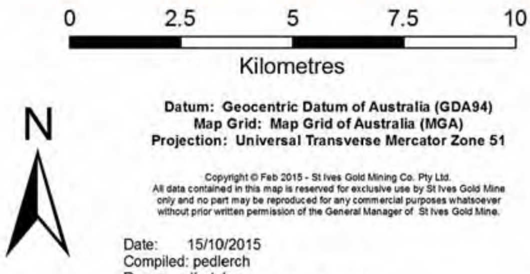
SIGM LEASE LOCALITY MAP

Elevated Total Arsenic Distribution



LEGEND

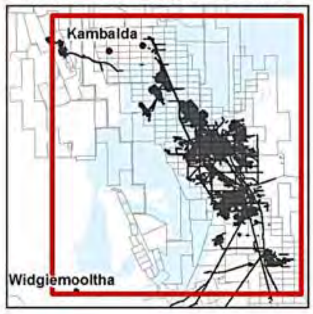
Main Roads
Sealed Road
Unsealed Road
Domains and Features
Total Arsenic Results (>9 mg/kg)
Lithology
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown



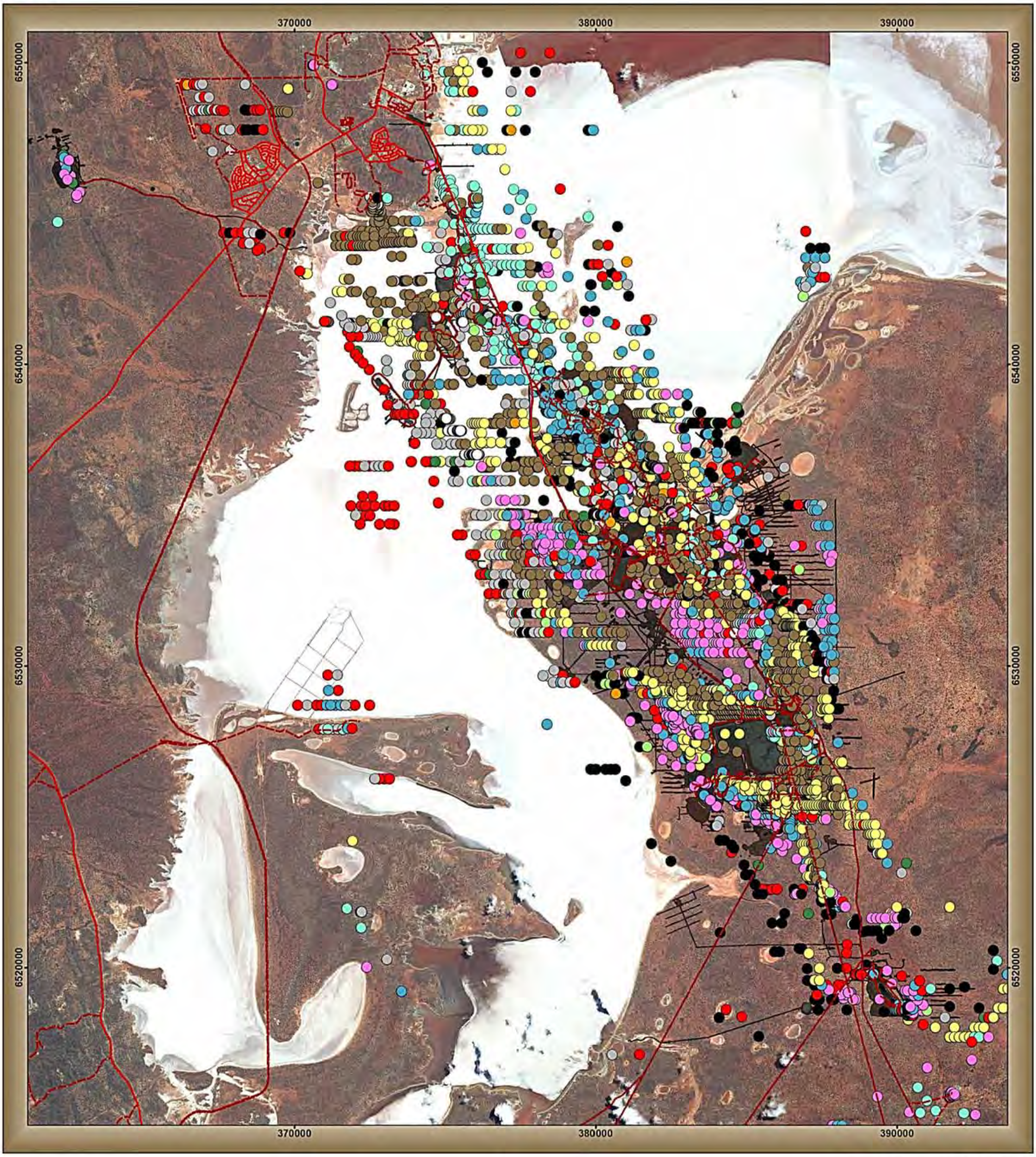
Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_As

SIGM LEASE LOCALITY MAP



Elevated Total Chromium Distribution



LEGEND

Main Roads
- Sealed Road
- Unsealed Road
- Domains and Features

Total Chromium Results (>80mg/kg)

Lithology
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown

N

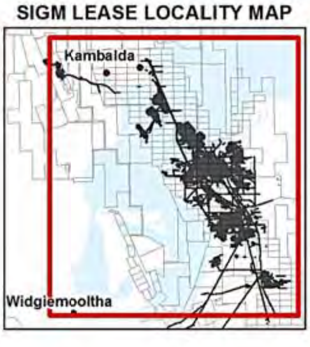
0 2.5 5 7.5 10

Kilometres

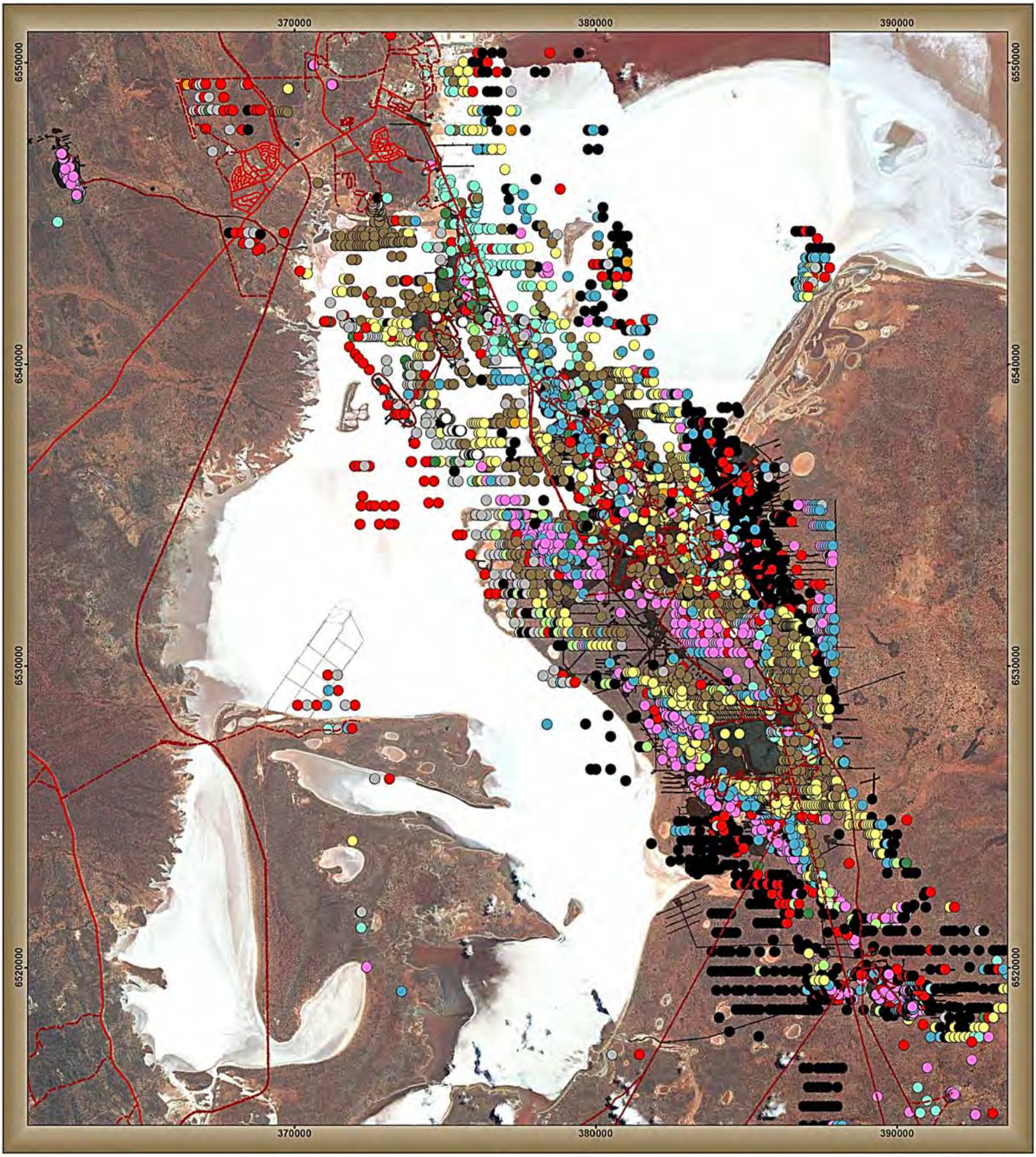
Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_Cr

SIGM LEASE LOCALITY MAP



Elevated Total Copper Distribution



LEGEND

Main Roads
- Sealed Road
- Unsealed Road
- Domains and Features

Total Copper Results (>16mg/kg)
Lithology
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown

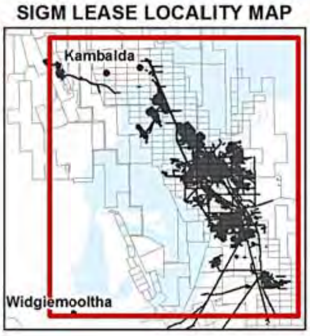
N

0 2.5 5 7.5 10
Kilometres

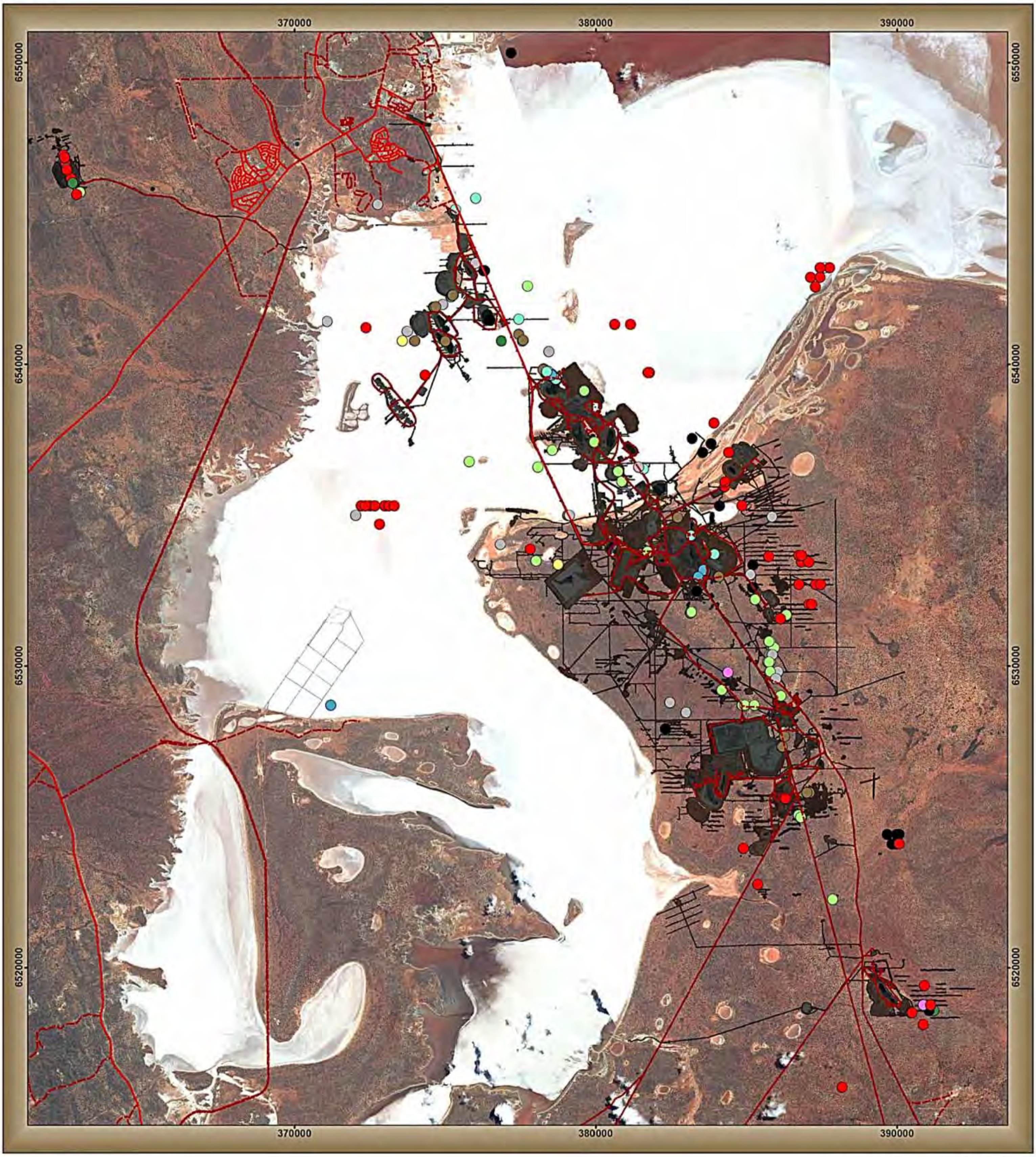
Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_Cu

SIGM LEASE LOCALITY MAP



Elevated Total Lead Distribution



LEGEND

Main Roads
- Sealed Road
- Unsealed Road

Domains and Features

Total Lead Results (>50mg/kg)

Lithology
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown

0 2.5 5 7.5 10

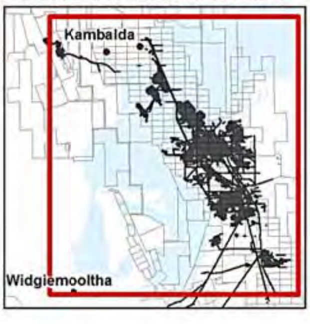
Kilometres

N

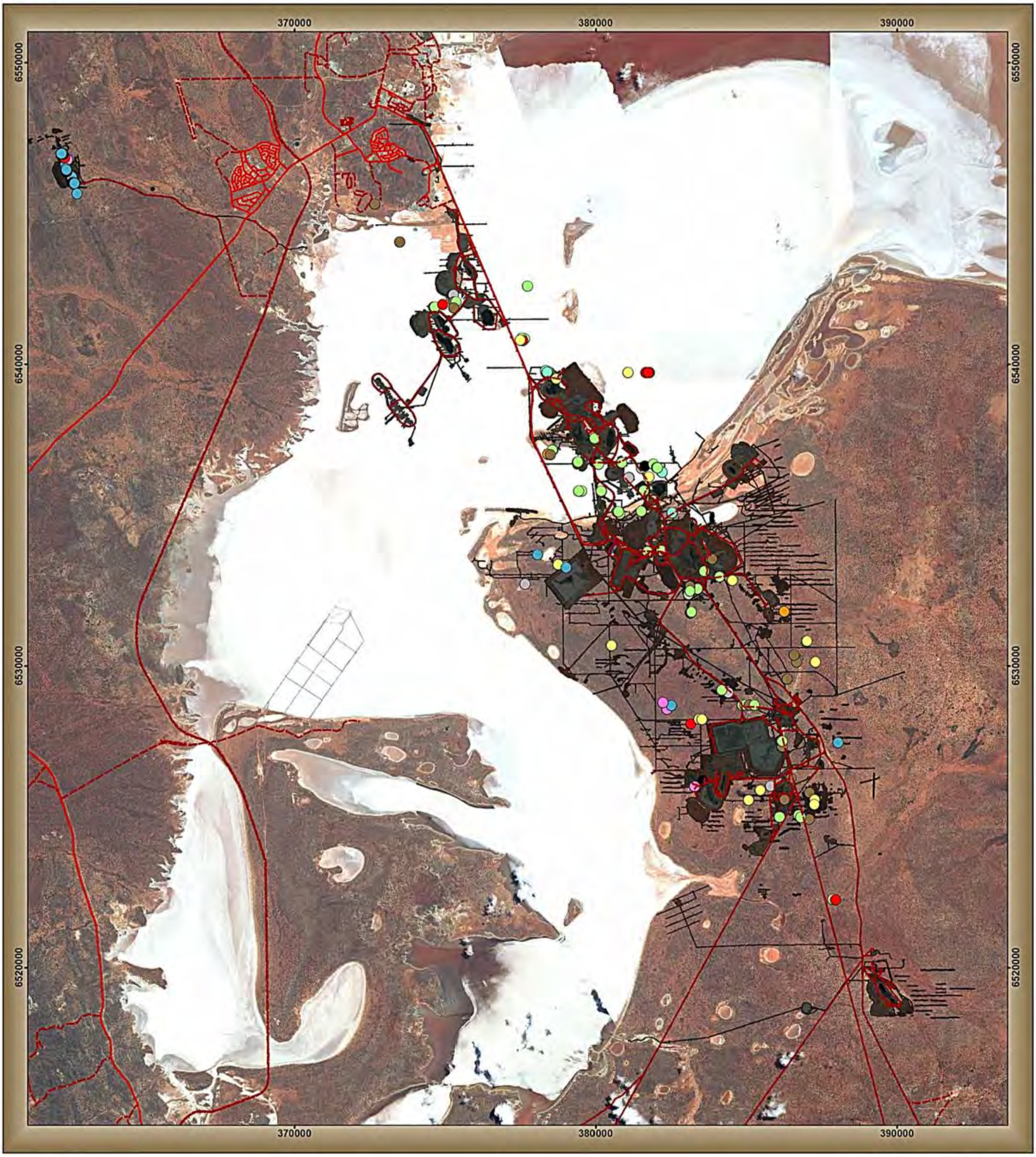
Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_Pb

SIGM LEASE LOCALITY MAP



Elevated Total Selenium Distribution



LEGEND

Main Roads
- Sealed Road
- Unsealed Road
- Domains and Features

Total Selenium Results (>5mg/kg)
Lithology
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown

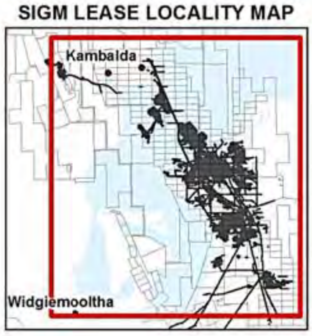
N

0 2.5 5 7.5 10
Kilometres

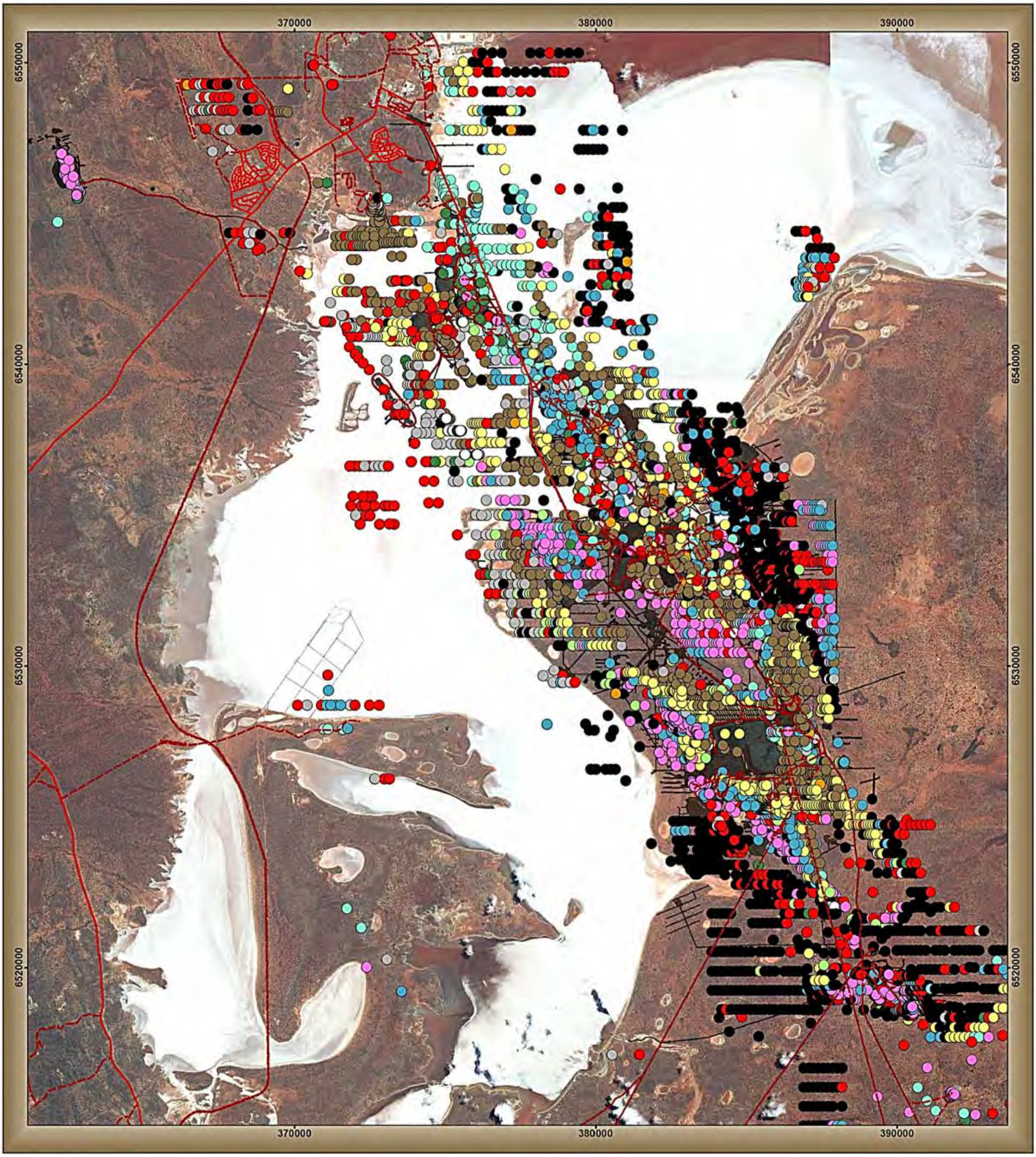
Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_Se

SIGM LEASE LOCALITY MAP



Elevated Total Zinc Distribution



LEGEND

Main Roads
- Sealed Road
- Unsealed Road
- Domains and Features

Total Zinc Results (>29mg/kg)

Lithology
- Condenser Unit 4
- Felsic Intrusion 1
- Black Flag Sediments
- Black Shale
- Defiance Unit 4
- Devon Consols Basalt
- Felsic Porphyry
- Intermediate Volcanics
- Lower Paringa Basalt
- Lunnon
- P-rich Porphyry
- Ultramafic
- Upper Paringa Basalt
- Unknown

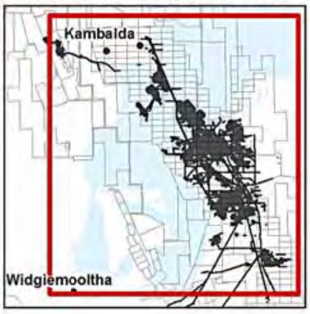
0 2.5 5 7.5 10
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 15/10/2015
Compiled: pedlerch
Drawn: thatchc
Name: STIV_GeoChem_Results_Zn

SIGM LEASE LOCALITY MAP



Appendix A Data Sources

Table A-1: Assessed Data Sources

Author	Title	Data type	Year Published	Number of sources
ALS	Laboratory report	Primary laboratory reports	2008-2015	101
AMMTEC	Laboratory report	Primary laboratory reports	2005	2
Dames and Moore	Public Environmental Review – Gold Mining Developments on Lake Lefroy	Tables in report	1999	1
Graeme Campbell and Associates	Characterisation of Process Tailings and Mullock Testing	Data in report	2003	2
MBS Environmental	Redback Mining Proposal	Original laboratory results in report	2013	1
Mehling Environmental Management Inc. & O'Kane Consultants Inc.	Waste Rock Characterisation and Implications from Site Waste Rock Management – with addendums	Tables in report	2005-2006	2
MESH Environmental Inc. & O'Kane Consultants Inc.	Geochemical Characterisation of Tailings	Tables in report (transcribed)	2008	1
MESH Environmental Inc. & O'Kane Consultants Inc.	Leviathan Waste Rock Assessment	Tables in report (some data missing)	2006	1
MWH Global	A5 Open Pit Mine AMD Assessment	Original laboratory results in report	2015	1
MWH Global	AMD Data Review	Original laboratory results in report	2015	1
SGS	Laboratory	Primary laboratory reports	2006-2007	3
St Ives Gold Mine	Annual Environment Management Plans and Annual Environment Reports	Tables in report	2001, 2009, 2011	3
St Ives Gold Mine	Athena, Apollo and Hamlet Mining Operations Mining Proposal	Table in report	2009	1
St Ives Gold Mine	Cave Rocks Mining Proposal	Original laboratory results in report	2006	1
St Ives Gold Mine	Diana Mining Proposal	Tables in text	2011	1
St Ives Gold Mine	Neptune Mining Proposal	Tables in report	2013	1

Author	Title	Data type	Year Published	Number of sources
SWC Group	AMD Summary Report	Tables in report	2013	1
Terrenus Earth Sciences	Invincible Mining Proposal	Original laboratory results in report	2013	1
URS Australia	Review of Potential Issues at St Ives Gold Mines	Tables in report	2000	1
Western Mining Corporation	Paris Mine Soil report	Tables in report	1997	1

Appendix B Collated Data Tables

Provided electronically

Appendix C Statistical Summary Table

Lithology	Number of samples	Number of zero values	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum	Skewness
pH										
Lake sediment	59	0	7.2	0.5	6.0	6.8	7.1	7.5	8.1	0.07
Tertiary sediment	191	4	6.7	1.0	4.0	6.1	6.7	7.4	8.8	-0.31
Upper Saprolite	114	9	6.5	1.1	4.5	5.6	6.6	7.3	9	0.14
Merougil Creek Beds	22	0	7.9	0.3	7.1	7.8	8.0	8.1	8.4	-0.84
Black Flag Beds	165	8	8.3	0.5	6.2	8.1	8.3	8.6	9.5	-0.9
Cave Rocks Sediment	175	0	8.6	0.7	3.6	8.5	8.8	9.0	9.7	-3.23
Kapai Slate	20	6	7.1	1.8	2.3	6.3	7.9	8.4	8.8	-1.39
Condenser Dolerite	184	17	8.2	0.7	5.8	8.0	8.4	8.7	9.2	-1.52
Defiance Doleriate	194	33	8.7	0.9	5.0	8.3	8.9	9.2	10.2	-1.39
Cave Rocks Dolerite	338	0	8.6	1.1	4.4	8.5	8.7	9.0	9.8	-6.5
Devon Consols Basalt	486	21	8.6	0.8	3.0	8.3	8.8	9.2	10.6	-1.86
Lunnon Basalt	8	4	8.2	0.3	7.7	8.2	8.3	8.5	8.5	-1.44
Paringa Basalt	379	16	8.6	0.8	4.5	8.3	8.7	9.0	9.9	-2.43
Tripod Hill Komatiite	162	8	8.8	0.6	6.6	8.5	8.8	9.1	9.9	-0.74
Felsic intrusion	66	19	8.3	1.2	4.4	7.7	8.7	9.0	9.8	-1.57
Intermediate intrusion	101	4	8.5	0.9	3.8	8.2	8.6	9.1	9.8	-2.32
Mafic intrusion	4	5	9.3	0.2	9.1	9.2	9.4	9.5	9.5	-0.75
Tailings	165	1	7.6	0.8	3.3	7.4	7.6	8.1	9.7	-2.38
EC										
Lake sediment	59	0	39375	24555	11	25600	33900	52800	129000	1.04
Tertiary sediment	180	15	19000	17689	320	5048	15150	26375	108000	1.75
Upper Saprolite	108	15	20543	23482	7	5053	12050	31925	136000	2.19
Merougil Creek Beds	22	0	8331	5139	689	4895	6390	11400	18100	0.76
Black Flag Beds	165	8	4600	5778	20	1510	2420	5135	31400	2.57
Cave Rocks Sediment	175	0	1160	1543	111	435	726	1270	14500	5.42
Kapai Slate	20	6	7088	13851	280	865	3810	7148	64000	4.01
Condenser Dolerite	184	17	5638	8157	161	927	2325	6053	34700	2.26
Defiance Doleriate	183	44	2501	3470	5	551	1390	2800	28700	3.86
Cave Rocks Dolerite	338	0	1055	1628.7	0	475	759	1210	26200	11.43
Devon Consols Basalt	490	17	4383	7443	0	795	1720	4133	47400	3.34
Lunnon Basalt	5	4	13156	11299	480	2690	14000	23200	29500	0.53
Paringa Basalt	395	0	2536	4894	0	620	1100	2340	53000	5.62
Tripod Hill Komatiite	160	10	4168	4758	1	1093	2950	5263	32100	2.72
Felsic intrusion	64	21	3839	7091	1	882	1700	3448	49600	4.78
Intermediate intrusion	99	6	3903	4990	1	691	2090	4310	22200	2.08
Mafic intrusion	0	9	ND	ND	ND	ND	ND	ND	ND	ND
Tailings	165	1	23457	28025	8	6530	12400	28100	176400	2.92
Total S										
Lake sediment	59	0	1.216	1.7	0.08	0.25	0.54	1.52	9.37	3.14
Tertiary sediment	190	1	0.4778	1.0	0.01	0.10	0.21	0.43	5.97	4.35
Upper Saprolite	114	6	0.472	1.4	0.01	0.08	0.15	0.31	10.90	5.85
Merougil Creek Beds	22	0	0.3045	0.2	0.04	0.17	0.32	0.35	0.85	0.98
Black Flag Beds	168	0	0.3558	0.3	0.02	0.11	0.26	0.52	1.52	1.5
Cave Rocks Sediment	154	11	1.982	1.5	<0.01	0.62	1.86	2.91	7.47	0.87
Kapai Slate	26	0	7.85	6.1	0.04	1.83	7.64	13.87	18.90	0.29
Condenser Dolerite	176	20	0.3431	0.5	0.01	0.08	0.19	0.41	2.95	2.97
Defiance Doleriate	191	31	0.5	1.5	<0.01	0.06	0.13	0.34	16.00	7.32
Cave Rocks Dolerite	303	35	0.5891	0.7	<0.01	0.14	0.30	0.74	3.78	2.17
Devon Consols Basalt	444	63	0.4262	1.1	0.01	0.07	0.18	0.39	11.50	7.3
Lunnon Basalt	12	0	0.9	0.6	0.3	0.37	0.74	1.30	2.14	0.94
Paringa Basalt	355	38	0.2504	0.6	0.01	0.06	0.11	0.22	8.37	8.6
Tripod Hill Komatiite	149	21	0.42	1.4	0.01	0.04	0.11	0.45	16.20	10.6
Felsic intrusion	85	0	0.3338	0.4	<0.01	0.10	0.18	0.36	2.88	3.24
Intermediate intrusion	96	9	0.2543	0.4	<0.01	0.05	0.11	0.29	3.76	5.58
Mafic intrusion	9	0	0.522	0.9	0.06	0.07	0.12	0.64	2.84	2.47
Tailings	164	1	1.1991	1.1	0.26	0.66	0.90	1.15	8.51	3.28
Sulfide S										
Lake sediment	59	0	0.1811	0.5	<0.01	<0.01	<0.01	0.08	3.40	4.75
Tertiary sediment	195	0	0.1004	0.2	<0.01	<0.01	0.02	0.12	1.33	3.58
Upper Saprolite	114	9	0.1153	0.4	<0.01	<0.01	<0.01	0.03	3.11	5.24
Merougil Creek Beds	22	0	0.1895	0.2	<0.01	0.08	0.15	0.28	0.78	1.98
Black Flag Beds	173	0	0.2544	0.3	<0.01	0.06	0.16	0.37	1.45	1.87
Cave Rocks Sediment	175	0	1.765	1.7	<0.01	0.28	1.34	2.75	7.55	1.07
Kapai Slate	25	1	7.28	6.1	<0.01	1.69	7.15	12.00	18.60	0.42
Condenser Dolerite	201	0	0.2532	0.4	<0.01	0.04	0.11	0.24	2.78	3.14
Defiance Doleriate	201	26	0.4058	1.4	<0.01	0.03	0.08	0.25	15.90	8.09
Cave Rocks Dolerite	335	3	0.455	0.7	<0.01	0.07	0.17	0.57	4.99	2.83
Devon Consols Basalt	475	32	0.2999	0.9	<0.01	0.02	0.09	0.26	10.30	7.58
Lunnon Basalt	12	0	0.685	0.4	<0.01	0.335	0.60	1.12	1.31	0.19
Paringa Basalt	394	1	0.1534	0.5	<0.01	0.02	0.07	0.12	7.99	11.29
Tripod Hill Komatiite	170	0	0.2953	0.6	<0.01	<0.01	0.06	0.39	5.10	4.56
Felsic intrusion	84	1	0.2466	0.4	<0.01	0.02	0.1	0.27	2.84	3.61
Intermediate intrusion	105	0	0.1722	0.4	<0.01	<0.01	0.04	0.16	3.74	6.54
Mafic intrusion	9	0	0.51	0.9	0.05	0.07	0.12	0.77	2.81	2.47
Tailings	149	17	0.6326	0.4	<0.01	0.43	0.59	0.77	4.27	4.22

Notes:

ND denotes No Data

Date below detection limit (denoted by "<" symbol) was assessed as zero in statistics caluculations of mean, standard deviation and skeness

Appendix D AMD Summary Presentation

Provided electronically