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Site Evaluation

**RUM JUNGLE MINE SITE: RESULTS OF SOIL & FLUVIAL ZONE SAMPLING &
ASSESSMENT**

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Executive Summary

CSA Global was awarded Contract Number D10-0355 on the 14th October 2010 for the Provision of Detailed Soil and Fluvial Contamination Assessment at the Rum Jungle Mine Site in the Batchelor Region of the Northern Territory.

The primary objective of the sampling work was to characterise parts of the Rum Jungle Mine Site to determine metal levels in surface and near surface soils, fluvial sediments, deep soil and waste material profiles across previously rehabilitated areas and un-rehabilitated areas. The other objective of the project was to estimate the volume of material with elevated or anomalous metal contents based on various cut off parameters.

The sampling work was carried out by CSA Global over a seven week period starting on the 1st November 2010. The samples collected were analysed between November 2010 and February 2011 and were analysed for Ag, As, Co, Cr, Cu, Fe, Hg, Mn, Ni, Rb, Sr, Sb, U, Zr, and Zn using a mixture of field portable XRF (FPXRF) and accredited laboratories in the NT. In addition, elements Ba, Cd, Pb and V were tested as requested by the Northern Territory Department of Resources (DoR).

The preliminary site investigation by DoR recognised four distinct terrains or Zones on the Rum Jungle site. Zones 1, 2 and 4 have undergone contamination assessment and quantification as required by the contract.

Prior to initiating the field work a detailed sampling programme was designed for each of the sampling zones. The purpose of the sampling was to determine:

- A robust way in which material with high levels of metallic elements could be quickly recognised in the field;
- the lateral and vertical distribution of various metal elements (also referred to as contaminants);
- the type and level of metallic elements present; and
- the extent of those metallic elements which appear above set threshold levels to enable the estimation of volumes of material with elevated metal contents.

Zone 1 is an area surrounding the other three zones which for the most part is un-rehabilitated. It comprises numerous surface dumps, scrap steel and miscellaneous mine waste. Zone 2, represents the areas where some form of rehabilitation has previously been applied. Zone 4, consists of the fluvial areas where surface and ground waters drain from the site and into the adjacent river system.

To establish what constituted an area of high metallic element content 32 orientation samples were collected from suspected contaminated areas and several samples from apparently uncontaminated sites. The results were used to establish background and contamination thresholds for key elements. Initial sampling showed copper and uranium

were key metallic elements with high concentrations as such these elements were used to guide sampling and calibration of the FPXRF units. It was recognised that copper was the most wide spread element with elevated levels.

The results indicated that material with less than 100ppm copper could be considered uncontaminated whilst those over 100ppm were contaminated. At each sampling site, down hole sampling was continued until the material in the bottom of the hole contained less than 100 ppm copper. The onsite analyses were completed using FPXRF analysers.

Zone 1: First-pass sampling was undertaken on a 100 x 100m grid and were generally collected by hand (mattock and shovel) at each sample site. At each sample site, samples were taken at regular intervals until the copper content was measured at less than 100ppm copper. In a few areas of Zone 1 it became apparent that deeper and more consistent sampling was required than can be achieved by hand-held tools. In these areas an auger attached to a Bobcat was utilised.

Zone 2: All of the sampling in Zone 2 was completed from pits dug on a 50m by 50m grid using a mini excavator or 30 tonne excavator. It quickly became apparent that at the Cu +/- 100 ppm threshold the mini-excavator was neither powerful enough nor capable of sampling deeply enough. A second large excavator was mobilised to complete the sampling pattern.

Zone 4: This zone represents the Rum Jungle Mine sites drainage and is characterised in the east by a broad sheet wash area with numerous ponds and evaporation sites. The western side is characterised by a well-defined channel with a rocky bed load. Further downstream the creek merges into the East Finniss River. There is ample visual evidence that over the past three decades a substantial quantity of material has leached into the eastern half of the drainage system.

The local indigenous people have several sites of significance associated with the drainage system and are very concerned that the drainage and river bed are only minimally disturbed. In accordance with the wishes of the Traditional Owners only limited mechanical sampling by a small powered “dingo” auger was undertaken in the eastern part of the drainage. In the central portion very limited sampling by a female field technician was permitted under the direct supervision of a traditional custodian. In the western part of the drainage system sampling was completed by taking over bank samples on each side of the channel and at a “centre of active drainage” site.

Miscellaneous Areas: The RFT also required consideration of the roads to be included and sites were tested using a “Bobcat” power auger.

Sample Testing Summary:

The Department of Resources (DoR) recommended the samples collected from the site be analysed by FPXRF in accordance with United States Environmental Protection Agency (USEPA) (2007), Method 6200, Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment.

Two FPXRF instruments were used on this project. Some samples were screened with an Olympus – Innov-X Delta Premium hand held FPXRF. Data from this instrument was used to guide field teams during sampling to ensure all contaminated material was sampled.

The samples were then re-analysed using an Olympus – Innov-X X-5000 portable bench top FPXRF with a tantalum anode. This equipment is more sensitive and delivers more reliable and accurate results, and these results form the basis of this report.

To ensure the reliability of the results a number of quality assurance and quality control (QA-QC) procedures were put in and are summarised below:

- All FPXRF units were calibrated and had precision checks daily. The results of the calibration and precision checks for sampling rounds are highlighted in this report.
- Blank samples (clean silica sand) were used to check for contamination occurring in the field and during sample analysis to ensure results were not affected by poor sampling or analysis procedures.
- One sample was taken from the initial test work to be used as a Site Specific Calibration Standard (SSCS). The SSCS was used to determine the amount of variation in the readings throughout the course of the project.
- Check samples were used to ensure the XRF readings were reliable. Five percent of the samples tested with the FPXRF were sent for laboratory analysis by Amdel using their ARM20 method, a two acid digestion followed by Inductively Coupled Plasma (ICP) analysis.
- Umpire Sampling: Samples tested by Amdel using the ICP series methods were also tested by NT Environmental Laboratories using their G400 series of analytical methods. The copper and uranium results from the two laboratories have been compared to ensure the data produced by Amdel is accurate. The comparison for both copper and uranium show the two datasets are comparable with R^2 values of 0.9988 and 0.9974 respectively. The data from both laboratories is therefore considered accurate.
- Field duplicates were used to assess the representivity of the samples that were taken. The results indicate that the sampling method has produced results which are representative of the areas they were taken from.

Discussion & Results Summary

The key purpose of the field sampling program was to define areas of elevated metallic content and estimate their volumes.

The critical consideration in defining elevated level of metallic material at an abandoned mine site is recognising where these elevated levels start and where the normal back ground values extend to. It is important that the reader notes that the orientation samples designated as “back ground” were taken away from the mine site and probably do not accurately reflect the actual metal concentrations that existed on the site prior to mining

operations. The samples provide little more than a regional context in which to place the mine site and not the local geological environment.

After discussion with staff from the Department of Resources, it was agreed that attempting to use published Health Investigation Levels (HIL's) to set trigger levels or threshold values was inappropriate, because:

- To successfully use HIL's a future land use is required. At this stage the future land use has not been resolved.
- HIL's are most commonly applied in urban or near urban settings and not over abandoned mine sites where back ground levels of some metals (ore) are naturally high.
- HIL's do not exist (to the authors knowledge) for some of the metals expected to be found at the Rum Jungle Mine site.
- The tropical environment of Northern Australia tends to form laterite. The lateritisation process typically depletes some and concentrates other metals.

The cut off or threshold values selected to define elevated metallic element or contamination areas are presented in the main body of this report (c.f. Table 5)

To define the areas with elements concentrated above threshold values this report presents a series of Tables and Plans which are referred to under Zone sub headings. For the readers convenience a consistent nomenclature has been used for their identification.

For each of the Zones and sample intervals presented in this report (c.f. Section 13.2), the volume of material with element values greater than the cut off threshold value has been estimated. The areas and hence volumes are defined by the threshold values selected for each element. No consideration has been given to ranking the contaminated areas either by individual elements or groups of elements. As such, changing the threshold value for just one element may have a significant effect on the size and volume of the contaminated area.

The geochemical sampling program conducted over the abandoned Rum Jungle Mine site has successfully defined the extent of contamination and allowed volumes for the material to be estimated.

It is recommended that the appropriate stakeholders representing all of the groups that have an interest in the area convene and:

- Define the intended future land use;
- Agree on a definitive set of element thresholds;
- Determine which elements are the most important in defining contamination

The final set of threshold levels can be used to redefine the areas and volumes of contaminated material. Combined with a remediation plan, minable volumes of material can be calculated using optimisation software designed for mine development but which could be used for this purpose.

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Note:

Details for Appendix 7 & 8 are submitted in hard copy format attached to this report.

Details for Appendix 9 are submitted in Digital format.

1 Introduction

1.1 Rum Jungle Mine Site

CSA Global was awarded Contract Number D10-0355 on the 14th October 2010 for the Provision of Detailed Soil and Fluvial Contamination Assessment at the Rum Jungle Mine Site in the Batchelor Region of the Northern Territory.

The terms of the contract are detailed in the Request for Tender (RFT) D10-0355 provided by the Department of Business and Employment, Ground Floor Enterprise House, 28-30 Knuckey Street, Darwin NT 0800.

The former Rum Jungle Mine site is located 105km by road, south of Darwin, near Batchelor in the Northern Territory. The mine operated from 1952 to 1971 recovering approximately 3,500 tonnes of uranium oxide and an additional 20,000 tonnes of copper concentrate from several open cut operations. Substantial contamination existed across the site after mining operations ceased, comprising denuded landscapes, depletion of aquatic fauna and flora along the downstream length of the East Finniss River, and public health hazards from exposed tailings material and open cut pits.

The objective of the sampling work detailed in the RFT was to characterise the Rum Jungle Mine Site (Section 2968, Hundred of Goyder) to determine metal levels in surface and near surface soils, fluvial sediments, and deep soil and waste material profiles across both previously rehabilitated areas and un-rehabilitated areas.

The sampling work was carried out by CSA Global over a seven week period starting on the 1st November 2010. The samples collected were analysed between November 2010 and February 2011. This report outlines the sampling work carried out in the Rum Jungle Mine site and the analytical results obtained. Furthermore areas which have concentrations of metallic elements above set threshold levels (contamination areas) are defined and the volumes of material with elevated metallic elements have been estimated as requested by the terms of the RFT.

The metallic elements that required analysis were Ag, As, Co, Cr, Cu, Fe, Hg, Mn, Ni, Rb, Sr, Sb, U, Zr, and Zn. In addition, elements Ba, Cd, Pb and V were tested as requested by the Northern Territory Department of Resources (DoR).

2 Field Sampling Parameters

2.1 Sampling Locations

The original Request for Tender (RFT) document showed that the now abandoned Rum Jungle Mine site could be divided into four zones based on previous use, rehabilitation attempts and geographic parameters. Figure 1, taken from the RFT shows the Rum Jungle Mine site with the zones that required geochemical sampling shown in different colours. Zone 2 further sub-divided into 6 areas.

Under the terms of the RFT, CSA Global was required to sample Zones 1, 2 and 4. In these zones the sampling was completed with the intention of determining

- the type and level of metallic elements present
and
- the vertical extent of those metallic elements which appear above set threshold levels so the volumes of material could be determined.

Note: The metallic elements as specified for detection were Ag, As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Rb, Sr, Sb, U, V, Zr, and Zn.

2.2 Survey Scope

Prior to initiating the field work a detailed sampling programme was designed for each of the sampling zones. The purpose of the sampling was to:

- Establish the lateral and vertical distribution of contaminants. For the purposes of this report the contaminants may also be referred to as metallic elements occurring as high level concentrations in the materials sampled.
- Determine the concentrations of metallic elements, and
- Aided by field observations, identify where possible the source(s) for the high levels of metallic elements.

Whilst planning the sampling regime it was considered that the first two points are more important than the third. It was accepted that any detection of high levels of metallic elements was caused by mining and related activities.

The preliminary site investigation and RFT recognised four distinct terrains on the Rum Jungle site. For three of the terrains or zones, contamination assessment and quantification has been completed as required by the tender.

- Zone 1, represents the area surrounding the most actively exploited areas. It comprises numerous surface dumps, scrap steel and miscellaneous mine waste. It is considered unlikely that high levels of metallic elements will extend beyond 300mm depth but greater depths were considered. At the completion of the field program over 300 sites were sampled by hand with more than 600 samples collected and assayed. In addition, approximately 150 sites were sampled by power auger for another 320 samples.
- Zone 2, represents the areas where some form of rehabilitation has previously been applied. Visual inspection indicates that the cover systems used are inadequate and leachate is escaping into the natural environment. Zone 2 has been divided into 6 separate areas based on the former use of the area and the cover system employed. Individual sampling methods were devised for each area, however as the sampling progressed it became apparent that the large (30 tonne) excavator was the most efficient sampling tool. In all over 500 sites were sampled for 1600 samples collected and assayed.
- Zone 3 is not considered in this report.

Zones 3 consists of waste rock and overburden heaps and will be the subject of another separate investigative and characterisation project by the NT Dept. of Resources.

- Zone 4, consists of the fluvial areas where surface and ground waters drain from the site and into the adjacent river system. Field inspection showed that the drainage to be sampled is divided into two distinctly different geographic domains. The eastern half of the drainage consists of a broad outwash zone with a poorly defined channel and several obvious ponding sites. The western half of the drainage system consists of a well-defined channel with cobbles to pebbles common in the bed load. Some waterholes are present but these do not appear to be sites of evaporation and salt accumulation. In zone 4, 191 sites were sampled for over 450 samples assayed.

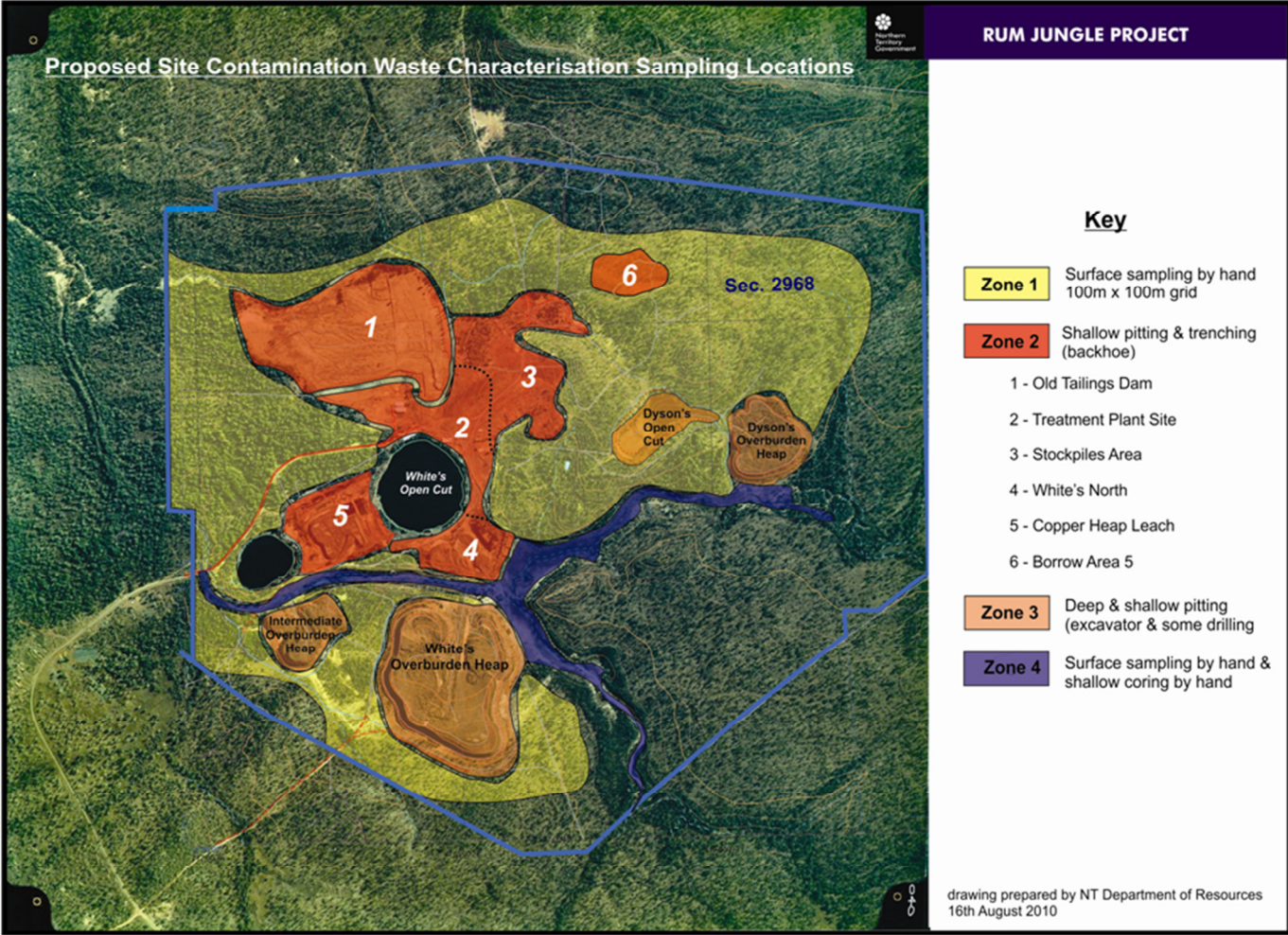


Figure 1. Rum Jungle Proposed Site Contamination Waste Characterisation Sampling Locations
 (Sourced from Request for Tender D10-0355, Dept. of Resources, Northern Territory)

2.3 Sampling Methods

To satisfy the requirements of the RFT it was necessary to complete the following two objectives:

1. To collect enough samples to cover the defined zones and samples from sufficient depth to define the extent of a contaminated area.
2. Determine a robust way in which material with high levels of metallic elements could be quickly recognised in the field.

The methods used to collect the samples in each zone are described below.

To make the decision on what constituted contamination or otherwise in the field several samples from suspected contaminated areas and several samples from apparently uncontaminated sites were collected and assayed (Please refer to Section 4.1 for details of the preliminary sampling carried out).

The results (c.f. Table 5) showed that copper at a level of 100 part per million (ppm) would make a suitable defining contaminant metallic element.

After discussions with the Department of Resources staff and CSA Global's XRF manager it was agreed that samples containing less than 100ppm copper would be considered uncontaminated whilst those over 100ppm were contaminated. At each site down hole sampling was continued until the material in the bottom of the hole contained less than 100 ppm copper. The onsite analyses were completed using Field Portable XRF (FPXRF) analysers. For most of the period in which the sampling occurred there were 2 or 3 handheld FPXRF instruments on site.

2.3.1 Zone One

First-pass sampling of zone 1 was undertaken on a 100 x 100m grid. In all but a few cases at least 2 samples were collected by hand (mattock and shovel) at each sample site. The "A" sample was collected from 0 to -10cm and a "B" sample was collected from -10 to -20cm. In several cases a "C" sample was collected from between -20 and -30cm and in a few cases a "D" sample was collected. As mentioned above sampling was continued until the copper content was measured by hand held FPXRF at less than 100ppm.

In a few areas of Zone 1 it became apparent that, at a contamination threshold of copper equals 100ppm (Cu +/- 100ppm), deeper and more consistent sampling than achievable by hand-held tools was required. In these areas an auger attached to a Bobcat was utilised. Samples in these areas were collected on a 50 by 50m spacing with the "A" sample from 0 to -20cm, the "B" sample from -20 to -80cm and the "C" sample from -80 to -150cm. At each site field notes describing the site were collected. The sites location was recorded using a GPS and a numbered pin-marker inserted next to the hole.

The results of the Zone 1 sampling are discussed in Section 13.2.1

2.3.2 Zone Two

Initially Zone two was sub-divided into six areas and it was proposed to sample each area using either a mini-excavator or a full sized, 30 tonne machine. The selection of machine was dependent on the probable thickness of the introduced cover, the anticipated thickness of the material containing high levels of metallic elements and the need to know how far into the basal material the contamination has penetrated.

All of the sampling in Zone 2 was completed from pits dug on a 50m by 50m grid. It quickly became apparent that at the Cu \pm 100 ppm threshold the mini-excavator was insufficient, neither powerful enough nor capable of sampling deeply enough. A second large machine was mobilised to complete the sampling pattern. It was also decided to forgo the Zone 2 sub-area nomenclature and treat the whole area as one because the reported cover thickness, on which the sub-areas were defined, was highly variable and in many cases just as contaminated as the material under the cover.

In Zone 2, over 500 sites were sampled with samples collected in 100cm increments starting with the "A" sample at 0 to -100cm and continuing to the "E" sample at -400 to -500cm. In all, over 1600 samples were collected and analysed. As for the Zone 1 samples the hand held XRF was used to measure the copper concentration in the holes. In Zone 2 all of the pits were back-filled and similar notes to those described for Zone 1 were collected.

2.3.3 Zone Four

Zone 4 represents the Rum Jungle Mine sites drainage and is characterised in the east by a broad sheet wash area with numerous ponds and evaporation sites. The western side is characterised by a well-defined channel with a rocky bed load. Further downstream the creek merges into the East Finniss River. There is ample visual evidence that over the past 3 decades a substantial amount of material has leached into the eastern half of the drainage system. The aim in this area was to assess the extent, depth and nature of the contamination in the drainage system.

It was also explained during the tendering process that the local indigenous people are very concerned that the drainage and river bed are only minimally disturbed. In accordance with the wishes of the Traditional Owners only limited mechanical sampling by a small powered "dingo" auger was undertaken in the eastern part of the drainage. In the central portion very limited sampling by a female field technician was permitted under the direct supervision of a traditional custodian. In the western part of the drainage system sampling was completed by taking over bank samples on each side of the channel and a "centre of active drainage" site.

In Zone 4 over 450 samples were collected from 191 sites. Across the zone the "A" samples corresponds to a depth of 0 to -10cm, the "B Sample from -10 to -30 cm, the "C" sample from -30 to -80cm and the "D" Sample from -80cm to -150cm. Geological notes and the site location was recorded for each site except those close to the Exclusion zone.

2.3.4 *Miscellaneous Areas*

The RFT also required consideration of the roads to be included. To this end provision was made for the mini-excavator to sample these areas. As mentioned earlier the mini-excavator lacked the power required to adequately sample the roads and the task was assigned to the “Bobcat” power auger. A total of 23 sites were tested with approximately 50 samples collected. The results of the auger sampling of the roads are discussed below.

2.4 Survey

At each sample site, excluding some in Zone 4 for cultural reasons, a pin-marker was placed at each sample site bearing the site number. Towards the end of the first phase of the sampling program, surveyors from Ausurv Pty Ltd were brought to Rum Jungle to accurately locate the sites using Differential GPS (DGPS). Ausurv established a base station on top of the main rock dump (White’s overburden heap) to provide control for their work. The decision to bring the surveyors in before the completion of the follow-up sampling was made due to concerns about the weather and the rapid growth of the long-grass.

As might be expected most but not all sample sites were recovered. In the data base those sites with co-ordinates containing decimal points were surveyed by the DGPS whilst those without decimals are the handheld GPS field co-ordinate.

2.5 Field Procedure

To control the flow of samples a series of procedures were emplaced.

- The two field parties were assigned different blocks of sample numbers to facilitate identification of the samplers.
- A pin-marker identifying the site was used at all sites except for some sites within Zone 4.
- A sample numbering convention that identified the site and the position of the sample in the hole was employed.
- The Zone in which each site was located was recorded along with other field observations. The field sheets are found as Appendix 7 to this report.
- Blank samples made up of washed quartz sand were inserted into the sample run by both teams at the end of the day. The results of the blank samples are discussed in the Section 7 “Blanks” of this report
- Duplicates were taken at the rate of five percent (one-in-twenty); the results of the duplicate samples are discussed in the Section 9 “Check Samples” of this report.
- The samples were stored in numbered calico bags and these were placed within poly-weave sacks for transport. Due to the damp condition of the samples there was very little dust generated.

- The handheld FPXRF units were used to field test some samples and to check the copper concentration in the bottom of the sample hole (or material from the bottom of the deeper holes)
- On return to base all of the samples were laid out and their identity checked against the field log. The samples were then placed in clean poly-weave sacks for transport to the laboratory in Darwin.
- A Sample Submission and Chain-of-Custody form accompanied each dispatch to the laboratory. The Chain-of-Custody forms are detailed as Appendix 8.
- Each evening the field parties entered the day's data into a prepared spread sheet. The project manager then compiled the daily data into master sheets. Mapinfo GIS plots were used to check the progress of the work and to locate errors in co-ordinates.
- During the peak sampling period the project manager delivered the samples to the laboratory daily.



Figure 2. Trenching work on Zone 2 (2)



Figure 3. Soil sample trench in Zone 2 (2)



Figure 4. Hand Held FPXRF analysis of soil in Zone 2 (2)

3 Sample Laboratory Testing/QAQC

3.1 Scope

The Department of Resources (DoR) recommended the samples collected from the site be analysed by FPXRF in accordance with United States Environmental Protection Agency (USEPA) (2007), Method 6200, Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment. The elements that require analysis are Ag, As, Co, Cr, Cu, Fe, Hg, Mn, Ni, Rb, Sr, Sb, U, Zr, and Zn. In addition, elements Ba, Cd, Pb and V were tested as requested by the DoR. Data for other elements was produced, this data was not verified with check assays.

3.2 FPXRF Sampling

FPXRF instruments are excellent field tools for quickly ascertaining the presence or absence of elements of interest in a sample; however they do not produce an assay. FPXRF analysis produces results that are not as accurate or precise as laboratory based equipment. Thorough quality assurance and quality control (QAQC) procedures and data manipulation is required to produce reliable data. The FPXRF data produced on this project has been manipulated to identify areas with high levels of metallic elements at Rum Jungle. The raw FPXRF data is not representative of true element concentrations in the samples tested. The raw data is adjusted using coefficients based on calibration tests conducted specifically for this project. Data manipulation procedures have been designed specifically to identify areas with high levels and concentrations of metallic elements. Manipulated data should not be used for other purposes without assessment of its validity for the purpose in question.

4 Sampling

4.1 Preliminary Orientation Sampling

Initially thirty two samples were collected, assayed and tested with the XRF to allow the existing metallic element concentrations to be identified. The sample numbers for these samples take the form of RJ0001. The samples were taken from 12 sites across the Rum Jungle project from background to material in areas with known high levels of metallic elements. Initial sampling showed copper and uranium were key metallic elements with high concentrations and these elements were subsequently targeted when precision checks were conducted.

The preliminary samples were assayed by Amdel and NT Environmental Laboratories (NTEL). Three methods were used to assay the samples, Amdel's ARM20 and Inductively Coupled Plasma (ICP) method (IC4E, IC4M and IC3E) plus method AA6 for mercury analysis (Appendix 10). NTEL method G400M was also used. This work showed that the ARM20 method was not suitable for accurately detecting barium, rubidium or strontium. These elements were not expected to pose a problem at the Rum Jungle site so ARM20 testing was used to assay check samples. ICP analysis was used to determine the accuracy of XRF testing of these elements.

The preliminary sampling suggested there were no significant issues arising from the geochemical or physical differences in material at the Rum Jungle site.

Preliminary assaying showed that the FPXRF would not be capable of detecting cobalt accurately. This is a common limitation of FPXRF technology and is due to interference caused by iron. Antimony, cadmium, mercury, and silver were found to be below detectable levels.

4.2 Rum Jungle Site Sampling

4.2.1 Instruments

Two FPXRF instruments were used on this project. Some samples were screened with an Olympus – Innov-X Delta Premium hand held FPXRF. Data from this instrument was used to guide field teams during sampling to minimise the risk of not sampling contaminated material.

The reported data was obtained from an Olympus – Innov-X X-5000 portable bench top FPXRF with a tantalum anode. This equipment is more sensitive and delivers more reliable and accurate results.

4.2.2 Sample Analysis

Samples were analysed using the 3 Beam Soil mode which provides parts per million (ppm) detection levels. This mode uses three power levels or 'beams' to excite the sample. An analysis time of 30 seconds per beam was used.

4.2.3 Sampling Method

The following sampling method was initially used to analyse samples collected in the field.

1. Take delivery of samples – sign chain of custody form
2. Dry samples for 16+ hours at 40 degrees (to preserve Hg)
3. Crush samples (all samples will pass through the crusher for consistency)
4. Pulverise samples to 85% passing 75 micron.
5. Package samples in thin plastic zip lock bags
6. Transport samples to FPXRF testing area (within the laboratory)
7. Check sample bags for surface contamination
8. Clean X-5000 sampling window with a puffer to remove dust
9. Check the correct instrument calibration has been selected
10. Analyse the sample
11. Record the analysis number on the XRF log sheet
12. Analyse one blank and one check standard every 20 samples
13. Place samples in cardboard storage boxes
14. Store samples

Preliminary sample assays found mercury was not present at detectable levels. The drying temperature was subsequently increased to 105°C to decrease sample turnaround time.

4.3 Check Analysis Programme

The QAQC checks used during the FPXRF analysis work found the data generated for arsenic contained numerous erroneous values and that the data for lead, nickel and uranium exhibited a number of irregularities. The cause of these issues could not be determined by the manufacturer. As a quality control measure all of the first pass samples were retested using a different X-5000 supplied by the manufacturer to provide reliable data. Results for the elements arsenic, nickel, lead and uranium were taken from this test work to replace those generated in the first round of test work. Infill samples and road samples were not re-

tested as it was felt the main contaminants, copper and uranium were adequate for these samples.

5 Energy Calibration Check

The X-5000 was checked by testing the manufacturer supplied standard immediately after the instrument was turned on every day. The instrument determines whether the standardisation is successful and notifies the user. The instrument cannot be operated if the energy calibration check fails.

6 Precision checks

6.1 Purpose

A precision check was conducted once per shift. Initially it was planned that one 'low' and one 'high' SSCS would be analysed to ensure the FPXRF was producing precise results. Few suitable samples were obtained by the preliminary sampling though, so one SSCS was used for this purpose. Data quality was further assessed using check samples.

The relative standard deviation (RSD) was calculated for each element and this value was used to assess precision. The check is considered passed if the RSD is not greater than 20%. The only exception is chromium where it is noted the check will pass if the RSD is not greater than 30%. The cut off percentage values are as recommended in Method 6200, Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment; United States Environmental Protection Agency (USEPA) (2007),

6.2 Method

A precision check was carried out at the beginning of each shift. A sample was tested seven times consecutively and an average value was generated. The results for copper and uranium were then checked immediately to ensure each reading fell within 20% of the average. The precision of other elements was checked once the testing of the full batch of samples was completed.

6.3 Results

The results of the precision checks for sampling rounds 1 and 2 can be found in Tables 1 and 2 respectively below. Elements present below detectable concentrations have been omitted. All elements present at detectable levels were detected with an RSD value of less than 20% in every test.

The results for chromium remained within the RSD limit of 20% but varied greatly with a minimum and maximum value of 1.21 and 11.09. The reason for this variability is unknown. When dealing with the chromium data the highest RSD value should be applied as the degree of variability in chromium precision throughout a shift is unknown.

Date	V	Cr	Mn	Fe	Co	Cu	Zn	Rb	Sr	Zr	Ba	Pb	U
11/11/2010	4.92	5.33	2.37	0.63	6.16	2.24	3.59	2.04	4.12	1.39	3.66	1.21	6.07
12/11/2010	4.13	6.49	2.65	0.51	5.16	2.41	4.00	1.76	2.98	0.90	5.53	0.94	4.50
13/11/2010	8.36	5.09	4.75	0.41	7.90	3.28	6.60	1.79	4.52	0.82	8.10	1.07	7.38
14/11/2010	4.52	6.44	2.94	0.65	3.14	1.47	5.72	2.04	4.01	1.16	6.79	1.99	2.46
14/11/2010	5.95	5.71	3.93	0.72	4.46	2.43	6.83	1.61	5.61	0.95	5.24	0.82	5.83
15/11/2010	7.08	7.70	2.27	0.45	9.62	2.78	8.03	2.21	5.52	0.58	4.22	1.32	6.02
17/11/2010	6.69	6.30	1.78	0.80	6.99	1.75	5.66	1.46	6.15	1.54	7.01	1.30	5.84
18/11/2010	3.10	5.16	2.60	0.70	5.25	2.26	5.54	2.08	4.27	0.83	4.63	1.42	5.35
19/11/2010	7.57	6.31	2.74	0.58	9.74	1.54	8.33	1.64	6.23	1.51	4.03	0.87	4.83
20/11/2010	5.03	3.22	3.39	0.69	6.48	2.07	9.36	1.46	3.51	1.99	3.84	1.19	4.31
22/11/2010	3.05	5.64	2.54	0.38	11.35	2.09	6.95	1.88	2.19	0.77	3.97	1.37	5.40
24/11/2010	3.71	10.32	2.02	0.43	5.51	1.81	7.72	1.44	3.25	1.04	5.15	1.87	7.45
26/11/2010	5.61	6.71	1.74	0.80	4.33	1.74	4.60	1.68	3.49	0.70	5.67	1.55	6.58
27/11/2010	4.97	4.49	2.26	0.34	4.35	1.28	8.31	1.73	4.35	1.15	5.24	1.16	5.84
28/11/2010	6.35	1.21	2.00	0.92	3.02	1.41	7.60	1.56	4.83	1.08	4.88	1.23	5.66
01/12/2010	5.96	11.09	1.47	0.41	6.50	1.53	7.57	1.73	6.70	0.75	4.51	0.60	5.53
02/12/2010	8.07	3.76	2.40	0.42	3.99	1.75	4.13	1.21	6.42	0.72	5.61	1.14	5.06
03/12/2010	5.67	4.46	4.89	0.23	7.73	1.90	3.69	2.35	3.55	0.52	2.06	1.54	8.62
11/01/2011	3.29	7.16	3.05	0.76	5.17	2.45	5.48	1.92	4.01	1.30	4.07	1.46	5.15
13/01/2011	7.47	5.14	2.79	0.64	10.89	1.39	3.86	1.01	4.48	0.84	3.14	1.32	6.67
14/01/2011	9.66	5.10	1.16	0.45	6.90	1.65	6.50	1.77	4.17	1.33	5.53	1.27	4.97

Table 1. Precision check results, % relative standard deviation, sampling round 1

Date	As	Pb	U
28/02/2011	13.97	2.97	4.71
28/02/2011	7.92	1.54	1.72
1/03/2011	11.23	1.55	5.94
1/03/2011	7.37	1.67	3.25
1/03/2011	8.48	1.13	3.29
2/03/2011	8.20	1.75	3.50
2/03/2011	9.17	2.21	7.74
2/03/2011	9.98	1.88	7.53
3/03/2011	11.33	2.76	4.43
3/03/2011	7.21	1.44	4.98
3/03/2011	13.69	2.11	2.55
4/03/2011	10.23	2.23	4.34
4/03/2011	6.36	2.15	5.57

Table 2. Precision check results, % relative standard deviation, sampling round 2

7 Blanks

7.1 Purpose

Blank samples were used to check for contamination occurring in the field and during sample analysis to ensure results were not affected by poor sampling or analysis procedures.

7.2 Field Control Samples

Field blanks were created by submitting a sample of builder's sand. While this sand isn't free of the elements of interest it allows contamination introduced by the sampling method to be detected as it contains relatively consistent concentrations of the elements of interest. The results of field control sample testing can be found in Table 3.

The project was started before blank material could be obtained. Field blank data is available from the 9th of November.

Not more than one result was found to fall more than two standard deviations from the mean for the majority of the elements, meaning contamination was not present at a detectable level. Sample 1341_D produced a result for manganese that fell more than three standard deviations from the mean. Sample 1461_D produced a result for lead that fell more than four standard deviations from the mean. Each of these results indicates that the samples were contaminated.

Sample 1341_D was taken directly after two samples containing very high lead values. The sample taken directly after, 1342_A, also contained a high concentration of manganese.

Field blank 1461_D was taken directly after two samples containing very high lead values. The sample taken directly after, 1462_A, contained only 5ppm lead. This indicates the contamination did not affect subsequent samples.

In both of these cases the contamination appears to have resulted from material left on sampling implements from previous samples. In the case of 1342_A the level of contamination detected (108ppm above the mean plus two standard deviations) is much less than 5% of the readings detected in samples immediately prior to and following the field blank. The level of contamination is therefore not considered significant.

In the case of 1461_D the contamination did not occur in the sample immediately following the field blank, indicating cleaning procedures have limited the impact of the contamination to one sample.

SampleID	V	Cr	Mn	Fe	Ni	Ni Re-Test	Cu	Zn	As	As Re-Test	Rb	Sr	Ba	Pb	Pb Re-Test	U	U Re-Test
1261_E	11	7	104	0.90	ND	ND	5	2	0	4	2	1	19	7	2	ND	3
1281_E	10	6	102	0.83	ND	ND	5	2	3	3	1	1	53	6	1	0	4
1301_F	13	9	114	1.06	ND	ND	20	1	0	5	2	0	22	19	12	ND	4
1321_C	11	9	110	0.98	ND	ND	16	ND	3	6	2	1	23	8	1	2	4
1341_D	14	16	407	1.28	ND	ND	8	1	ND	5	3	2	57	8	2	0	3
1361_D	12	18	153	1.57	ND	ND	21	3	4	7	4	2	26	11	1	2	6
1381_F	11	8	144	1.10	ND	ND	9	10	3	4	2	ND	41	10	4	1	5
1401_D	13	12	162	1.56	ND	ND	14	3	4	5	2	2	42	11	5	2	5
1421_D	11	14	128	1.38	ND	ND	12	ND	5	6	2	0	15	8	2	ND	5
1441_E	12	9	113	1.18	ND	ND	12	5	4	5	1	2	37	14	8	3	3
1461_D	12	10	174	1.40	ND	ND	16	2	ND	6	2	1	35	41	38	1	3
1481_E	13	10	200	1.40	ND	ND	7	1	4	4	2	0	46	10	5	2	5
1501_E	12	14	129	1.05	ND	ND	7	0	ND	5	2	1	28	6	0	ND	5
2010_D	12	8	115	1.07	ND		11	ND	1		2	2	2	6		ND	
2030_C	15	8	181	0.87	3		7	3	ND		2	1	38	3		1	
2050_D	17	19	301	1.40	ND		6	1	3		3	1	65	12		ND	
2070_C	10	10	125	0.92	ND		6	2	4		2	0	19	6		0	
2090_C	14	8	144	0.98	ND		9	ND	2		2	1	40	9		ND	
2110_D	10	9	121	0.98	ND		3	4	5		5	1	21	4		0	
2130_C	11	7	116	1.10	ND		5	2	ND		3	1	34	6		1	
4010C	10	8	106	0.95	ND		10	2	0		3	0	20	6		0	
5321_F	14	11	211	1.81	ND	ND	27	3	3	5	3	2	40	8	3	1	5
5341_F	14	11	160	1.17	ND	ND	14	1	2	6	2	1	40	7	0	2	5

Table 3. Field Control Sample results: Raw XRF values

7.3 Laboratory Blanks

A SiO₂ blank sample was used to check for contamination during sampling. The blank was tested every twenty samples to determine if the instrument had become contaminated during the testing process. The instrument was considered contaminated if any element of interest apart from iron was detected by the instrument. Iron was present in the blank at very low levels, therefore the instrument was considered contaminated if the iron concentration exceeded 100ppm - as this constitutes a negligible level of contamination.

In the event that the blank detected contamination, the operator was instructed to clean both the blank and the instrument sampling window and then re-run the blank to ensure the source of contamination had been removed. Once the instrument was cleaned, all the samples tested after the previous clean blank run were tested again.

No blank returned values above the detection limit for any of the elements of interest apart from iron, which did not exceed 100ppm on any occasion during the first round of sampling.

No blanks returned values above the detection limit for the elements targeted in sampling round 2.

See Appendix 1 and Appendix 2 for graphs of the blank results obtained for sampling rounds one and two respectively.

8 Site Specific Calibration Standard Testing

8.1 Introduction

One sample was taken from the initial test work to be used as a Site Specific Calibration Standard (SSCS). This sample was chosen from the preliminary sampling work based on the concentrations of target elements it contained. A sample that contained ideal concentrations of all the elements of interest could not be obtained in the time allowed so a standard containing the key indicators of contamination, copper and uranium, was used.

The SSCS was used to determine the amount of variation in the readings throughout the course of the project. When dealing with FPXRF equipment, the reported values should not fall more than 20% from the mean.

8.2 Results – First Round of Sampling

The graphs of the results of SSCS testing during the first round of sampling can be found in Appendix 3.

The results for the testing of chromium and zinc differed from the mean by more than 20 percent on two occasions and one occasion respectively. Results from the testing of all other elements did not fall further than 20% from the mean.

8.3 Results – Second Round of Sampling

The graphs of the results of SSCS testing during the second round of sampling can be found in Appendix 4.

The results for the testing of arsenic show four check samples fell more than 20% above the mean and six samples fell more than 20% below the mean from a total of 127 check samples. A minimum and maximum value of 23 and 41 was recorded with an average value of 31. This appears to be the result of a higher than expected detection limit resulting in a higher degree of scatter in the data.

All lead values and all but one uranium values fell within 20% of the mean.

9 Check Samples

9.1 Introduction

Check samples were used to ensure the XRF readings were reliable. Five percent of the samples tested with the FPXRF were sent for laboratory analysis by Amdel using their ARM20 method, a two acid digestion followed by ICP analysis.

An additional 101 samples were tested using methods IC3E, IC4E and IC4M, a 'total solution' method. These samples were primarily used for FPXRF calibration but were also used as check samples where the ARM20 technique failed to produce accurate data. The results are presented in Appendix 5: Check Samples.

The check samples were used to determine the precision of the FPXRF machine by plotting the FPXRF results against the laboratory results. The coefficient of determination (R^2) value was then calculated to provide a measure of how well the two datasets match. An R^2 value of 1 indicates a perfect match while an R^2 value of 0 indicates no match. An R^2 value of 0.7 is considered an acceptable level of precision while an R^2 value of 0.9 indicates a very good correlation.

In some instances this technique can produce misleading results. When two entire datasets are plotted against each other a very high R^2 value may be obtained even though portions of the data correlate very poorly. This is most likely to occur when data is spread over a wide range and is a result of how this statistical technique works. Selected portions of the data have been plotted where this has occurred to provide a better understanding of the accuracy of the data.

As testing of barium, cadmium, vanadium and lead was requested after sampling had commenced, check assays were not obtained for Ba or V. Check assays for lead were obtained however the laboratory did not conduct QAQC testing for lead data. Results for Cd were below detection limits.

9.2 Results

9.2.1 Arsenic

The FPXRF and ARM20 data for arsenic produces an R^2 value of 0.8483 when plotted in its entirety. If arsenic results below 100ppm are plotted the R^2 value falls to 0.4968. This drop in correlation with laboratory data is mainly due to one extreme outlier. If this outlier is removed an R^2 value of 0.7662 is obtained, above the limit of 0.7 for acceptable data.

9.2.2 Chromium

The FPXRF and ARM20 data for chromium produces an R^2 value of 0.7481 when plotted in its entirety. While there are some minor outliers, much of the difference between the FPXRF and laboratory data is due to scatter. There are no trends that indicate interference from other elements, the scatter appears to be due to FPXRF and laboratory assay method limitations.

9.2.3 Copper

The FPXRF and ARM20 data for chromium produces an R^2 value of 0.9945 when plotted in its entirety. This demonstrates a very strong correlation between the two datasets. No outliers are visible.

9.2.4 Iron

The FPXRF and ARM20 data for iron produces an R^2 value of 0.8339 when plotted in its entirety and a value of 0.8861 when results below 40% are plotted. Three clear trends can be seen in the data above 20% Fe. These trends are probably caused by changes in the sample matrix, however as the trends are present above critical levels the cause has not been investigated. The R^2 value shows the FPXRF data correlates to laboratory data well.

9.2.5 Manganese

The FPXRF and ARM20 data for manganese produces an R^2 value of 0.9332 when plotted in its entirety and a value of 0.9858 when samples with a result under 7,500ppm are plotted. Overall there is a very good correlation between the FPXRF and laboratory data, with a large margin of error present at very high values (>15,000ppm).

9.2.6 Nickel

The FPXRF and ARM20 data for nickel produces an R^2 value of 0.9483 when plotted, however a large number of spurious readings were removed to obtain this result. Of 196 results, 119 were removed as the FPXRF reported they were below the detection limit even though assay data shows they contained from 0 to 90ppm nickel. The cause of this error is suspected to be iron, but the data could not be corrected by correlating nickel data with iron data. As 200ppm nickel is well below the level of contamination no further work was carried out to correct this data.

9.2.7 Rubidium

The FPXRF and ARM20 data for rubidium produces an R^2 value of 0.1403 when plotted in its entirety. A clear trend is evident for part of the data but a large portion does not correlate. This is because the ARM20 assay technique failed to completely digest the sample, resulting in the laboratory reporting a lower result in many samples. A comparison of FPXRF data to G400M data gives an R^2 value of 0.9608 when all 97 samples assayed with this technique are plotted. This demonstrates the rubidium values produced by the FPXRF are precise.

9.2.8 Strontium

The FPXRF and ARM20 data for strontium produces an R^2 value of 0.5443 when plotted in its entirety. There is a great deal of scatter present in the data due to a failure of the ARM20 technique to completely digest the sample. Plotting FPXRF results for strontium against all available G400M results gives an R^2 value of 0.9792. This demonstrates the rubidium values produced by the FPXRF are precise.

9.2.9 Uranium

The FPXRF and ARM20 data for uranium produces an R^2 value of 0.8404 when plotted in its entirety and a value of 0.5059 when values below 200ppm are plotted. The very low value obtained from uranium results below 200ppm is due to a single outlier. When this outlier is removed an R^2 value of 0.8516 is obtained, demonstrating a good correlation between the two datasets.

9.2.10 Zinc

The FPXRF and ARM20 data for zinc produces an R^2 value of 0.9606 when plotted in its entirety with three minor outliers. This demonstrates a very good correlation between the two datasets.

9.2.11 Lead

The FPXRF and ARM20 data for lead produces an R^2 value of 0.9972 when plotted in its entirety and an R^2 value of 0.6347 when values below 500ppm are plotted. There is a significant number of samples that the ARM20 technique was not able to detect the levels of lead reported by the FPXRF. When plotted against G400M data an R^2 value of 0.9986 is obtained, demonstrating the FPXRF correlates well with assay data.

10 Umpire Samples

Samples tested by Amdel using the IC series methods were also tested by NTEL using the G400 series of methods. The copper and uranium results from the two laboratories have been compared to ensure the data produced by Amdel is accurate.

The comparison for both copper and uranium show the two datasets are comparable with R^2 values of 0.9988 and 0.9974 respectively. The data from both laboratories is therefore considered accurate.

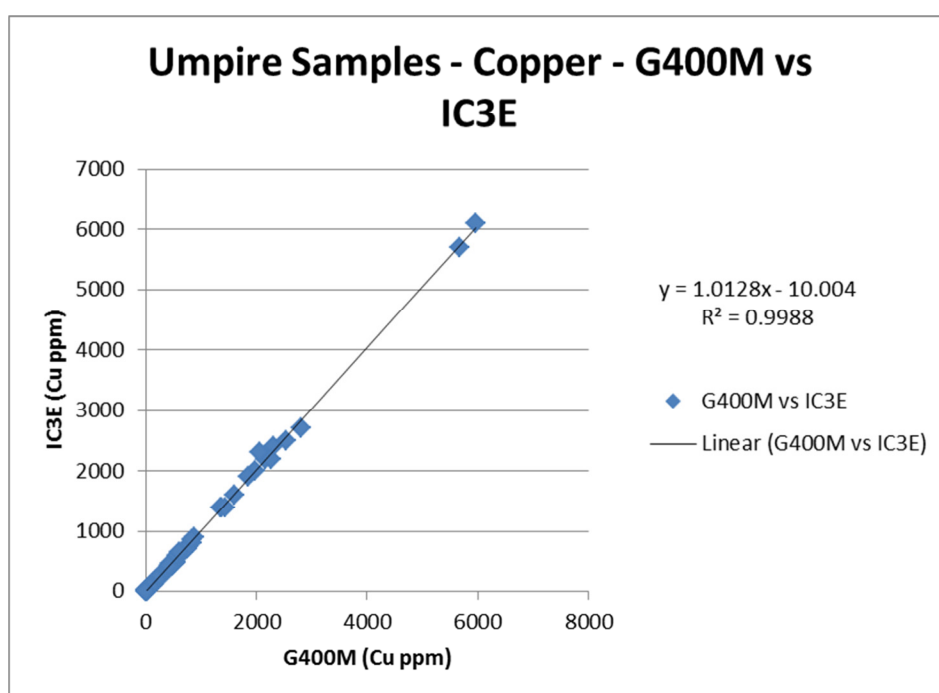


Figure 5. Umpire Samples: Comparison of G400M (NTEL) and IC4M (Amdel) copper results

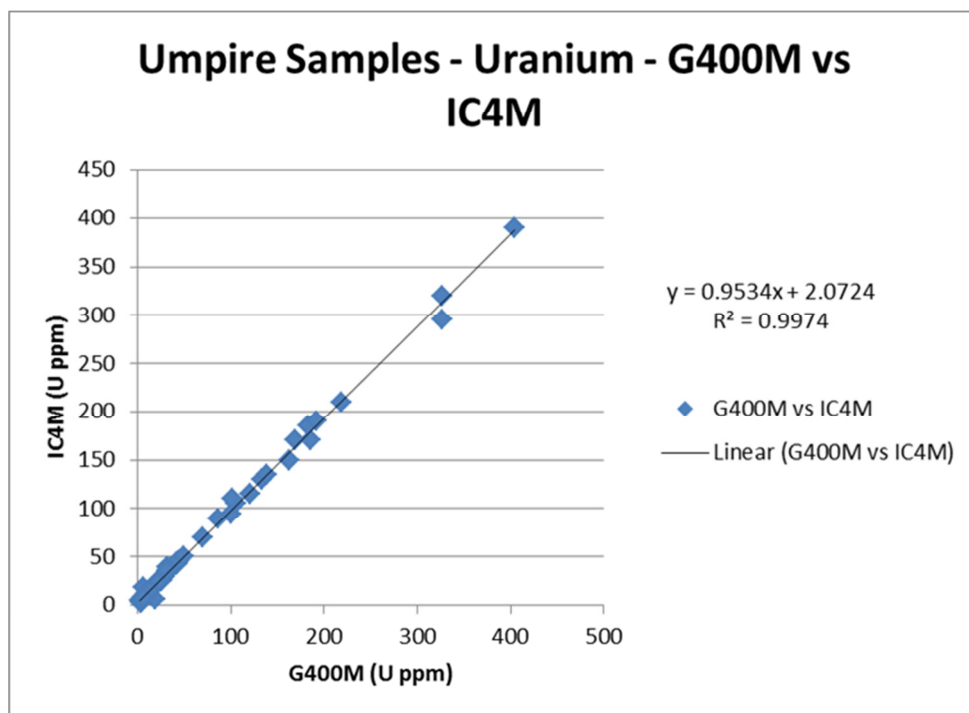


Figure 6. Umpire Samples: Comparison of G400M (NTEL) and IC4M (Amdel) uranium results

11 Field Duplicates

Field duplicates were used to assess the representivity of the samples that were taken. A second pit, the duplicate, was sampled at every twentieth sampling site and the copper and uranium results from the two sets of samples were compared. The original and duplicate samples were taken from pits within 1 meter of each other.

The results show a significant degree of scatter but R² values are above 0.7 for both copper and uranium where the entire datasets are plotted and where only low concentrations are plotted. This indicates the sampling method has produced results that are representative of the areas they were taken from.

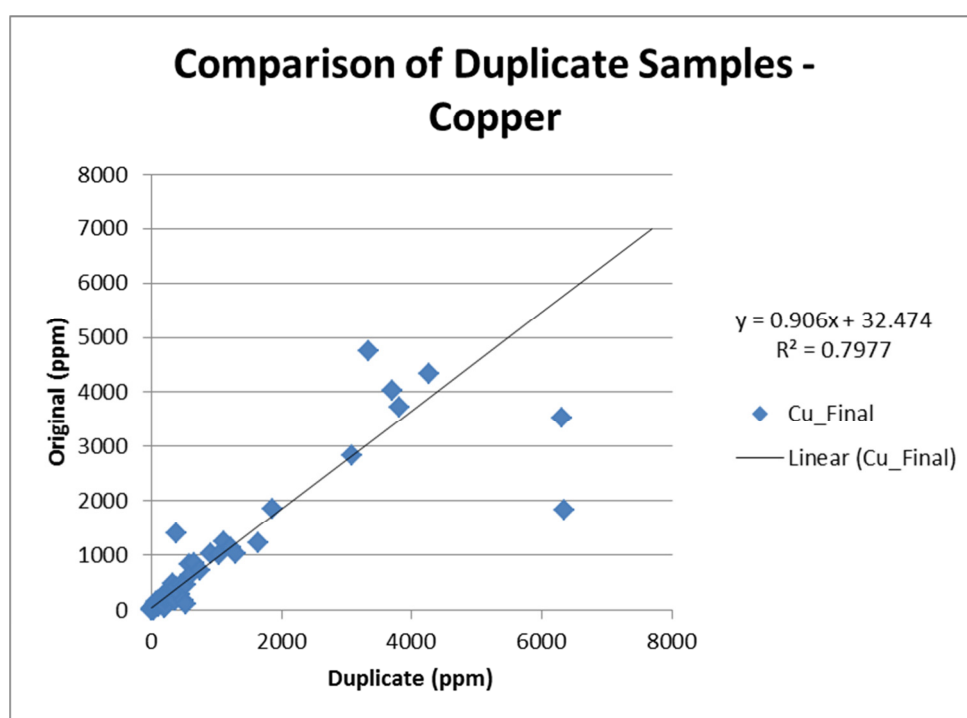


Figure 7. Comparison of copper results taken from original and duplicate samples

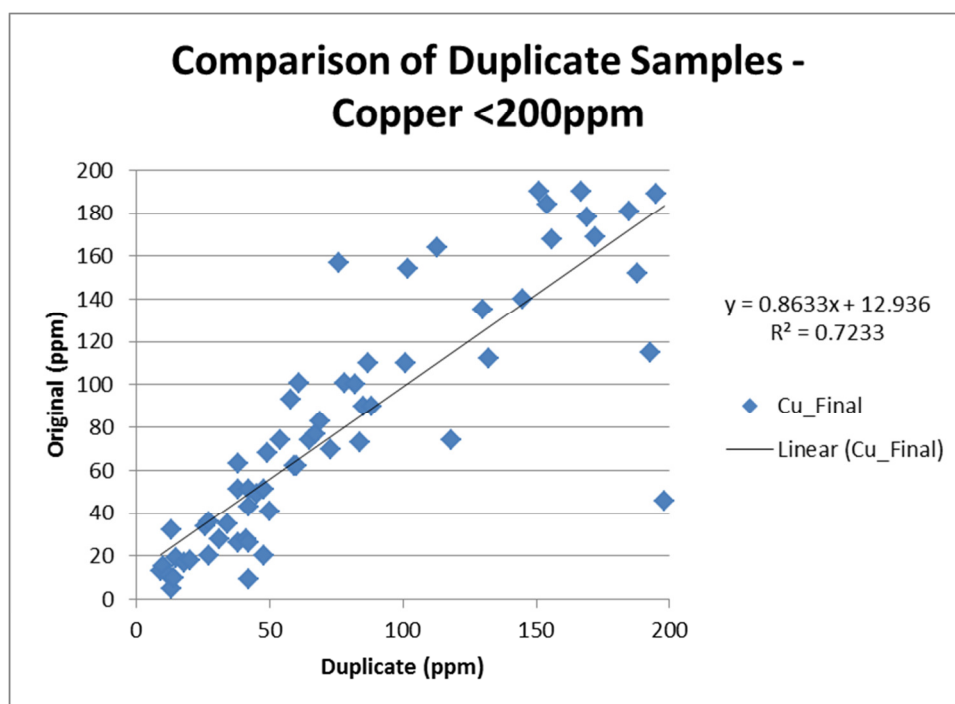


Figure 8. Comparison of copper results below 200ppm taken from original and duplicate samples

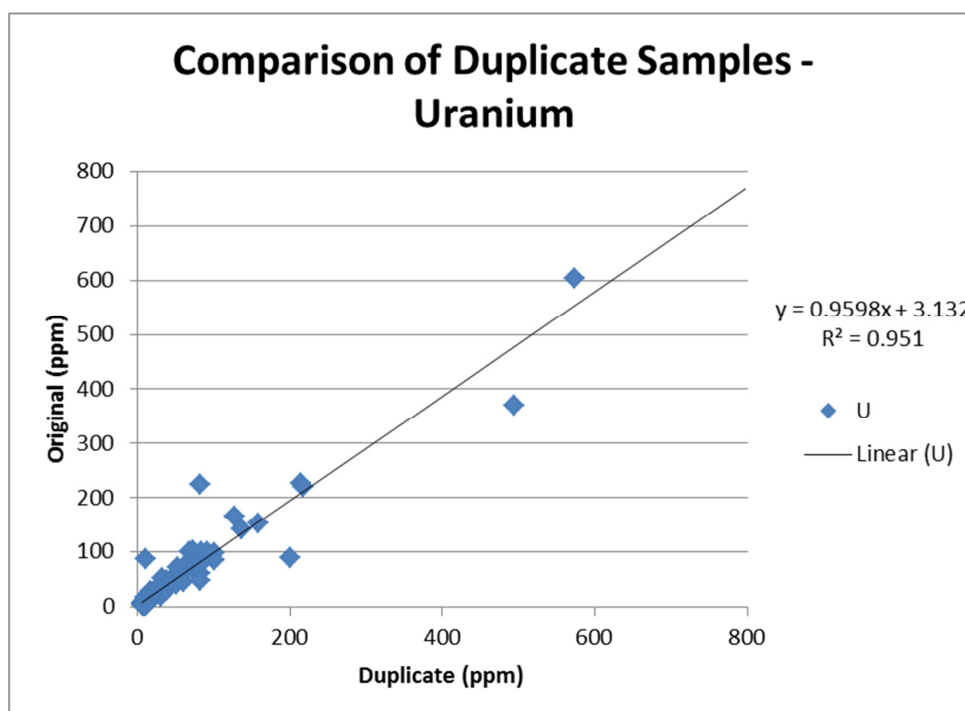


Figure 9. Comparison of uranium results taken from original and duplicate samples

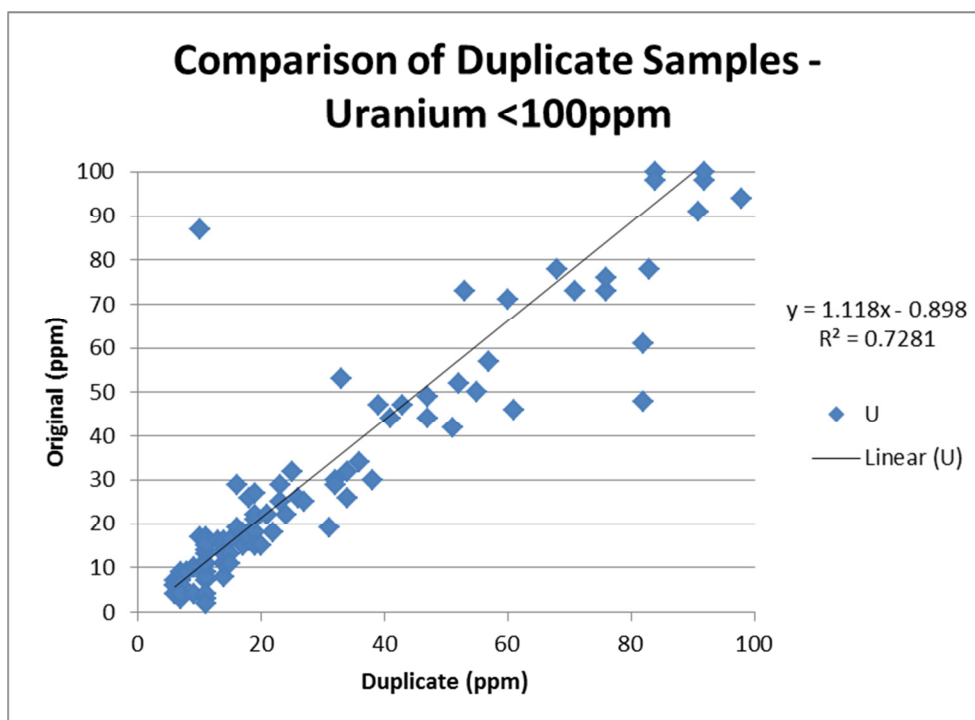


Figure 10. Comparison of uranium results below 100ppm taken from original and duplicate samples

12 FPXRF Data Correction Procedures

12.1 Introduction

FPXRF results are derived by reading the spectra of a sample then determining a result by applying a series of corrective equations. These equations make certain assumptions about the chemical makeup of the sample. There are two possible outcomes when the sample does not conform to these assumptions. The most common effect is a bias in the readings. The FPXRF results still correlate well with laboratory assays but exhibit either a positive or negative bias. It is standard practice to correct these errors by plotting laboratory assays against the FPXRF results to obtain a line equation. This line equation may then be applied to correct the FPXRF results to bring them in line with assay data.

Each correction equation is specific to one element in a particular sample matrix. Therefore a sufficient number of samples must be assayed across a representative range of concentrations so that an equation for each element of interest may be generated. The equations used on this project and their associated graphs are included in Appendix 6.

Occasionally, the corrective equations will not be able to produce an accurate result from spectral data. This can result in FPXRF data that does not correlate with laboratory assays. In these cases the FPXRF data cannot be corrected and the FPXRF data should not be used.

12.2 Comparison data

A combination of ARM20 and G400M assays completed by Amdel were used to generate correction equations. ARM20 data was used where it correlated well with FPXRF readings as more ARM20 assays were available, resulting in a better curve. G400M data was used where the ARM20 method failed to produce comparable data.

It should be noted that Cu, U, Pb and Zn displayed very good correlation once the data had been corrected.

12.3 Matrix Effects

The physical and geochemical properties of the material found at Rum Jungle varied greatly across the site from natural material to processed tailings. This variation was expected to necessitate multiple correction equations for each element, with equations divided between natural and processed material. Clear differences due to these effects were only found in iron data, other elements appeared to be unaffected by changes in physical and geochemical properties.

12.4 Correction Equations

One correction equation has been developed for each element. Each equation is based on a limited range of samples. Samples were limited according to their accuracy as determined by QAQC data. In most cases the ARM20 data was found to be too inaccurate according to the R^2 value and visual checks. In these cases more accurate G400M/G400I data was used to correct FPXRF readings. These samples were culled further where interference effects that could not be corrected were found.

Correction equations could not be developed for elements present at concentrations below the FPXRF's detection limits. These include antimony, cadmium, mercury and silver. Data for cobalt was extremely poor due to a very strong interference effect caused by iron. This effect is too complex to be corrected by algorithms and is a limitation of FPXRF technology. Data for zirconium also correlated poorly with laboratory data. This is an unexpected result and the cause of this is unknown. Further work may allow the zirconium results to be resolved into useful data.

12.4.1 Arsenic

Arsenic results from the first round of sampling did not correlate with laboratory assay results. All of the first pass samples were re-tested with a different X-5000 instrument to produce a new dataset for arsenic. This data was then plotted against G400M data. A total of 94 samples containing arsenic concentrations from 0.5 to 115ppm were used to create the correction equation. The range of concentrations was obtained from G400M data.

The equation produces an R^2 value of 0.9412, indicating a very good correlation between FPXRF and laboratory data in this range. G400M assay results were not available for higher concentrations so data outside of this range cannot be reliably corrected using this equation.

12.4.2 Chromium

A total of 52 FPXRF results for chromium ranging from 55 to 180ppm were plotted against G400I data to produce a correction equation with an R^2 value of 0.7754. Like many light elements, chromium is a difficult element to detect precisely with FPXRF equipment and the relatively low R^2 value reflects this. The result is considered adequate for identifying areas of contamination.

12.4.3 Copper

A total of 182 FPXRF results for copper ranging from 10 to 6,100ppm were plotted against ARM20 data to produce a correction equation with an R^2 value of 0.9943. This is an exceptionally good correlation. The low curvature of the polynomial line produced by the equation indicates it may be possible to extrapolate the correction equation beyond the upper limit of the available data with little loss of accuracy.

12.4.4 Iron

A total of 165 FPXRF results for iron ranging from 1.37 to 12.4% were plotted against ARM20 data to produce a correction equation with an R^2 value of 0.8591. Three separate trends can be seen in the data above an iron concentration of 10%. These trends appear to be the result of matrix effects. It is likely that separate correction equations could be developed to produce one continuous curve, however as these trends are beyond the FPXRF manufacturer's maximum reported detection limit of 10% this has not been conducted.

12.4.5 Manganese

A total of 86 FPXRF results for manganese ranging from 550 to 7,400ppm were plotted against ARM20 data to produce a correction equation with an R^2 value of 0.9781. Two minor outliers are visible in the graph, but overall there is a very good correlation between the two datasets.

12.4.6 Nickel

A total of 17 FPXRF results for nickel ranging from 187 to 1020ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9933. The very low number of samples used is a result of very poor data quality below this concentration. The FPXRF reported samples being below the detection limit even though assay data shows these samples contained nickel ranging from 0 to 90ppm. As the vast majority of samples fell in this range very few samples were available for use in the correction equation.

The correlation between G400M and FPXRF data for the available samples is very strong but the limited number of available assay results means the correction equation may be unreliable. A minimum of 40 samples is recommended to develop a reliable correction equation.

12.4.7 Rubidium

A total of 58 FPXRF results for rubidium ranging from 29.5 to 178ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9442. Two minor outliers are visible in the graph at the lower end of the range. These samples may represent a different matrix type or they may be spurious. As there are only two outlier samples no conclusions can be drawn, therefore they cannot be relied upon. The effective range of this correction equation is therefore limited to concentrations above 50ppm.

12.4.8 Strontium

A total of 79 FPXRF results for strontium ranging from 10 to 74.6ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9746. No outliers are visible. A very straight line was produced by this data, meaning extrapolation beyond the upper limit of the data used may be possible without a large drop in accuracy.

12.4.9 Uranium

A total of 68 FPXRF results for uranium ranging from 5.97 to 404ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9891. Two minor outliers are visible in the graph.

12.4.10 Zinc

A total of 47 FPXRF results for zinc ranging from 50 to 750ppm were plotted against ARM20 data to produce a correction equation with an R^2 value of 0.9579. Three minor outliers are visible in the graph. A very straight line was produced by this data even though outliers were present. Extrapolation beyond the upper limit of the data used may be possible without a large drop in accuracy.

12.4.11 Lead

A total of 36 FPXRF results for lead ranging from 24.4 to 1,870ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9989. While the correlation between the two datasets is very good, 36 samples is not enough to create a reliable correction equation. Four more assays, preferably above 1,000ppm lead, are required to deem the equation reliable.

12.4.12 Vanadium

A total of 42 FPXRF results for vanadium ranging from 40 to 420ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.78. The relatively low R^2 value is a result of technological limitations. Light elements such as vanadium are difficult to detect with FPXRF equipment, resulting in a relatively high degree of scatter, especially at low concentrations.

12.4.13 Barium

A total of 57 FPXRF results for barium ranging from 49 to 834ppm were plotted against G400M data to produce a correction equation with an R^2 value of 0.9828. One minor outlier is visible in the graph.

Element	Assay Method	Calibration Equation	Correlation
As	G400M	$y = 0.0038x^2 + 0.6757x - 0.2405$	$R^2 = 0.9412$
Cr	G400M	$y = -0.0012x^2 + 1.1176x - 18.709$	$R^2 = 0.7754$
Cu	ARM20	$y = 2E-05x^2 + 1.0178x - 1.9662$	$R^2 = 0.9943$
Fe	ARM20	$y = -0.0172x^2 + 0.8343x + 0.7015$	$R^2 = 0.8591$
Mn	ARM20	$y = -3E-05x^2 + 1.2022x - 82.331$	$R^2 = 0.9818$
Ni	G400M	$y = 2E-05x^2 + 1.0358x + 95.741$	$R^2 = 0.9933$
Rb	G400M	$y = -0.0009x^2 + 1.3179x - 21.114$	$R^2 = 0.9442$
Sr	G400M	$y = -0.0007x^2 + 1.0735x - 0.5527$	$R^2 = 0.9746$
U	G400M	$y = -0.0004x^2 + 1.1639x - 7.1621$	$R^2 = 0.9891$
Zn	ARM20	$y = 4E-05x^2 + 1.0075x + 16.555$	$R^2 = 0.9597$
Pb	G400M	$y = 2E-06x^2 + 1.1226x + 2.6457$	$R^2 = 0.9989$
V	G400M	$y = -0.0046x^2 + 3.1573x - 62.751$	$R^2 = 0.78$
Ba	G400M	$y = 0.0002x^2 + 0.9452x + 15.921$	$R^2 = 0.9828$

Table 4. Correction equations

13 Discussion and Results

13.1 Cut-off Values

The key reporting requirement of the RFT and in fact the entire purpose of the field sampling program was to define areas of elevated metallic content and calculate their volumes. In Section 2 above, the methodology used in the sampling has been discussed.

This section reports on the methods used to define the impacted areas and hence the volume of material involved is discussed.

The critical consideration in defining elevated level of metallic material at an abandoned mine site is recognising where these elevated levels start and where the normal back ground values extend to. In modern times a geochemical survey is completed before the mine development would be undertaken. The data collected would be used during closure to define the residual levels of metallic elements in the waste rock. In the case of the Rum Jungle Mine site the data is not available and other methods to define the metallic element thresholds must be utilised.

To assist in selecting the metallic element threshold values a group orientation of samples from a non-contaminated area and others from suspected contaminated areas were collected and assayed. Table 5 contains the results of the analysis for the elements used in this study. It is of critical importance that the reader remember that the samples designated as “back ground” were taken away from the mine site and probably do not accurately reflect the actual metal concentrations that existed on the site prior to mining operations. The samples provide little more than a regional context in which to place the mine site and not the local geological environment.

None-the-less, to define the zones of elevated metallic material content, it is necessary to establish a set of values for the metallic elements of interest that discriminate between the natural back ground and the results of mining activities.

Examination of Table 5, comparison of back ground and elevated metallic samples shows why copper at 100 ppm was selected as the discerning element for use in the field. In the comparison data table all of the back ground samples contained less than 100 ppm copper whilst all of the other rock samples contained well over 100 ppm. While copper with a threshold value of 100 ppm was considered appropriate during the field work phase of the program it is now considered an inappropriate level for defining above threshold values at the Rum Jungle Mine site. Results from both the orientation sampling and the wider sampling program indicate that a much higher threshold should be considered to define areas with elevated metallic element content at the Rum Jungle site.

The Selected Cut-Off Values are presented in Table 5 against preliminary background and contaminated sample material. Further discussion of the rationale for determining the final threshold values is included after Table 5.

After careful consideration and discussion of some critical aspects with staff from the Department of Resources, it was agreed that attempting to use published Health Investigation Levels (HIL's) to set trigger levels or threshold values was inappropriate. The key considerations were:

- To successfully use HIL's a future land use is required. At this stage the future land use has not been resolved.
- HIL's are most commonly applied in urban or near urban settings and not over abandoned mine sites where back ground levels of some metals (ore) are naturally high.
- HIL's do not exist (to the authors knowledge) for some of the metals expected to be found at the Rum Jungle Mine site.
- The tropical environment of Northern Australia tends to form laterite. The lateritisation process typically depletes some and concentrates other metals.

Sample Source	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	U (ppm)	V (ppm)	As (ppm)	Pb (ppm)	Zn (ppm)
Background	72	32	0.86	230	55	94	26	1	116	10	12	20
Background	60	15	1.38	422	-99	68	15	-99	125	3	14	10
Background	9	6	0.33	84	12	100	12	2	50	-99	11	9
Background	6	-99	0.33	33	8	114	22	2	61	1	18	6
Background	6	5	1.10	912	-99	20	5	-99	19	9	39	7
Background	8	75	1.04	514	24	36	11	12	19	11	17	5
Background	-99	77	6.48	3570	-99	43	7	-99	124	55	42	12
Background	-99	48	2.68	297	24	35	8	9	42	10	17	39
Background	63	67	3.70	1118	-99	32	7	10	99	22	21	18
Contaminated - white Salt	25	5	0.21	111	420	0	41	1	-99	-99	-99	-99
Contaminated - white Salt	-99	4	4.43	10	-99	11	14	13	20	17	95	-99
High S	-99	-99	0.26	-99	-99	-99	-99	-99	-99	-99	-99	-99
Contaminated	-99	2357	2.51	-99	829	118	26	88	-99	-99	4530	30
Contaminated	-99	426	1.14	-99	-99	87	0	-99	25	-99	-99	-99
Contaminated	28	739	3.58	1437	-99	26	-99	31	65	2	39	-99
Contaminated	-99	498	2.94	2147	-99	22	-99	10	28	9	2	-99
Contaminated	-99	319	5.06	1362	-99	17	-99	-99	149	9	4	-99
Contaminated	414	402	0.26	1854	653	56	54	106	643	158	79	227
Contaminated	1544	1419	1.76	8497	4337	120	113	346	1100	128	137	639
Contaminated	-99	203	2.66	39	-99	71	17	27	125	-99	139	36
Contaminated	52	1239	3.61	-99	19	63	28	275	122	-99	744	86
	Cr	Cu	Fe%	Mn	Ni	Rb	Sr	U	V	As	Pb	Zn
Selected Cut-off Value	300	2000	15.00	7000	600	200	50	100	350	200	1000	3000

Note: -99 means Not Detected

Table 5. Comparison of Background and Contaminated Samples

As previously noted, the cut off or threshold values selected to define elevated metallic element areas are presented in the comparison table, Table 5. The rationale for why the various thresholds were selected is presented below.

- Chromium (Cr): the threshold of 300ppm was selected as it lies well above the level expressed in the background samples and the value is less than seen in some contaminated samples. Cr accumulates in a lateritic environment.
- Copper (Cu): the threshold of 2000ppm was selected as it represents the sort of copper value that might be expected in soils near out-cropping copper mineralisation. Values of this magnitude and more would be considered normal around a body such as the Woodcutters Mine. The Rum Jungle Mine was mined for copper.
- Iron (Fe): a threshold of 15% for iron is considered suitable given iron accumulates in lateritic environments, there may have been an Fe rich gossan originally marking the mineralisation's position and several rocks in the region (Koolpin Fm, Gerowie Tuff, Whites Fm, Moondogie SS) all contain iron accumulations of over 50%.
- Manganese (Mn): 7000 ppm is within the range of values shown in the comparison table. Manganese is also cumulative in lateritic environs. In several samples manganese nodules and selvages were seen to be forming.
- Nickel (Ni): The selection of 600 ppm is within the data range shown in the comparison table. Nickel like manganese is also accumulative in the lateritic environment.
- Rubidium (Rb): The selected value for rubidium of 200ppm is above the level for the element shown in the comparison table. However, examination of the thousands of field samples suggested that Rb at 200ppm was a meaningful cut off.
- Strontium (Sr): 50ppm was selected for strontium as it lies within the data range shown in the comparison table.
- Uranium (U): The selection of 100ppm Uranium is considered appropriate given the area was mined for that metal and the whole Pine Creek Orogen is known for its high Uranium Background readings. The nearby Cullen Granite has a background Uranium content of 20 to 30 ppm and very low-grade uranium ore has a grade of about 250ppm. The 100ppm value selected lies within a few times of the granite background value but is still much less than ore-grade.
- Vanadium (V): the threshold for V was set at 350ppm which is within the range of values measured for the comparison samples. The value is approximately 10% of a value considered to be marginally minable.
- Arsenic (As): The arsenic value of 200 ppm is slightly above the levels seen in the comparison table. However, As is widely distributed in the Pine Creek Orogen and particularly, Arsenopyrite is found in auriferous quartz veins and along with

chalcopryite (Cu) mineralisation. An As in soil sample value of 200ppm is the concentration that might be expected to found around copper-gold-uranium mineralisation.

- Lead (Pb): The value of 1000ppm is within the data range expressed in the comparison table and in-line with the expected value seen near mineralisation in the Woodcutters area.
- Zinc (Zn): The value of 3000 ppm is well above the values in the comparison table but as for lead, the value is what might be expected in soil samples near the Woodcutters area.

As stated above, the selection of threshold values is the most critical feature in defining the extent of contamination. Some of the effects of varying the thresholds are contained in Section 13.2 below. The recommendations section (c.f. Section 13.4) also addresses this issue.

13.2 Defining areas with elements concentrated above threshold values

In this section a series of Tables and Plans are referred to under Zone sub headings and for the readers convenience a consistent nomenclature has been used for their identification. For illustrative purposes, the reference on a table or plan is based on the following example:

“Zone 1 A Samples” means sample sites located in Zone 1 as defined in the RFT document and the “A” sample is the first sample from the pit dug at that site.

In the RFT document (c.f. Figure 1) :

- Zone 1 is the area surrounding the active mine and mill site
- Zone 2 is the partially rehabilitated mine and mill site; and
- Zone 4 is the sites drainage system.

Each of the Zone subheadings referred to contain summary information about the sample results. They contain

1. an upper table which identifies the location, the depth from which the sample was taken and the approximate number of samples that make up the data set. For the readers convenience the threshold values from Table 5 are presented on each. The threshold values are constant across zones and sample intervals.
2. a second lower table which refers to
 - areas designated 1, 2, 3 etc. and highlighted on an associated map plan.
 - the list of elements above threshold level

The list of elements that are above the threshold level in each of the Areas defined in the Zone and at the nominated sample interval. The information

is supplied to highlight the elevated metal associations and their significance.

For the purpose of defining an area, any two adjacent sites defined an area and not a point. No hierarchy is expressed or implied in the area designation. In all cases an Area contaminated with one element is considered to be the equal of any other area contaminated with single or multiple elements.

Please also note that a designation Area 1/2 implies that two contamination areas have joined up at depth. A missing number implies a previously defined area does not penetrate to the next depth level.

- volumes of material in each contaminated area
- 3. a map plan. The figures below are for illustration only. Separate 1:5000 scale, A1 size plans are submitted with this report as part of the RFT conditions.

As mentioned in Section 2 of the report sampling was continued until:

- The hand held XRF reported copper concentration at less than 100ppm,
- The machine reached its safe working limit,
- Large rock or concrete slabs were encountered
- or cultural sensitivities dictated a less intrusive sampling method was required.

13.2.1 Zone One

Zone 1 A (0 – 10cm) Samples

- 9 areas defined which have element concentrations greater than cut off threshold values. Mn contributing most to the size of the areas.
- Contamination appears to be related to miscellaneous dump sites, general rubbish and WRD drainage.

Zone 1 A Samples					0 to 10 cm depth					Number of samples ~300			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	5	nil	25	4	1	11	9	10	8	14	2	nil

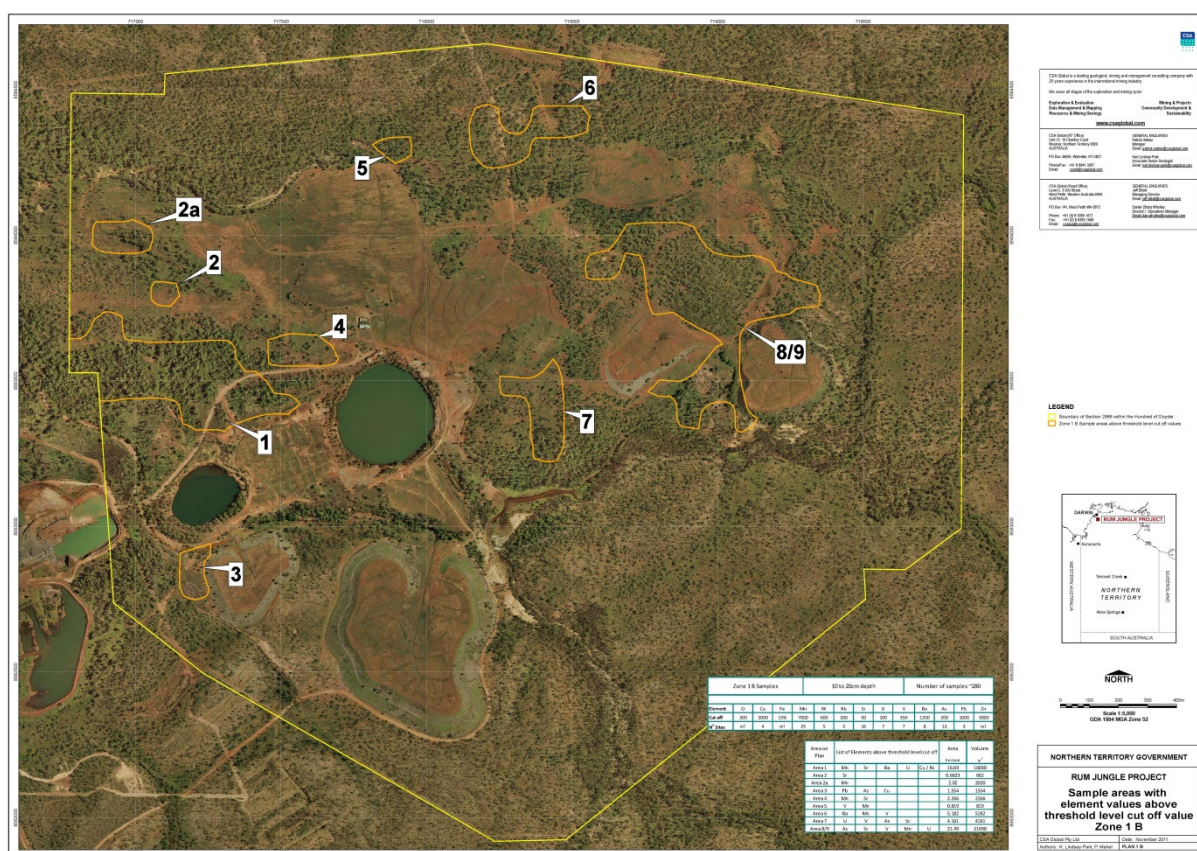
Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn	Cu	Ni	U	Sr	15.47	15470
Area 2	Sr					2.03	2030
Area 3	Pb	As	Ni	Cu		1.498	1498
Area 4	U	Cu	Sr			2.090	2090
Area 5	Mn	V	Ba			1.918	1918
Area 6	Mn	V	Ba	Cu		6.222	6222
Area 7	U	As	V	Sr		4.593	4593
Area 8	Sr	V	As			11.16	11160
Area 9	As	U	Sr			4.489	4498



- The distribution of elements above threshold values is very similar to the “A” sample distribution.
- Mn contributes the most to the size of the contaminated areas.

Zone 1 B Samples					10 to 20cm depth					Number of samples ~280			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	4	nil	25	5	3	16	7	7	8	12	3	nil

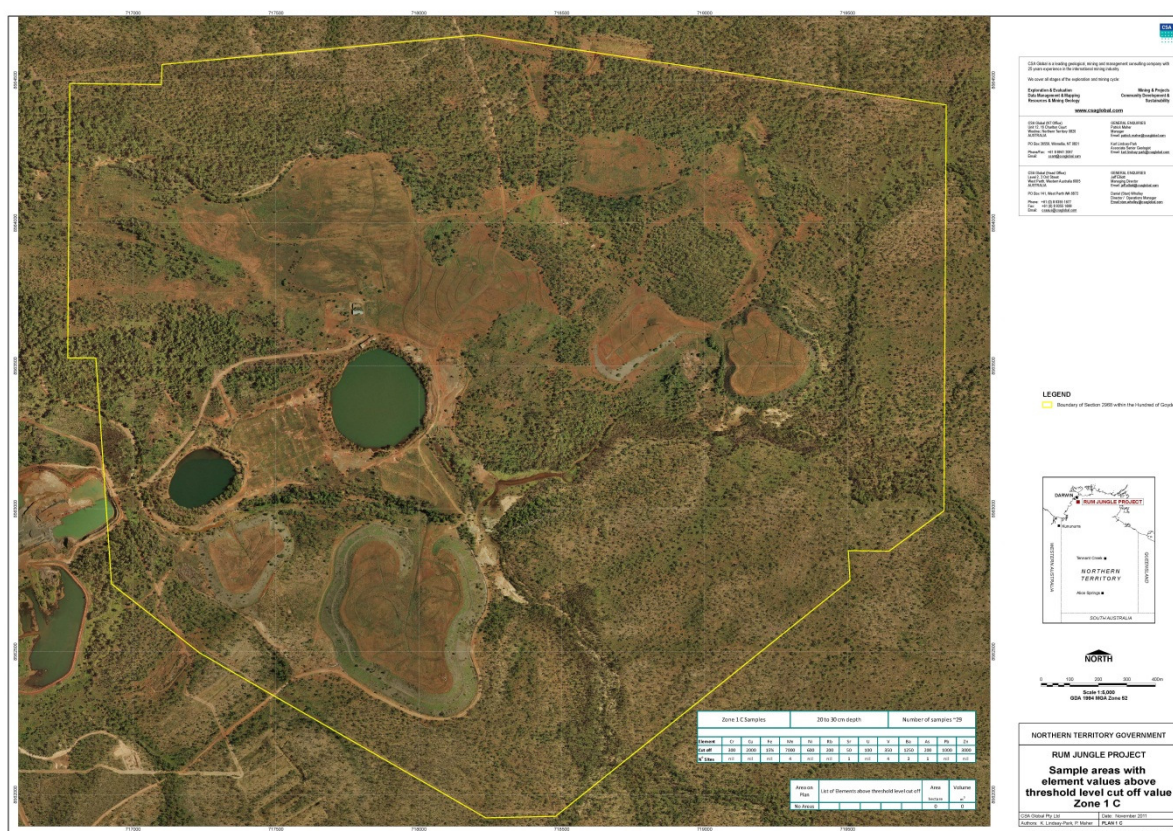
Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn	Sr	Ba	U	Cu / Ni	16.03	16030
Area 2	Sr					0.6623	662
Area 2a	Mn					2.020	2020
Area 3	Pb	As	Cu			1.554	1554
Area 4	Mn	Sr				2.266	2266
Area 5	V	Mn				0.819	819
Area 6	Ba	Mn	V			5.182	5182
Area 7	U	V	As	Sr		4.161	4161
Area 8/9	As	Sr	V	Mn	U	21.49	21490



- There are no areas defined, just isolated points.
- Infill and deeper sampling were undertaken where the handheld XRF reported >100 ppm Cu.

Zone 1 C Samples					20 to 30 cm depth					Number of samples ~29			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	4	nil	nil	1	nil	4	3	1	nil	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
No Areas						0	0

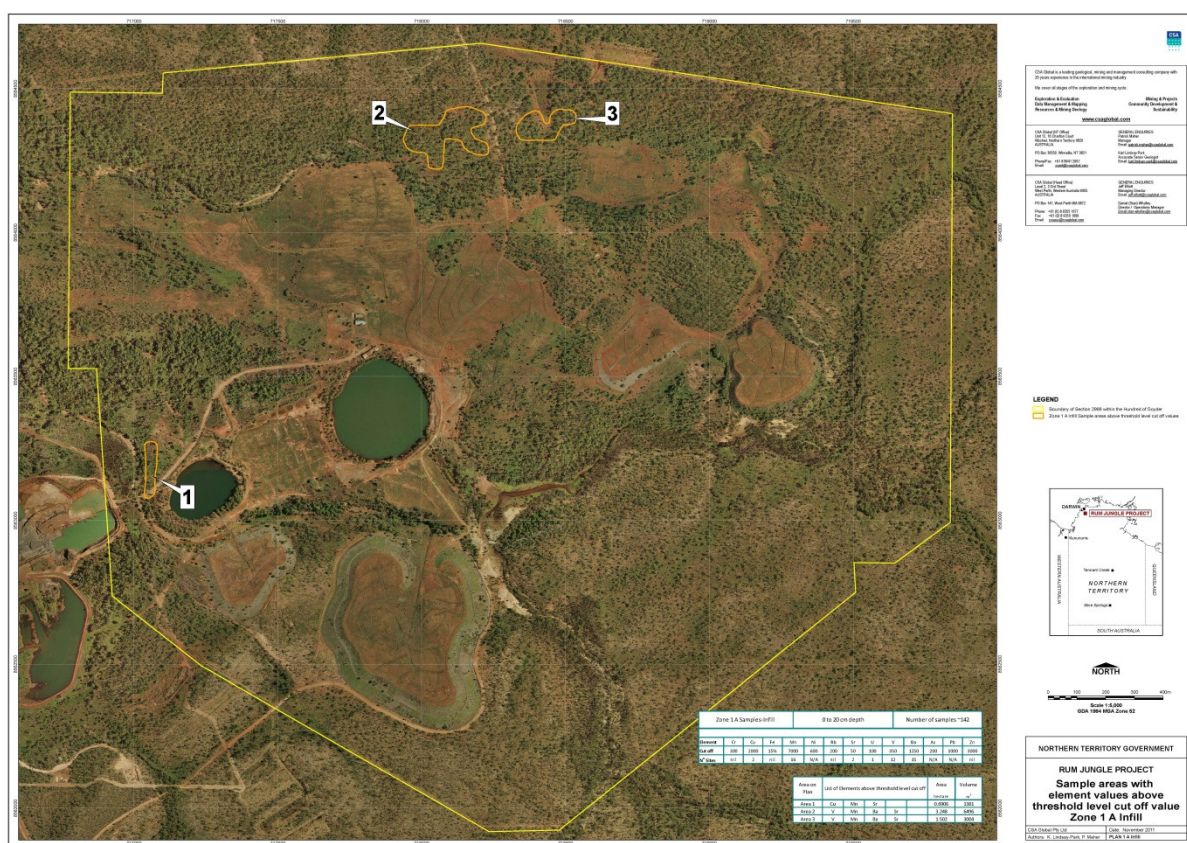


Zone 1 A (0 – 20cm) Samples- Infill

- An area similar to that as indicated in areas 5 and 6 in the Zone 1 A Samples.

Zone 1 A Samples-Infill				0 to 20 cm depth				Number of samples ~142					
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	2	nil	16	N/A	nil	2	1	12	15	N/A	N/A	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Cu	Mn	Sr			0.6906	1381
Area 2	V	Mn	Ba	Sr		3.248	6496
Area 3	V	Mn	Ba	Sr		1.502	3004



Zone 1 B (20 – 80cm) Samples- Infill

- A similar area as that seen in the “A” sample- infill above.

Zone 1 B Samples-Infill					20 to 80 cm depth					Number of samples ~133			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	1	nil	21	N/A	nil	1	nil	16	16	N/A	N/A	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area2/3	Cu	Mn	Sr	V	Ba	5.932	35592

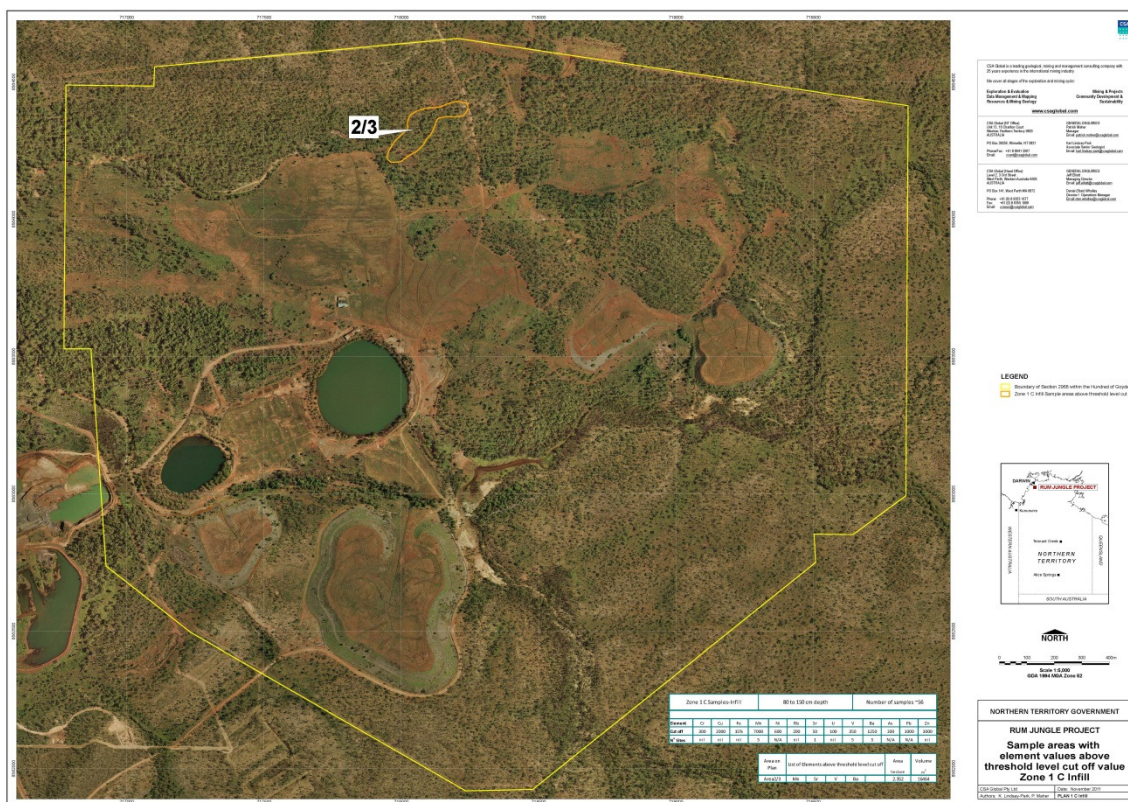


Zone 1 C (80 – 150cm) Samples- Infill

- A similarly positioned but reduced in size area as above “A” and “B” Infill samples.

Zone 1 C Samples-Infill				80 to 150 cm depth						Number of samples ~56			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	5	N/A	nil	1	nil	5	5	N/A	N/A	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area2/3	Mn	Sr	V	Ba		2.352	16464



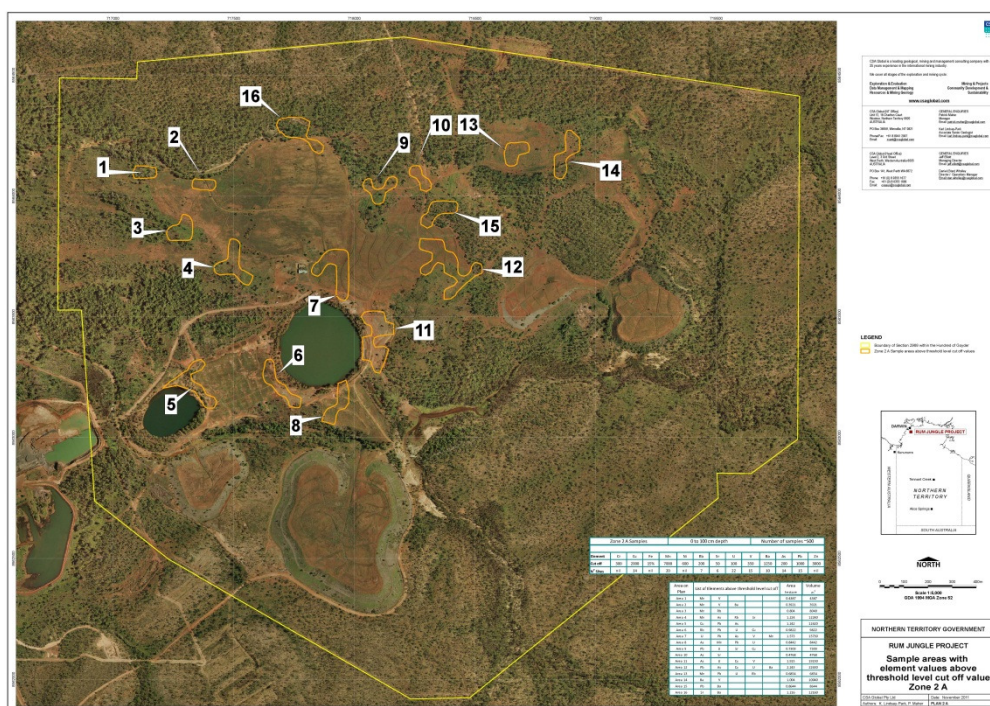
13.2.2 Zone Two

Zone 2 A (0 – 100cm) Samples

- Numerous relatively small areas defined which have element concentrations greater than cut off threshold values.

Zone 2 A Samples				0 to 100 cm depth				Number of samples ~500					
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	14	nil	20	nil	7	6	22	15	10	14	15	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn	V				0.4387	4387
Area 2	Mn	V	Ba			0.3921	3921
Area 3	Mn	Rb				0.804	8040
Area 4	Mn	As	Rb	Sr		1.224	12240
Area 5	Cu	Pb	As			1.242	12420
Area 6	Rb	Pb	U	Cu		0.9822	9822
Area 7	U	Pb	As	V	Mn	1.573	15730
Area 8	As	Mn	Pb	U		0.8442	8442
Area 9	Pb	U	Sr	Cu		0.7309	7309
Area 10	As	Sr				0.4768	4768
Area 11	As	U	Cu	V		1.915	19150
Area 12	Pb	As	Cu	U	Ba	2.243	22430
Area 13	Mn	Pb	U	Rb		0.6854	6854
Area 14	Ba	V				1.004	10040
Area 15	Pb	Ba				0.8644	8644
Area 16	Sr	Ba				1.216	12160

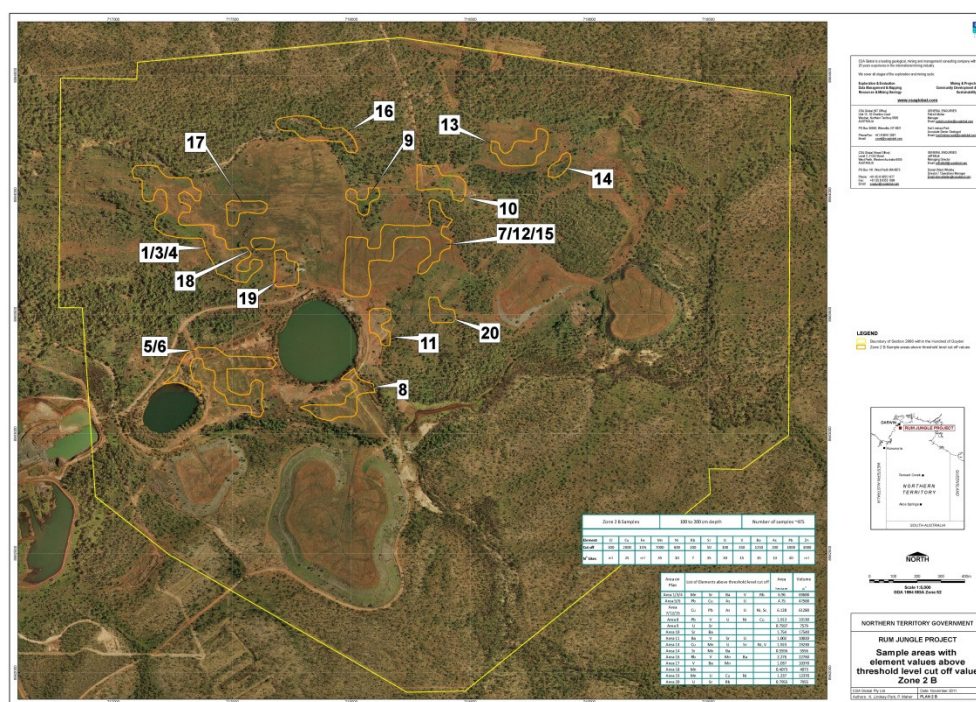


Zone 2 B (100 – 200cm) Samples

- Larger areas defined compared to the Zone 2 “A” samples.
- Significant volumes of material with elements concentrated above threshold values.

Zone 2 B Samples				100 to 200 cm depth				Number of samples ~475					
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	25	nil	35	10	7	35	30	15	15	13	40	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1/3/4	Mn	Sr	Ba	V	Rb	6.960	69600
Area 5/6	Pb	Cu	As	U		4.750	47500
Area 7/12/15	Cu	Pb	As	U	Ni, Sr,	6.128	61280
Area 8	Pb	V	U	Ni	Cu	1.913	19130
Area 9	U	Sr				0.7597	7579
Area 10	Sr	Ba				1.754	17540
Area 11	Ba	V	Sr	U		1.002	10020
Area 13	Cu	Mn	U	Sr	Ni, V	1.923	19230
Area 14	Sr	Mn	Ba			0.5556	5556
Area 16	Rb	V	Mn	Ba		2.276	22760
Area 17	V	Ba	Mn			1.037	10370
Area 18	Mn					0.4073	4073
Area 19	Mn	U	Cu	Ni		1.237	12370
Area 20	U	Sr	Rb			0.7955	7955

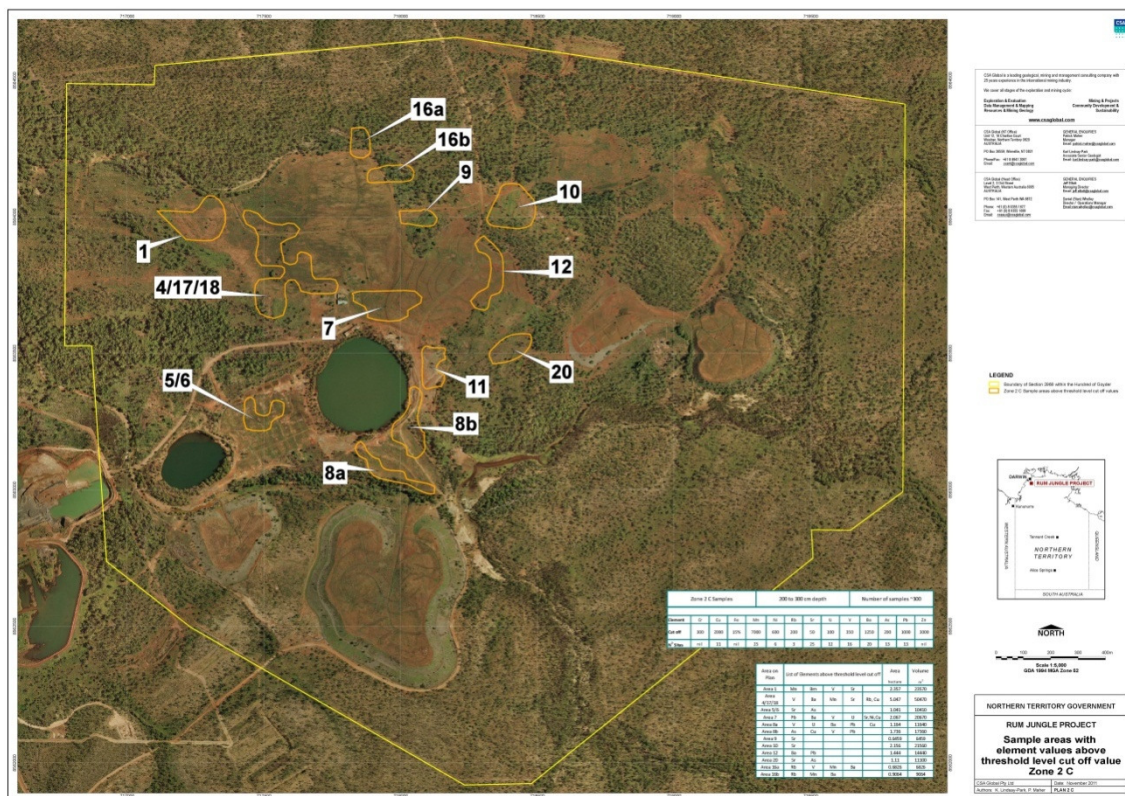


Zone 2 C (200 – 300cm) Samples

- Broad areas with element values greater than cut off threshold value persist with significant volumes of material.
- Numerous holes stopped by bedrock, concrete footings and by not containing >100ppm Cu.

Zone 2 C Samples					200 to 300 cm depth				Number of samples ~300				
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	11	nil	25	6	3	25	12	16	20	13	13	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn	Bm	V	Sr		2.357	23570
Area 4/17/18	V	Ba	Mn	Sr	Rb, Cu	5.047	50470
Area 5/6	Sr	As				1.041	10410
Area 7	Pb	Ba	V	U	Sr, Ni, Cu	2.067	20670
Area 8a	V	U	Ba	Pb	Cu	1.164	11640
Area 8b	As	Cu	V	Pb		1.736	17360
Area 9	Sr					0.6459	6459
Area 10	Sr					2.156	21560
Area 12	Ba	Pb				1.444	14440
Area 20	Sr	As				1.110	11100
Area 16a	Rb	V	Mn	Ba		0.6826	6826
Area 16b	Rb	Mn	Ba			0.9064	9064

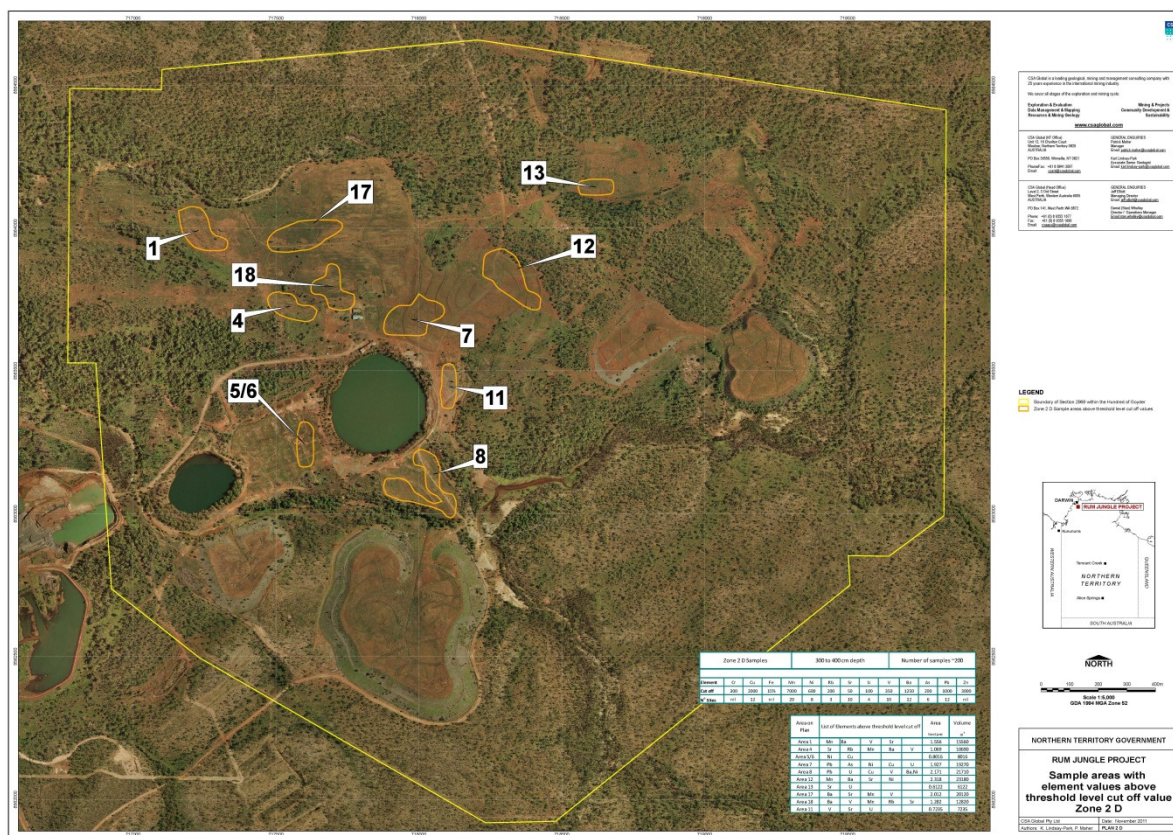


Zone 2 D (300 – 400cm) Samples

- Several areas of element values greater than cut off threshold value persist.
- Numerous holes terminated in rock.

Zone 2 D Samples					300 to 400 cm depth					Number of samples ~200			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	12	nil	20	8	3	10	4	10	12	6	12	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn	Ba	V	Sr		1.556	15560
Area 4	Sr	Rb	Mn	Ba	V	1.069	10690
Area 5/6	Ni	Cu				0.8016	8016
Area 7	Pb	As	Ni	Cu	U	1.927	19270
Area 8	Pb	U	Cu	V	Ba, Ni	2.171	21710
Area 12	Mn	Ba	Sr	Ni		2.318	23180
Area 13	Sr	U				0.6122	6122
Area 17	Ba	Sr	Mn	V		2.012	20120
Area 18	Ba	V	Mn	Rb	Sr	1.282	12820
Area 11	V	Sr	U			0.7235	7235

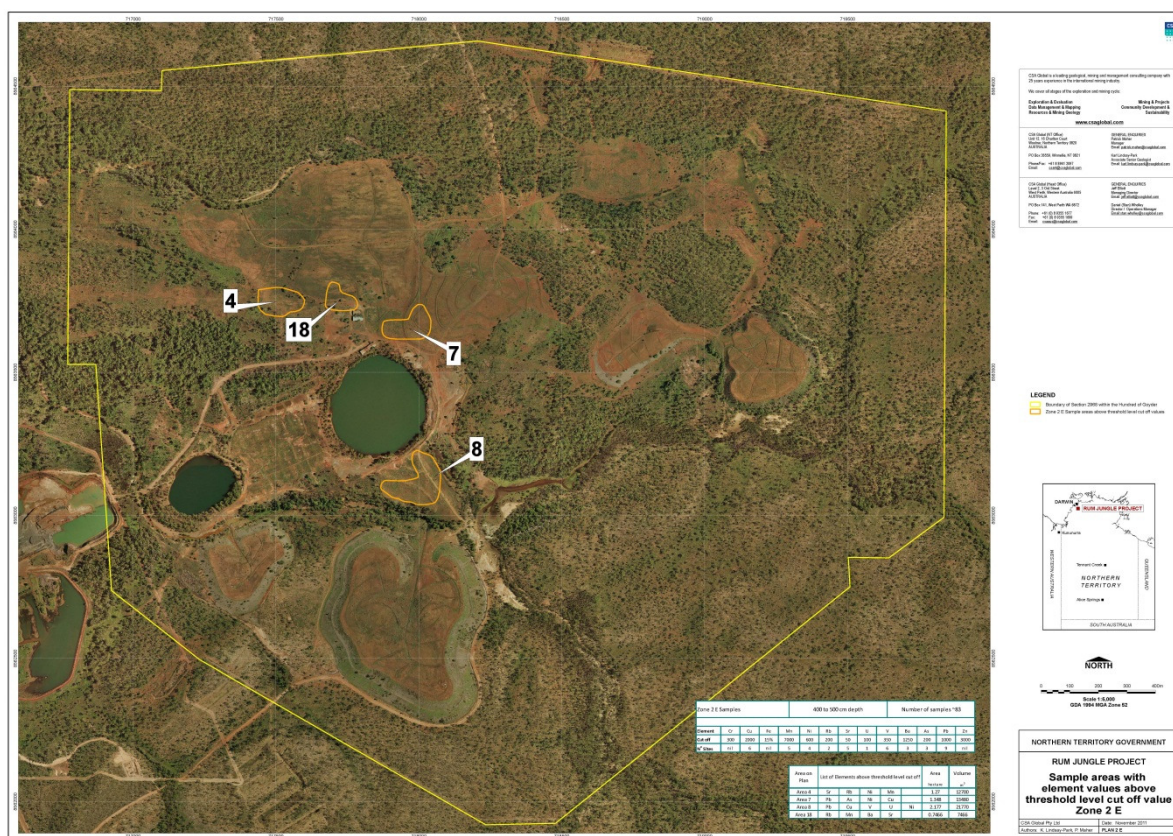


Zone 2 E (400 – 500cm) Samples

- Element values greater than cut off threshold value persists in several areas and does so presumably to bedrock.
- A few “F” and “G” samples were collected but these are insufficient to define areas.

Zone 2 E Samples					400 to 500 cm depth				Number of samples ~83				
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	6	nil	5	4	2	5	1	6	3	3	9	nil

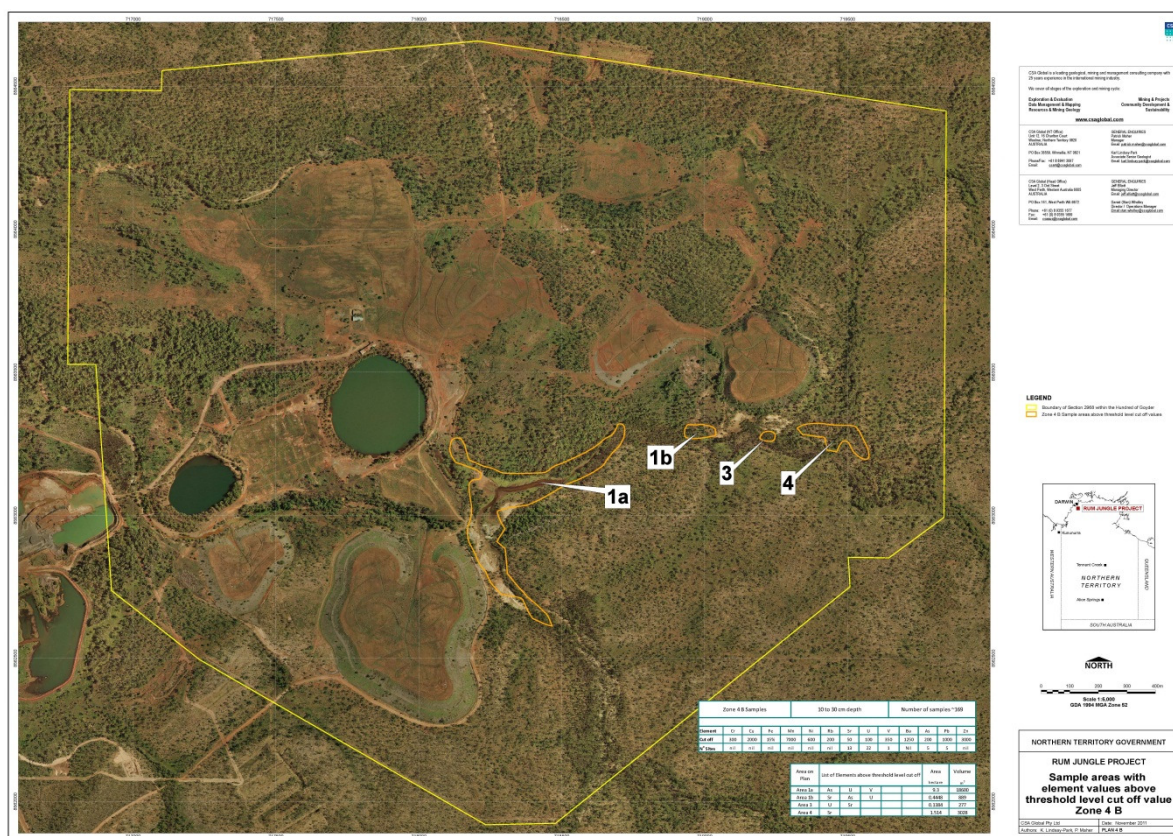
Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 4	Sr	Rb	Ni	Mn		1.270	12700
Area 7	Pb	As	Ni	Cu		1.348	13480
Area 8	Pb	Cu	V	U	Ni	2.177	21770
Area 18	Rb	Mn	Ba	Sr		0.7466	7466



- A very similar pattern to the Zone 4 'A' samples.

Zone 4 B Samples					10 to 30 cm depth					Number of samples ~169			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	nil	nil	nil	13	22	1	Nil	5	5	nil

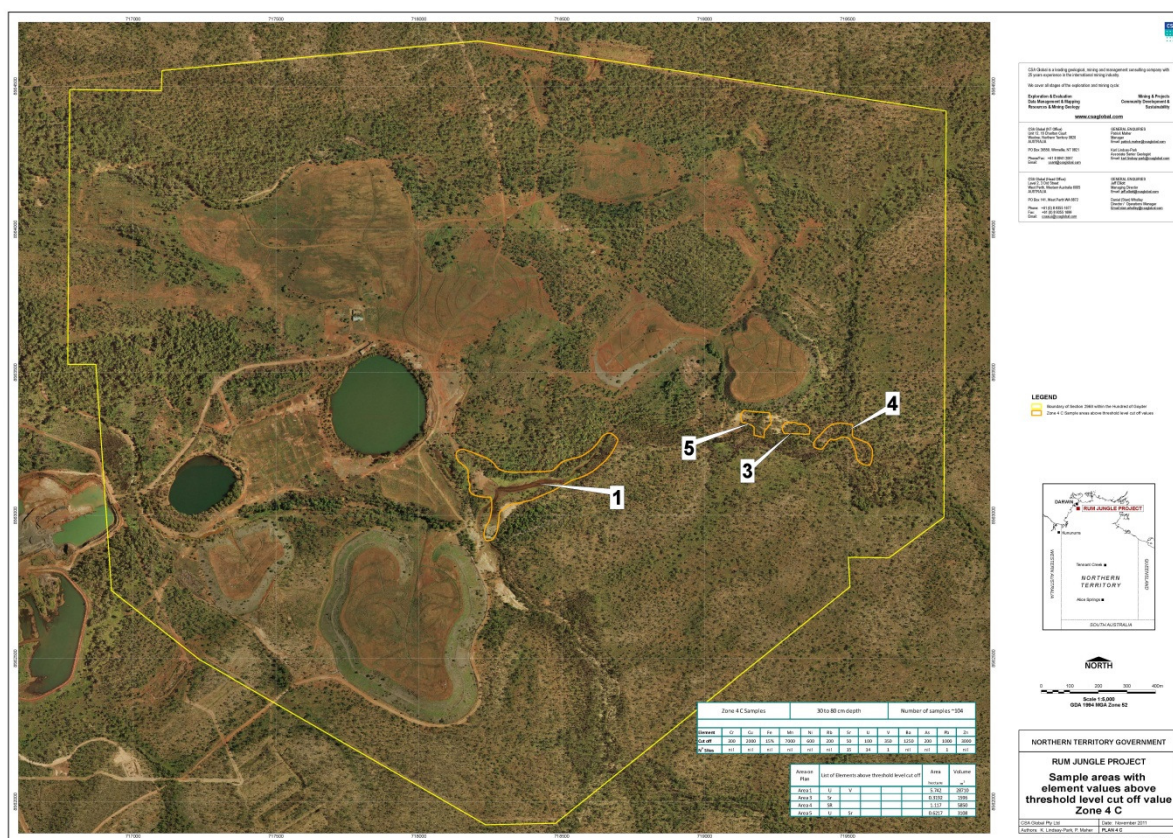
Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1a	As	U	V			9.300	18600
Area 1b	Sr	As	U			0.4448	889
Area 3	U	Sr				0.1384	277
Area 4	Sr					1.514	3028



- A slightly reduced, in area, pattern similar to Zone 4 "A" samples.

Zone 4 C Samples					30 to 80 cm depth				Number of samples ~104				
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	nil	nil	nil	15	14	1	nil	nil	1	nil

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	U	V				5.742	28710
Area 3	Sr					0.3192	1596
Area 4	SR					1.117	5850
Area 5	U	Sr				0.6217	3108

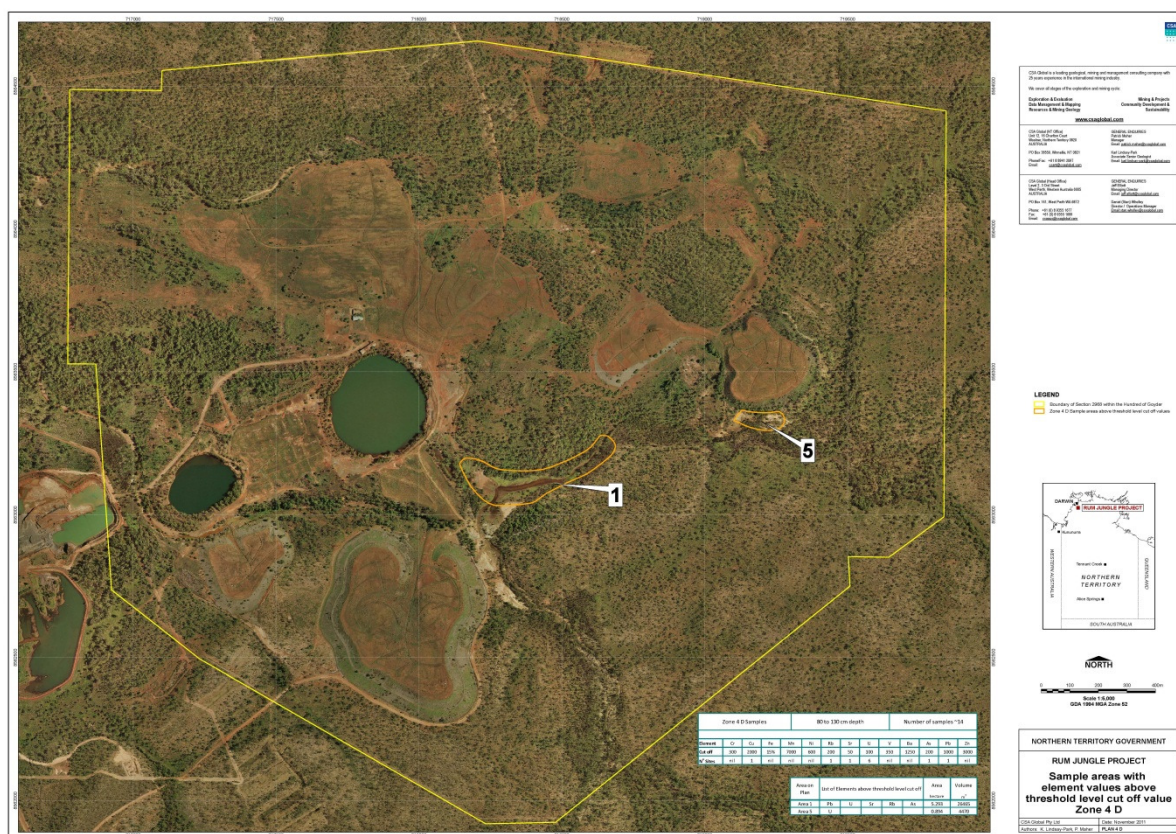


Zone 4 D (80 – 130cm) Samples

- Only a few data points but element values greater than cut off threshold value persists.

Zone 4 D Samples					80 to 130 cm depth					Number of samples ~14			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	1	nil	nil	nil	1	1	6	nil	nil	1	1	nil

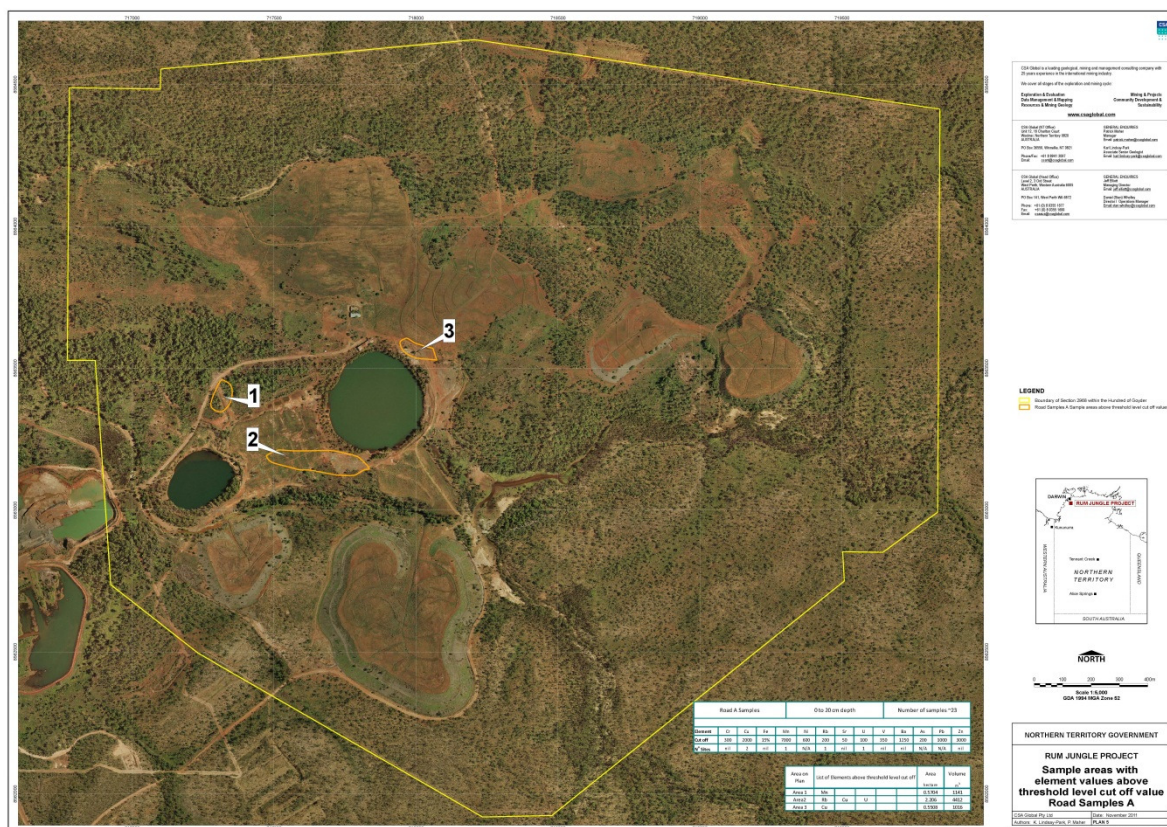
Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Pb	U	Sr	Rb	As	5.293	26465
Area 5	U					0.8940	4470



Road A (0 – 20cm) Samples

- | Road A Samples | | | | | 0 to 20 cm depth | | | | | Number of samples ~23 | | | |
|-----------------|-----|------|-----|------|------------------|-----|-----|-----|-----|-----------------------|-----|------|------|
| Element | Cr | Cu | Fe | Mn | Ni | Rb | Sr | U | V | Ba | As | Pb | Zn |
| Cut off | 300 | 2000 | 15% | 7000 | 600 | 200 | 50 | 100 | 350 | 1250 | 200 | 1000 | 3000 |
| N° Sites | nil | 2 | nil | 1 | N/A | 1 | nil | 1 | nil | nil | N/A | N/A | nil |

Area on Plan	List of Elements above threshold level cut off					Area hectare	Volume m ³
Area 1	Mn					0.5704	1141
Area2	Rb	Cu	U			2.206	4412
Area 3	Cu					0.5508	1016



Road B (20 – 80cm) samples

- Only one site with element values greater than cut off threshold value.

Road B Samples					20 to 80 cm depth					Number of samples ~18			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	nil	N/A	nil	nil	1	nil	nil	N/A	N/A	nil

Road C (80 – 120cm) samples

- No sites with element values greater than cut off threshold value.

Road B Samples					80 to 120 cm depth					Number of samples ~7			
Element	Cr	Cu	Fe	Mn	Ni	Rb	Sr	U	V	Ba	As	Pb	Zn
Cut off	300	2000	15%	7000	600	200	50	100	350	1250	200	1000	3000
N° Sites	nil	nil	nil	nil	N/A	nil	nil	nil	nil	nil	N/A	N/A	nil

13.3 Calculation of Volumes

For each of the Zones and sample intervals presented in Section 13.2, the volume of material with element values greater than the cut off threshold value has been calculated as requested in the RFT.

The volumes, have been derived by multiplying the size of the defined area by the sample interval. The areas depicted are an attempt to place as many adjacent contaminated sites in the fewest number of perimeters. With the exception of Zone 4, which is restricted to the drainage zone the perimeters drawn are uncontrolled and do not represent underlying geology or geography.

Caution should be exercised when using the volume information for anything other than indicative purposes. The volumes are independent of each other and do not represent mineable volumes. In several cases the “B” sample area is larger than the overlying “A” sample area but to extract the “B” sample material would require mining a larger “A” sample area. In the situation where the “B” (or C, D, E) sample area is larger than the overlying area the material that has to be extracted but is not contaminated can be separated for re-use.

As stated in Section 13.1 the areas and hence volumes are defined by the threshold values selected for each element. No consideration has been given to ranking the contaminated areas either by individual elements or groups of elements. As such, changing the threshold value for just one element may have a significant effect on the size and volume of the contaminated area.

In Zone 4, due to cultural sensitivities the amount and methods available for sampling were restricted. Prudence suggests that the contamination detected will be reasonably constant over similar environments and the areas depicted as contaminated have been extended to the limits of the drainage environment. In some cases this is well beyond the limit of the sampling coverage.

13.4 Recommendations

The geochemical sampling program conducted over the abandoned Rum Jungle Mine site has successfully defined the extent of contamination and allowed volumes for the material to be calculated. However, at this stage the intended future land use has not been decided and as such there is uncertainty over what constitutes contamination.

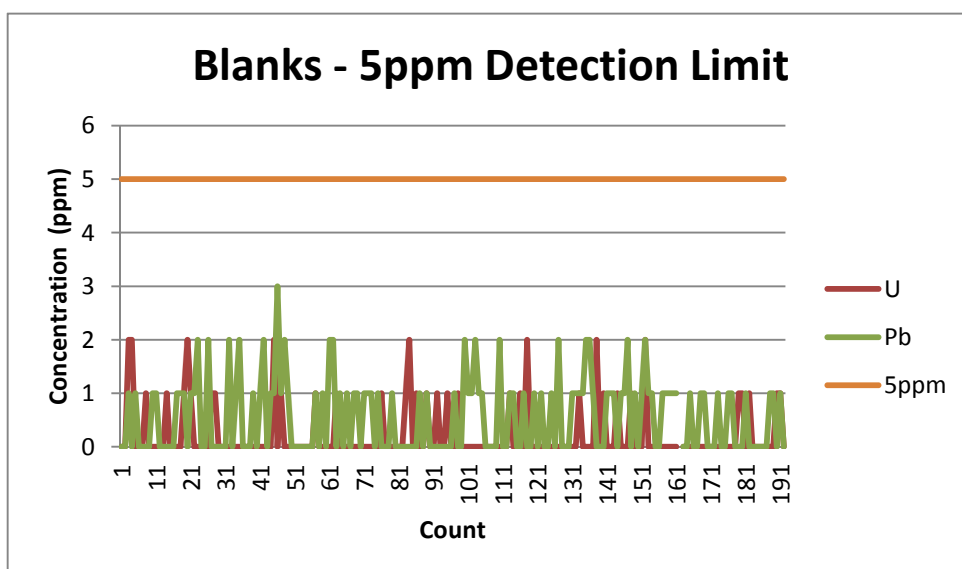
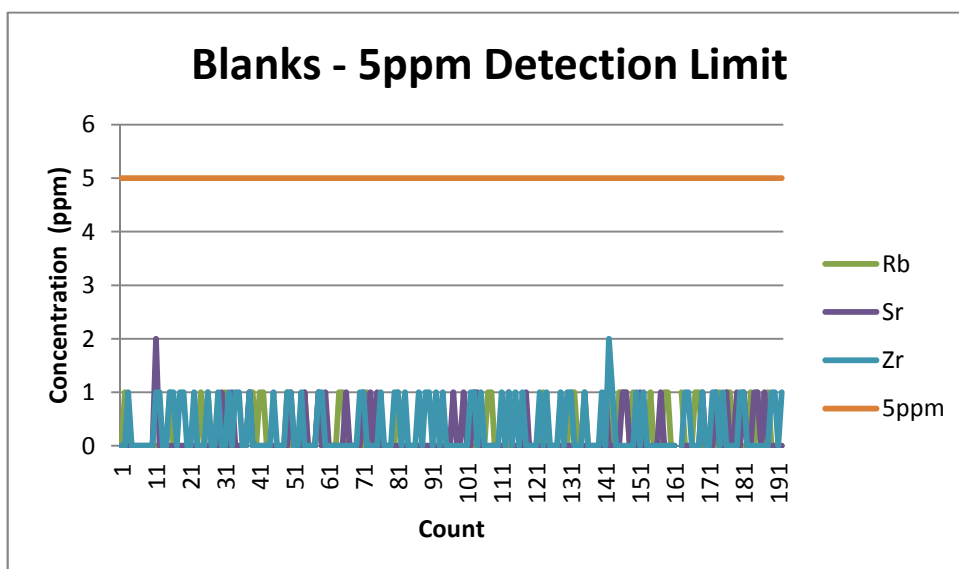
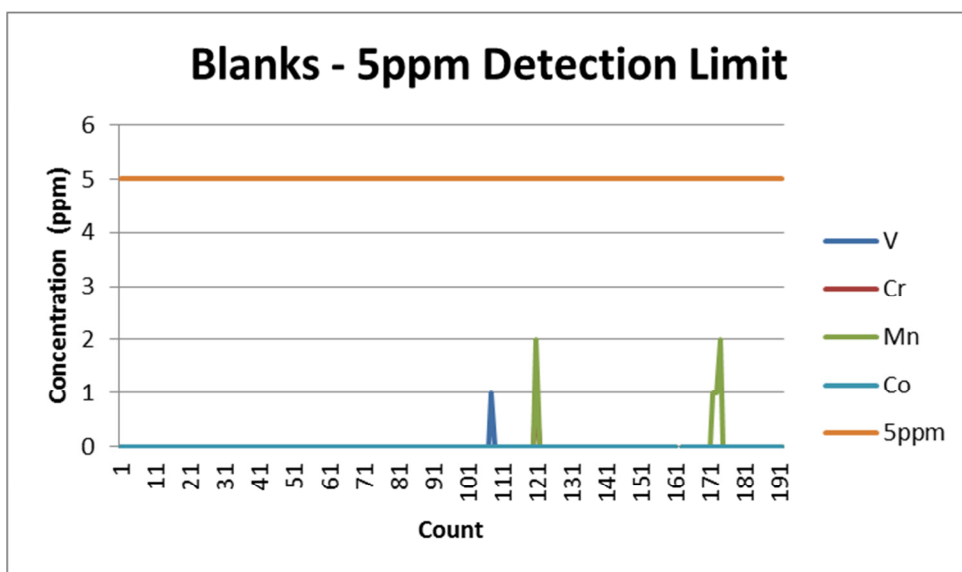
It is recommended that the appropriate stakeholders representing all of the groups that have an interest in the area convene and:

- Define the intended future land use;
- Agree on a definitive set of element thresholds;
- Determine which elements are the most important in defining contamination

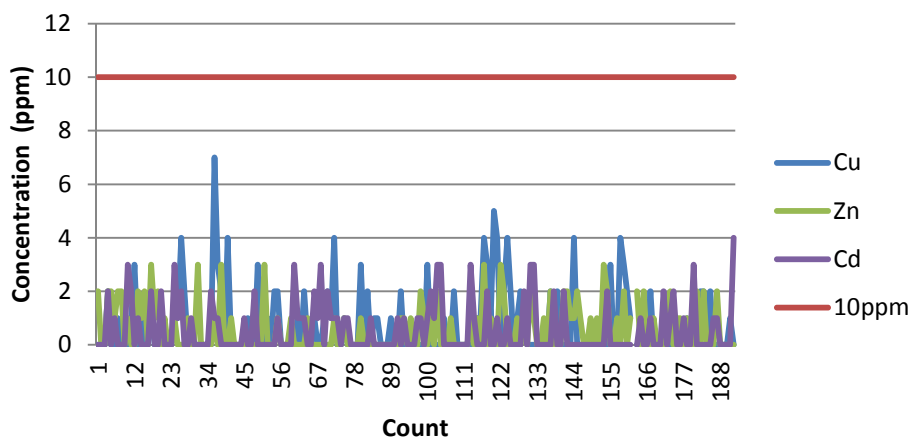
The final set of threshold levels can be used to redefine the areas and volumes of contaminated material. Combined with a remediation plan, minable volumes of material can be calculated using optimisation software designed for mine development but which could be used for this purpose.

It was also noted during the field work program that there are several isolated piles of dumped dirt and rock in Zone 1. There are also several small to large piles of old pipe, 44-gallon drums and the like. It is considered that a short site visit (2 to 3 days) examining the areas defined as contaminated in Zone 1 may reveal discrete sources of contaminants. If discrete sources of contaminants are located the scope of remediation options can be expanded to include removal of the contaminant source without excavating.

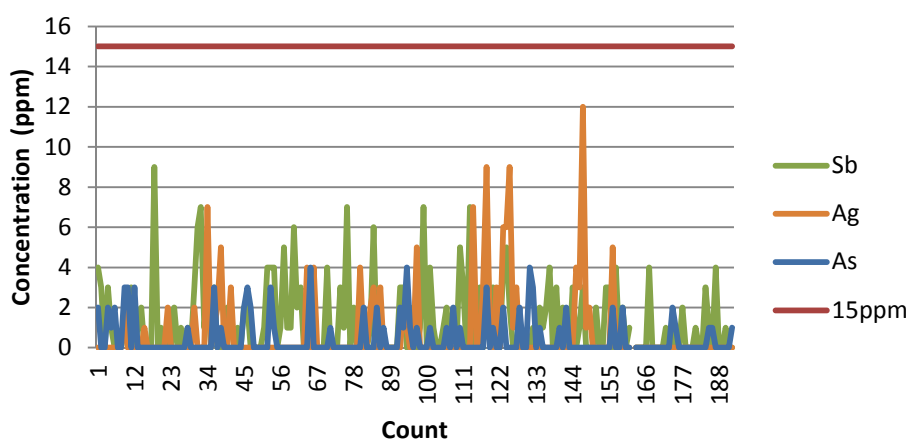
Appendix 1. Blanks – First Round



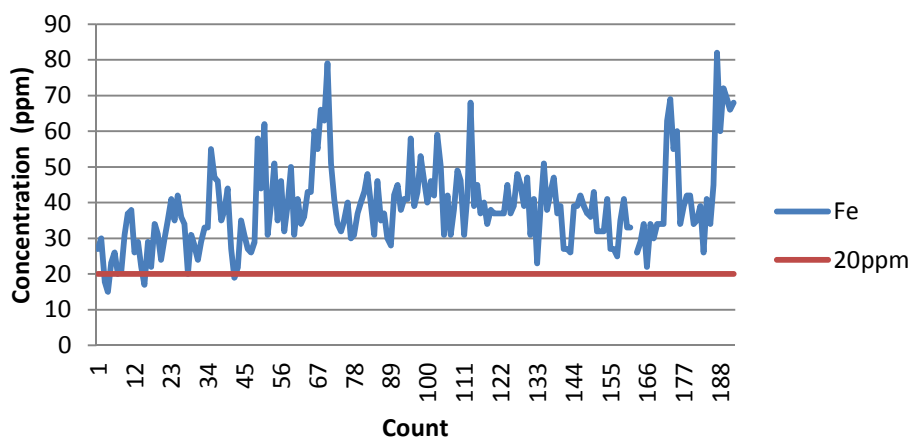
Blanks - 10ppm Detection Limit



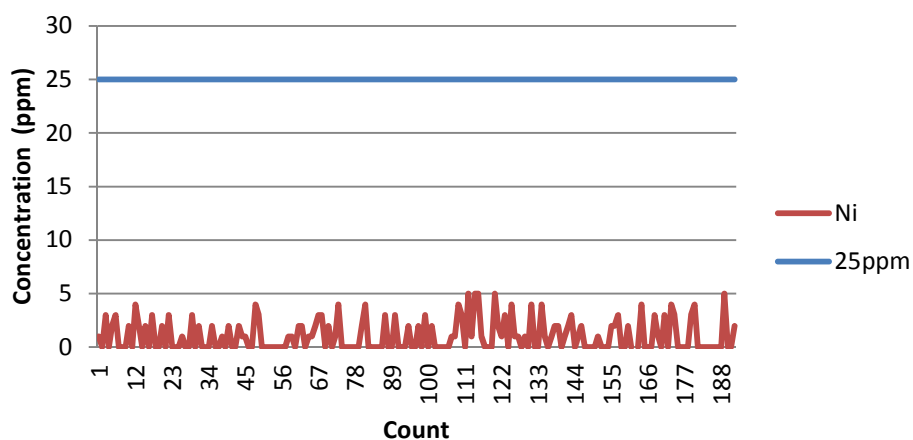
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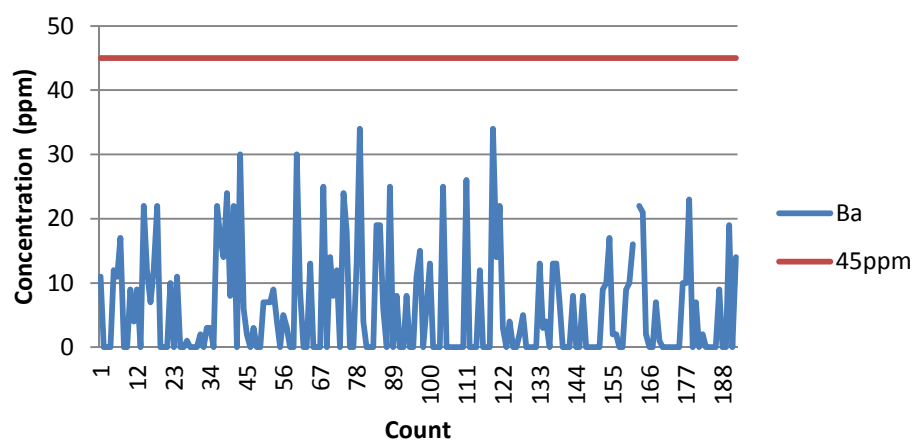
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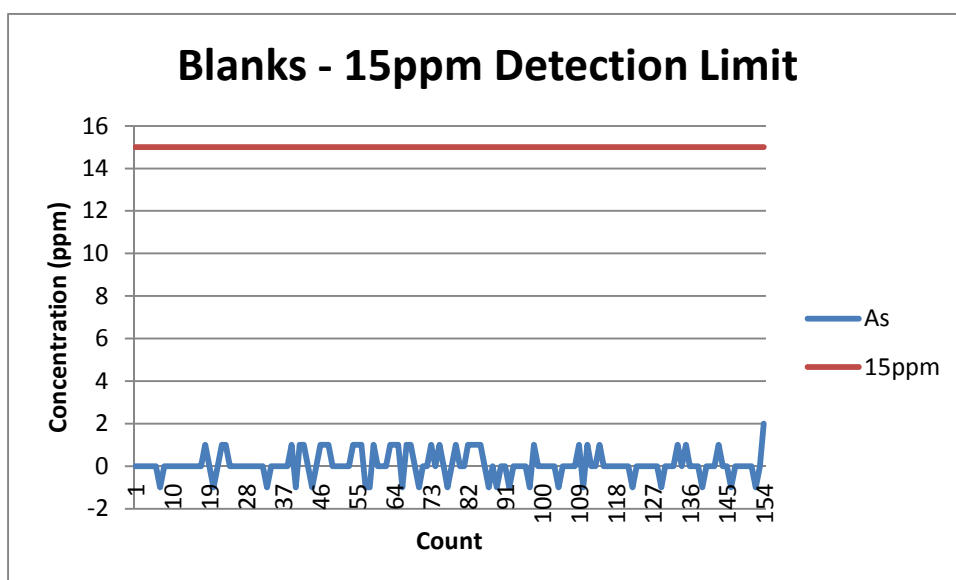
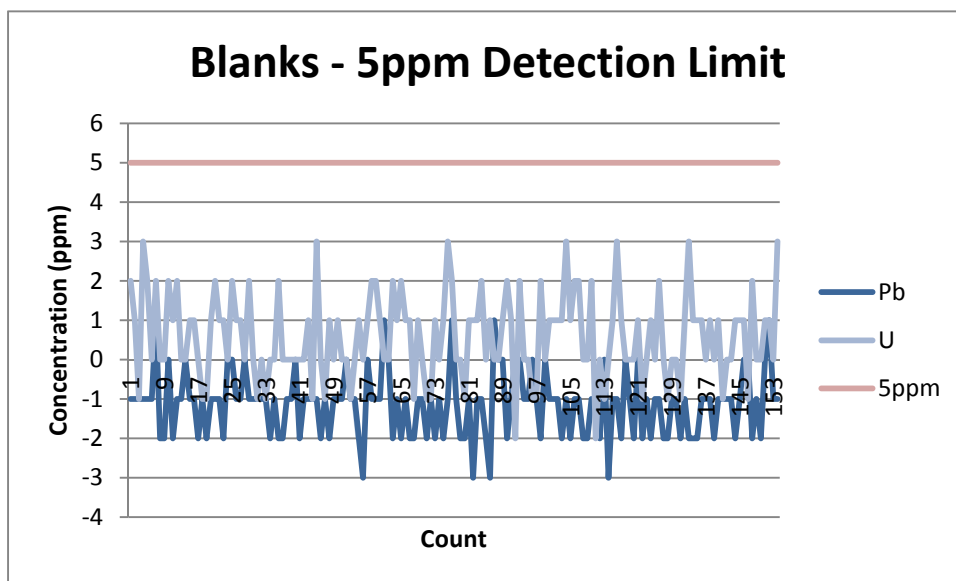
Blanks - 25ppm Detection Limit

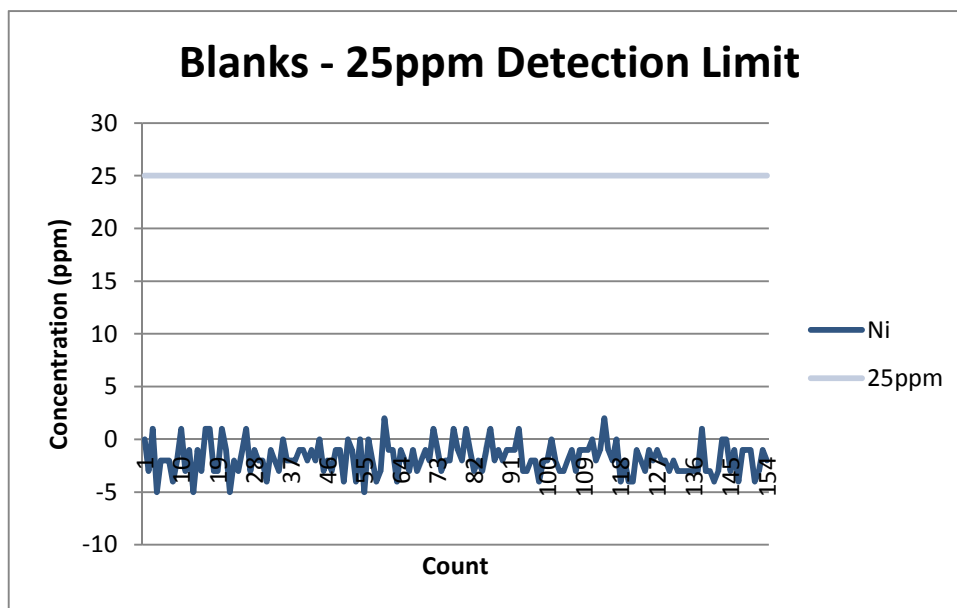


Blanks - 45ppm Detection Limit



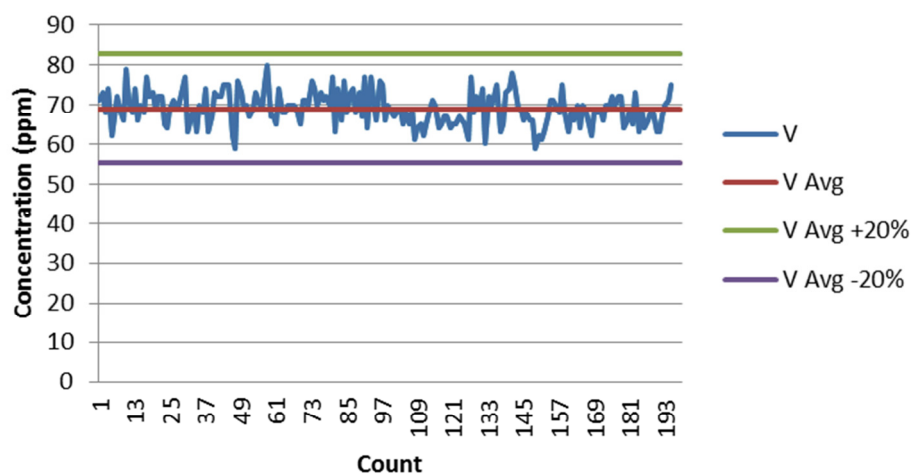
Appendix 2. Blanks – Second Round



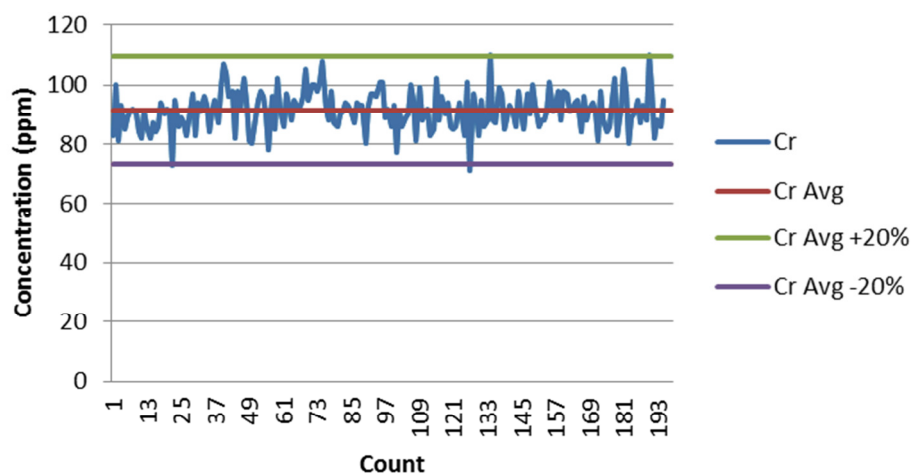


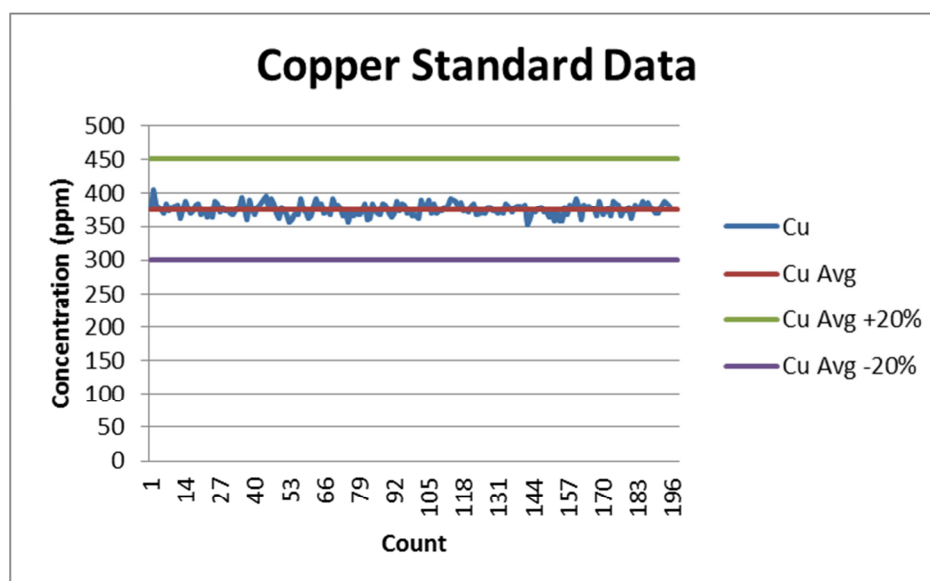
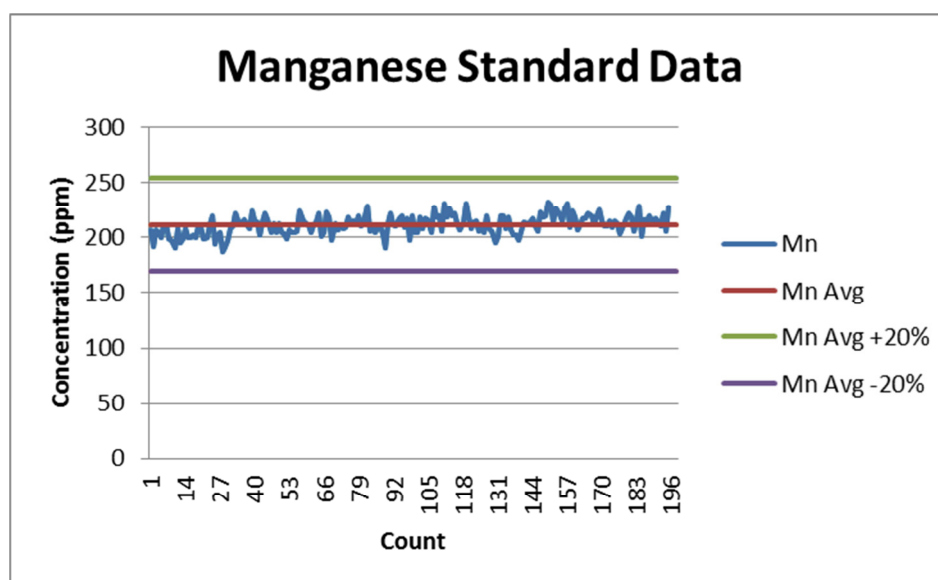
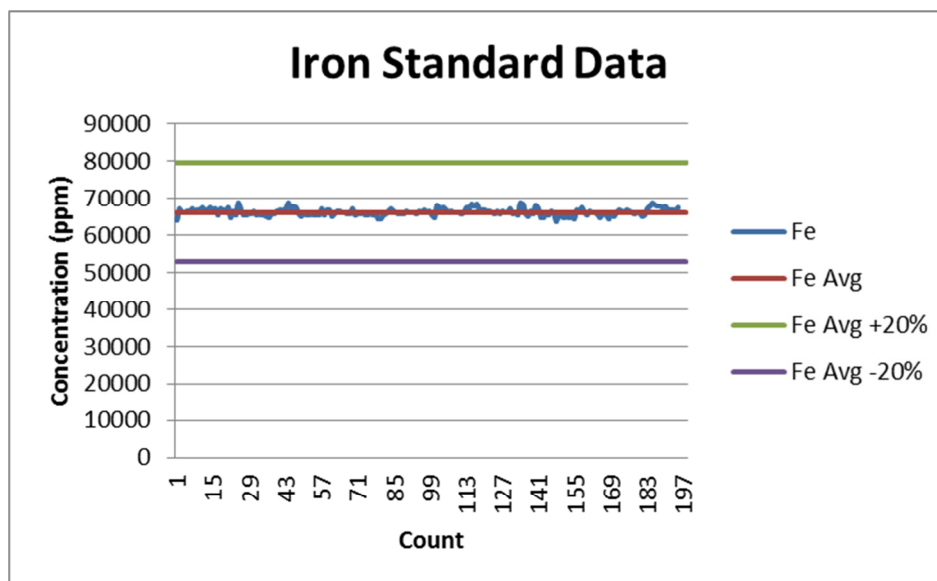
Appendix 3. SSCS Testing – First round

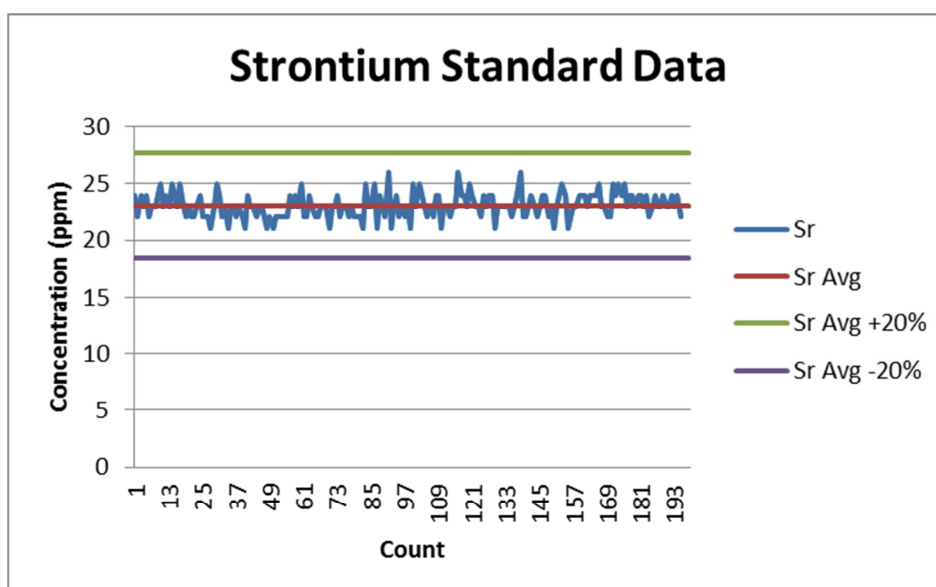
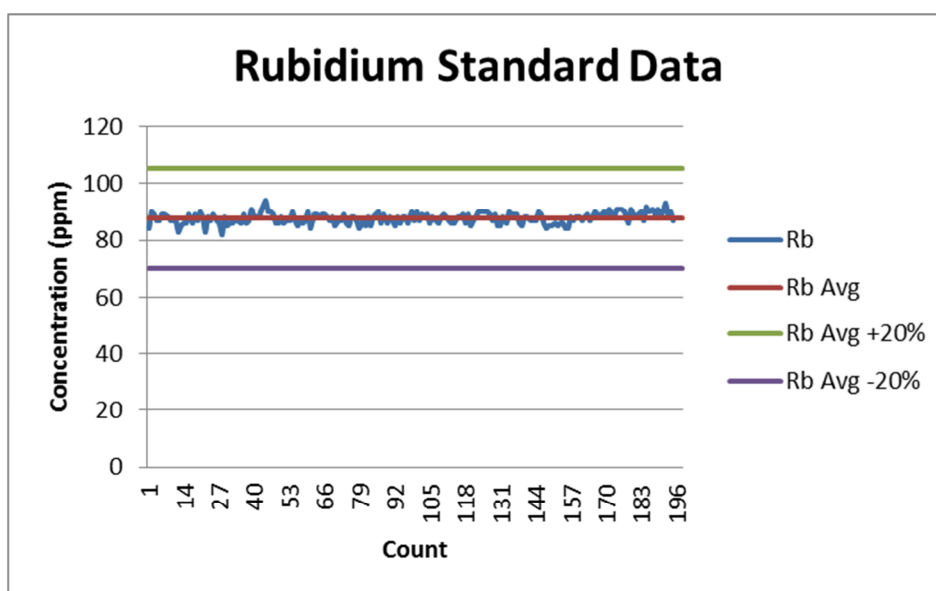
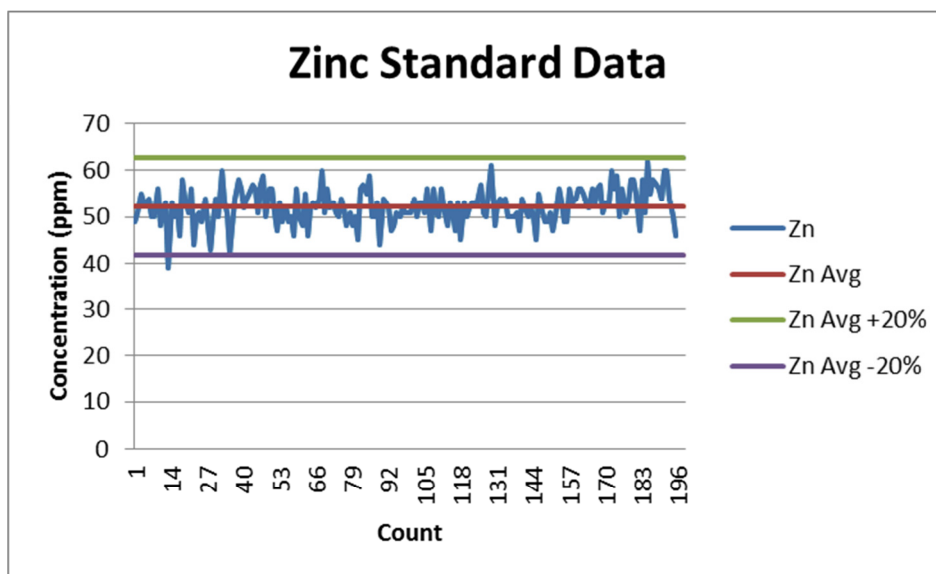
Vanadium Standard Data



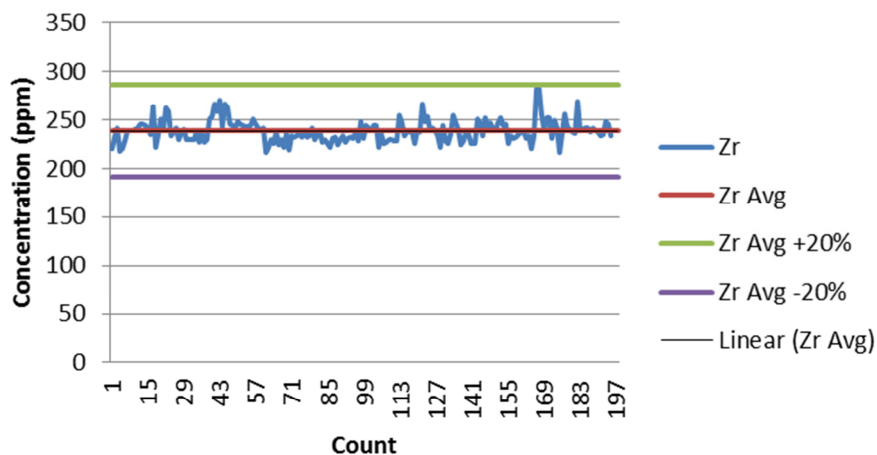
Chromium Standard Data



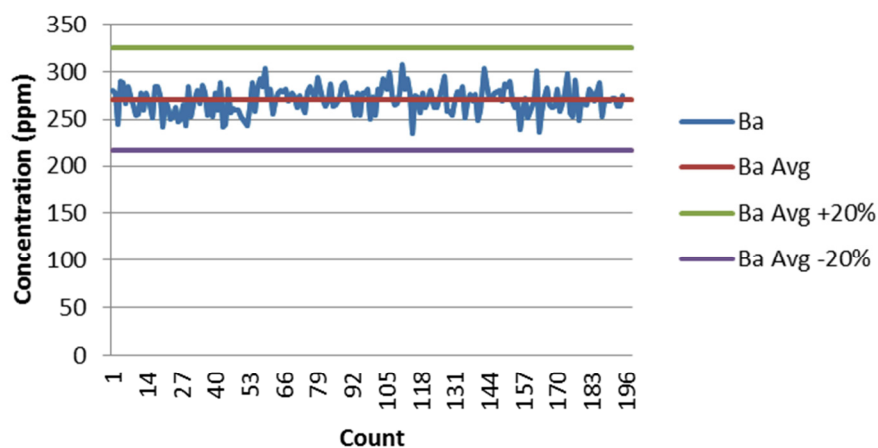




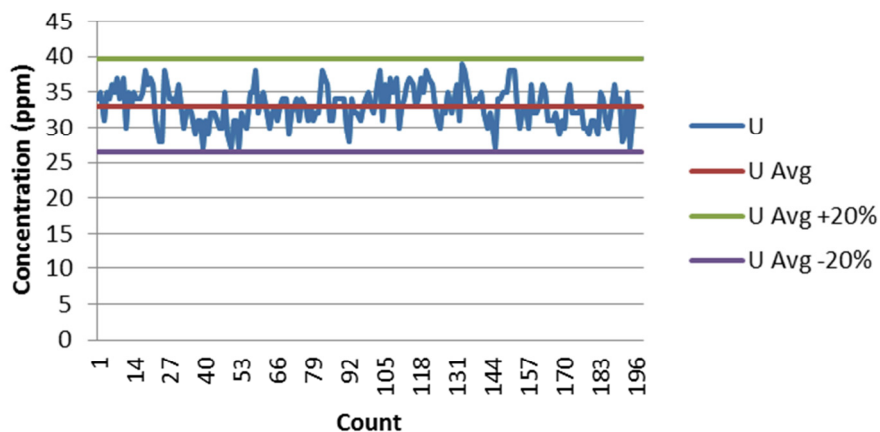
Zirconium Standard Data

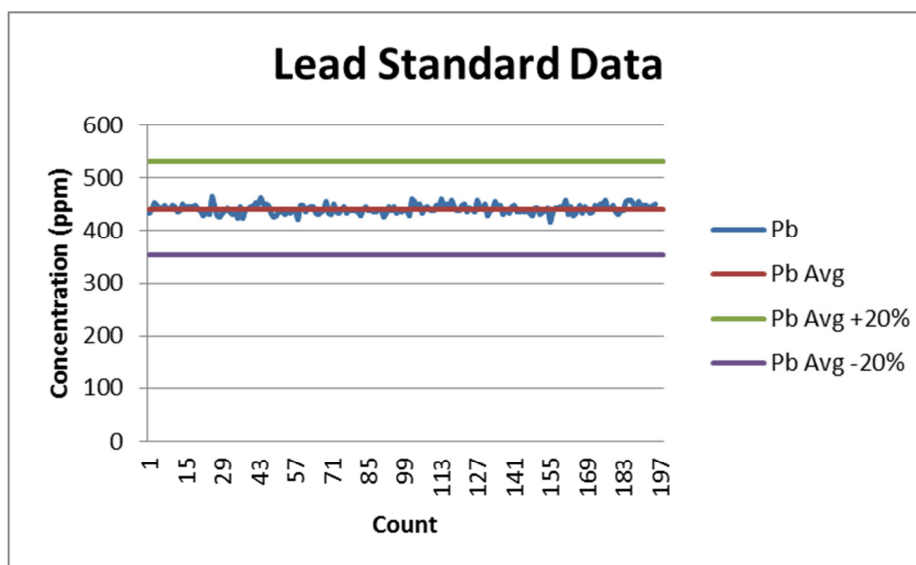


Barium Standard Data

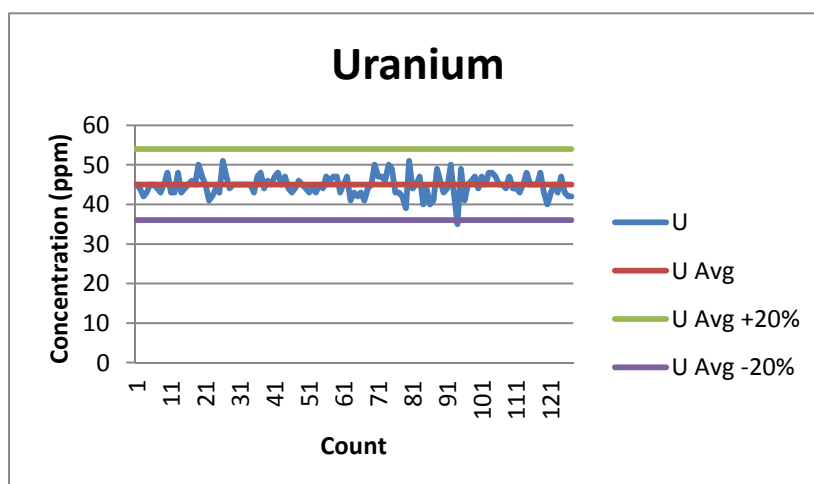
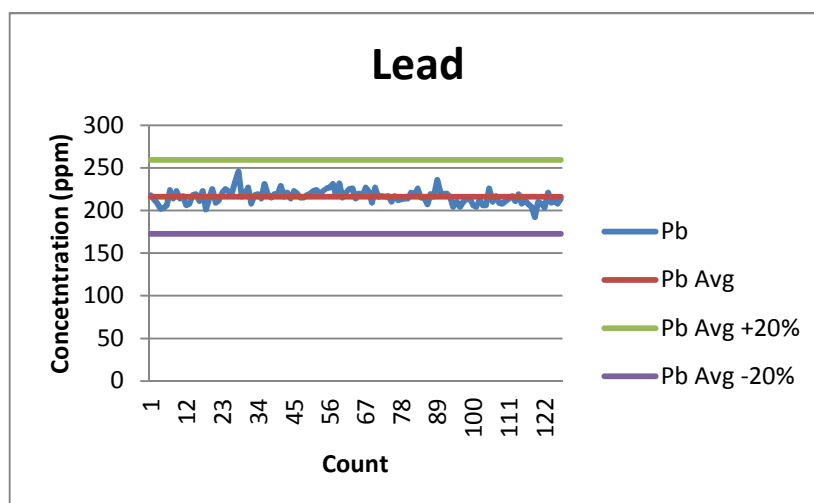
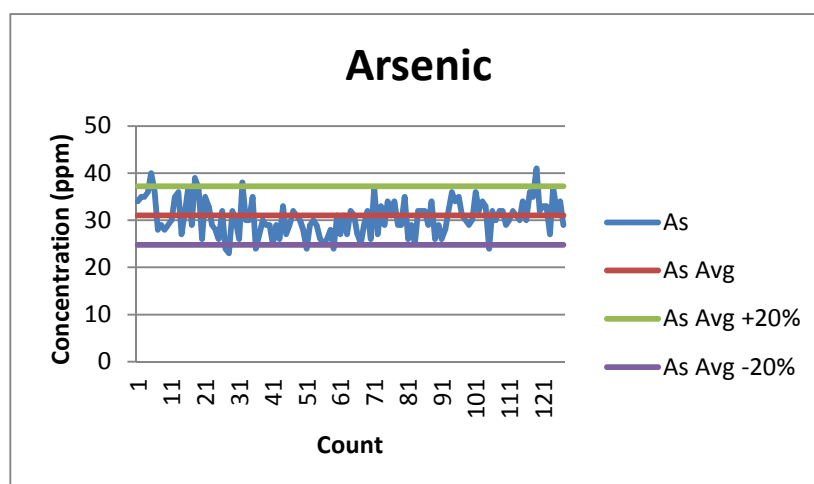


Uranium Standard Data

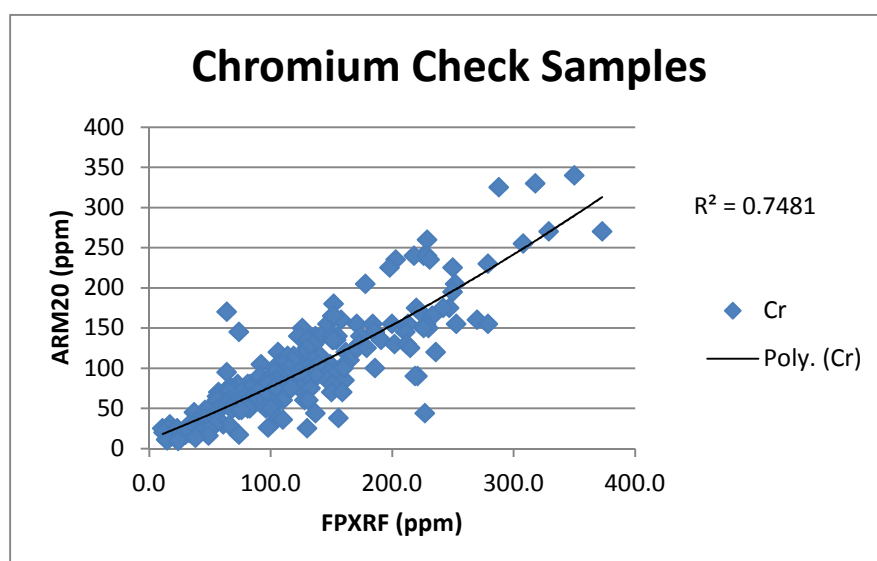
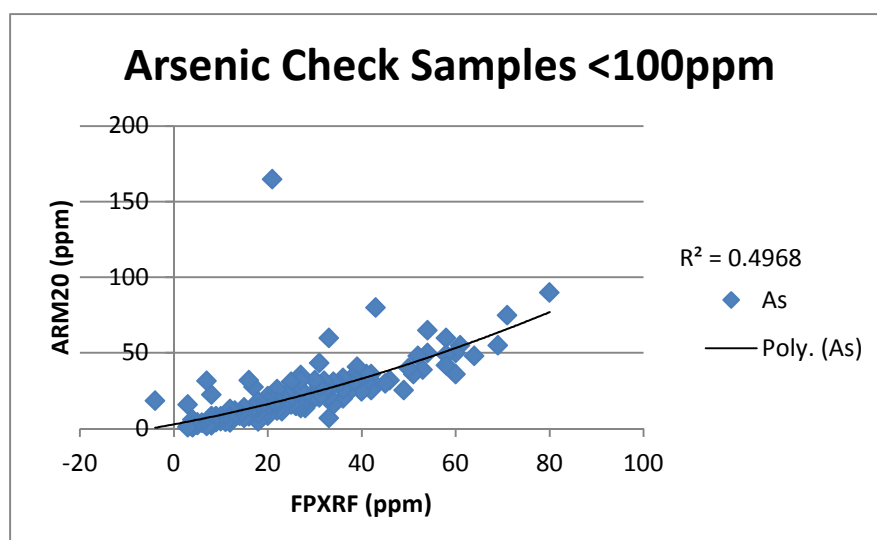
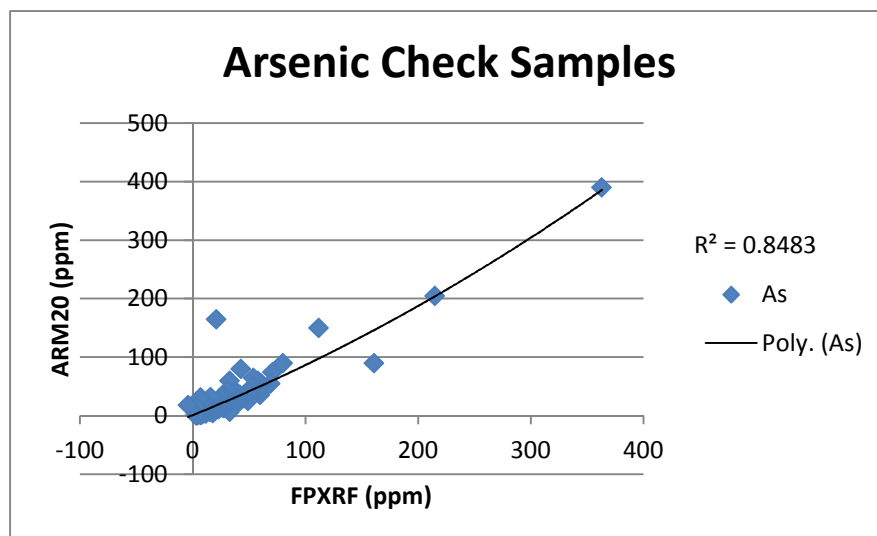




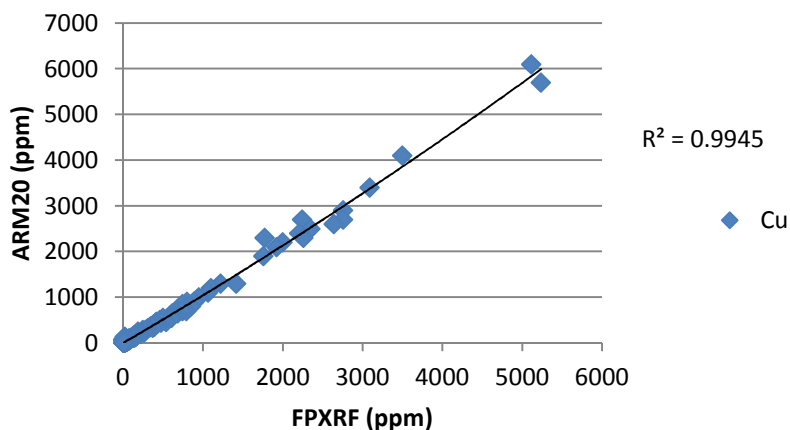
Appendix 4. SSCS Testing – Second Round



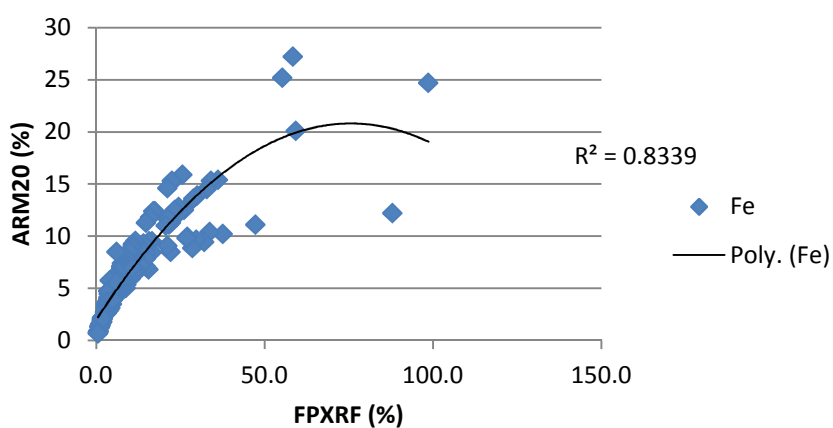
Appendix 5. Check Samples



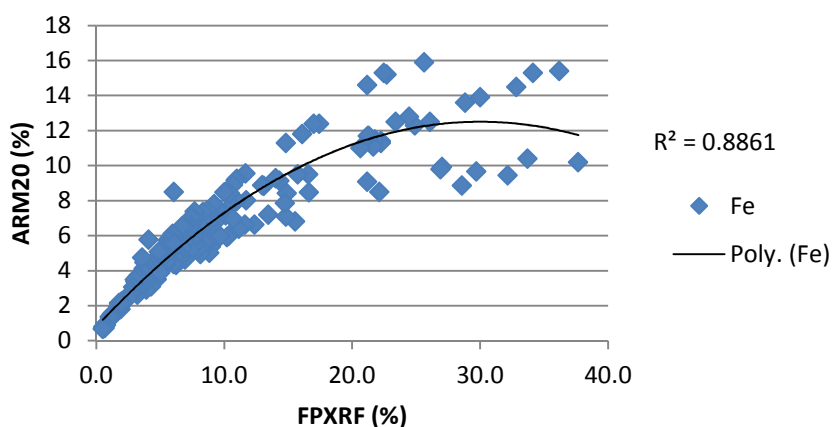
Copper Check Samples

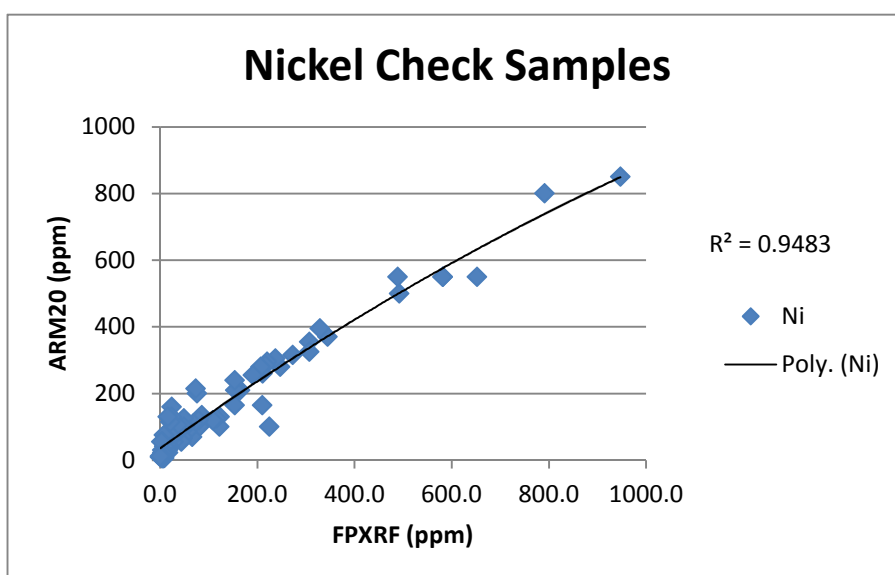
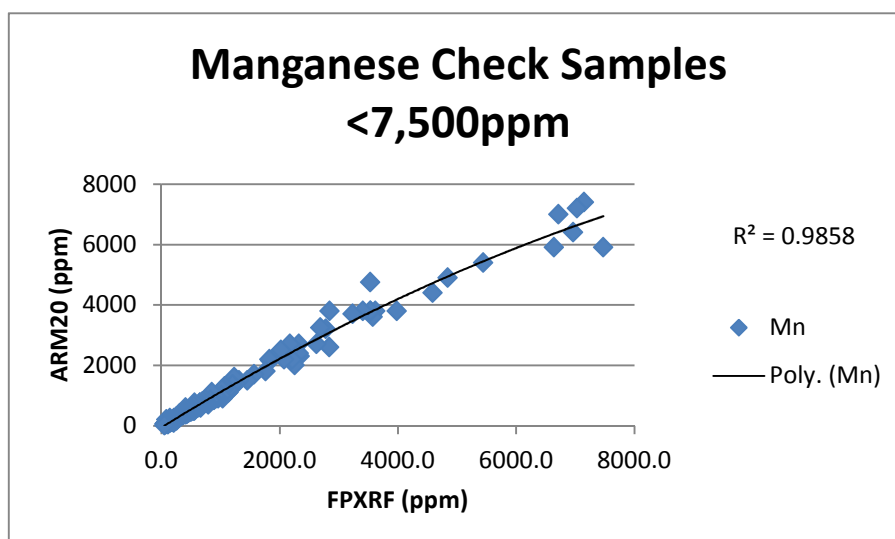
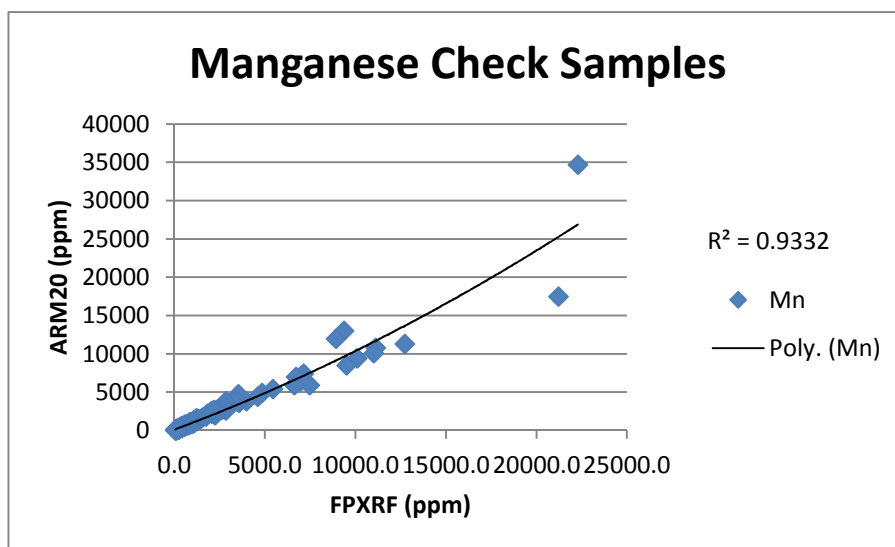


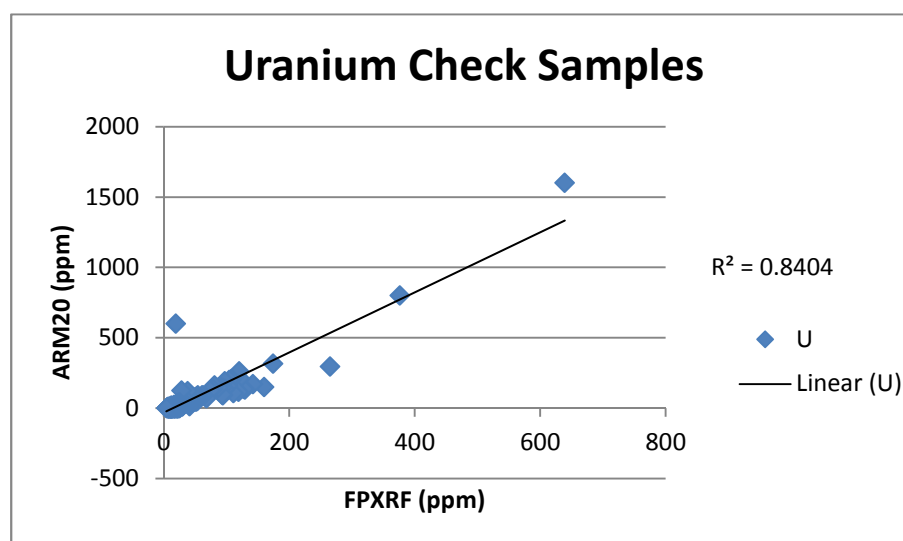
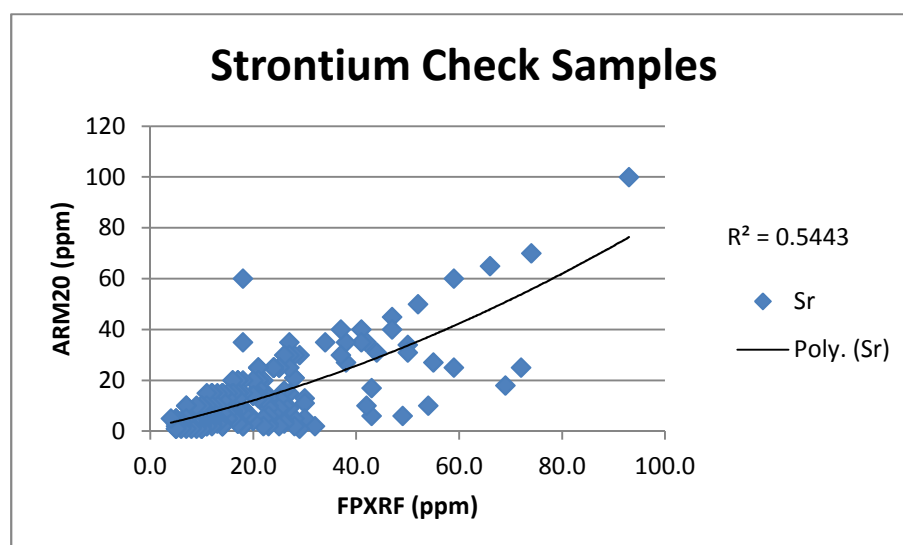
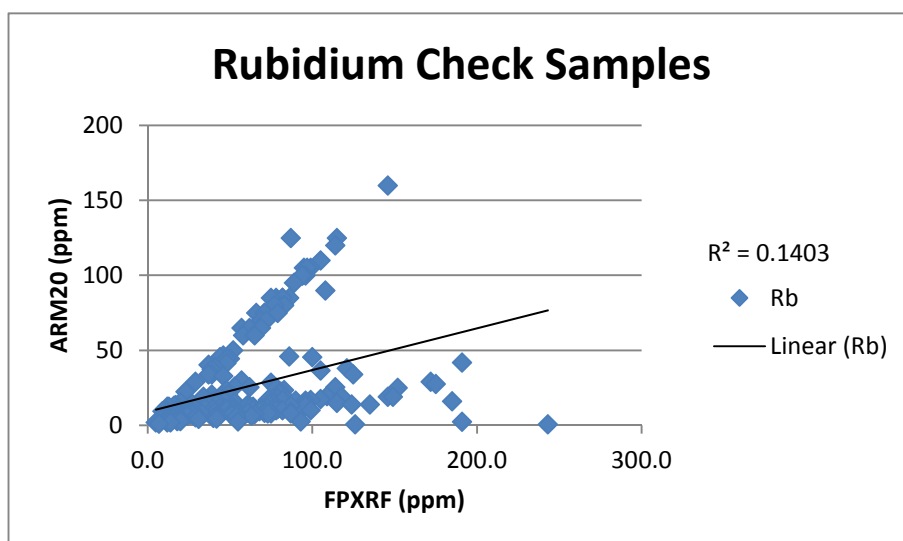
Iron Check Samples



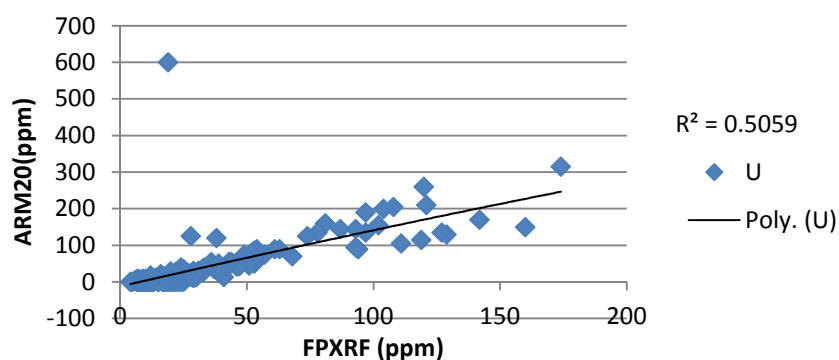
Iron Check Samples <40%



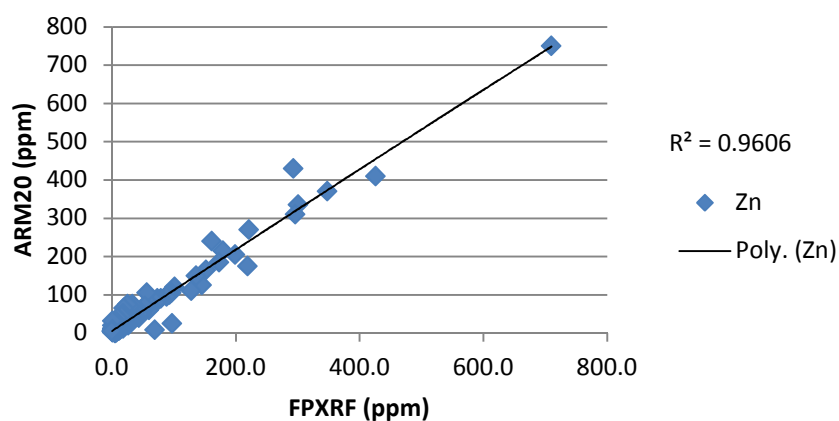




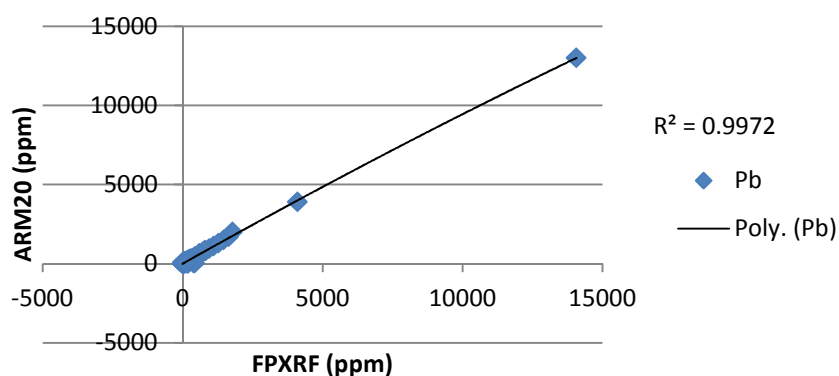
Uranium Check Samples <200ppm

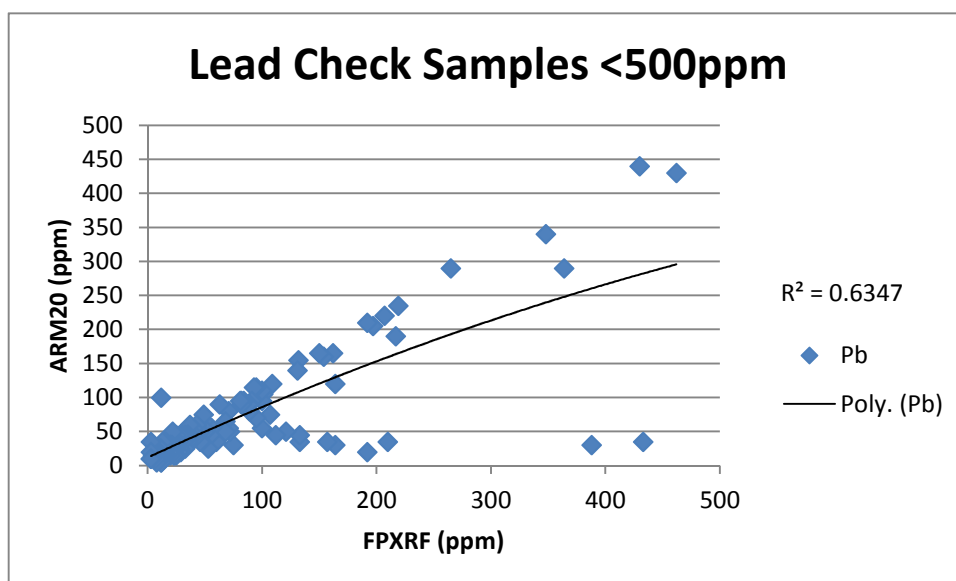


Zinc Check Samples



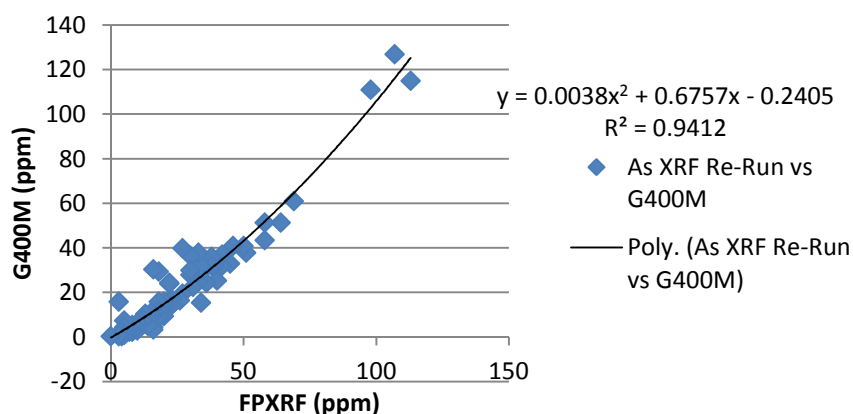
Lead Check Samples



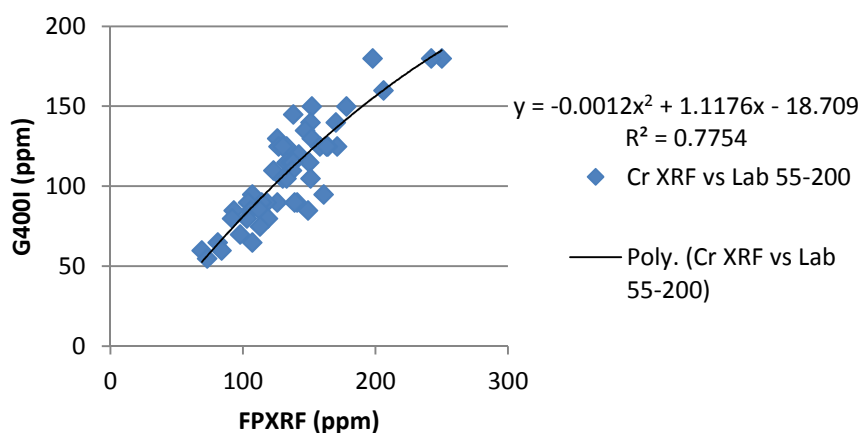


Appendix 6. Calibration Graphs

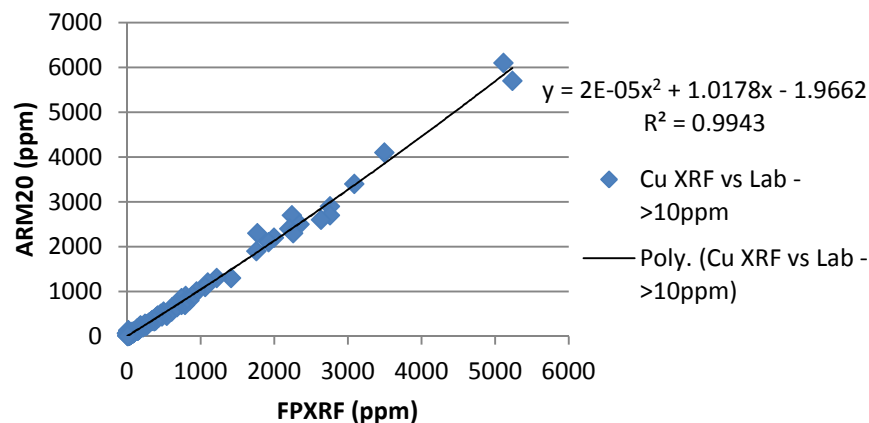
Arsenic Correction Graph



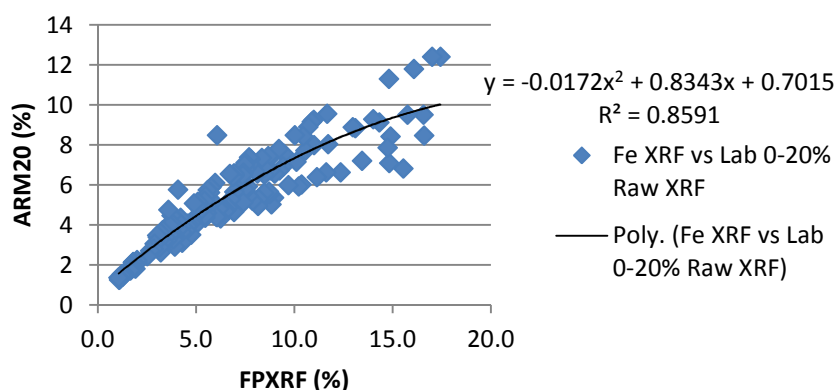
Chromium Correction Graph



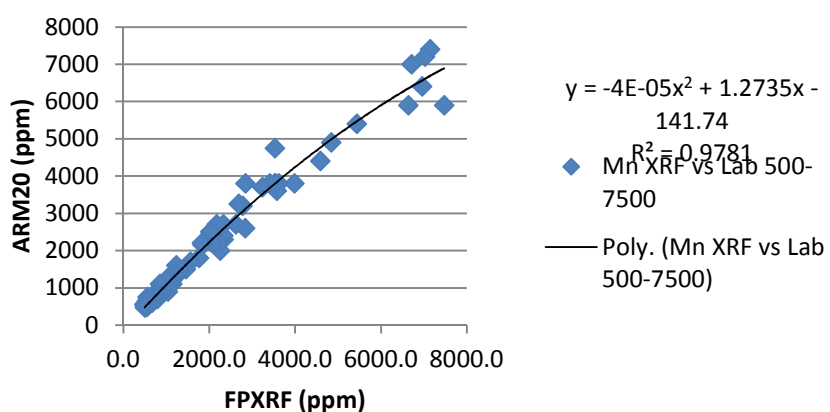
Copper Correction Graph



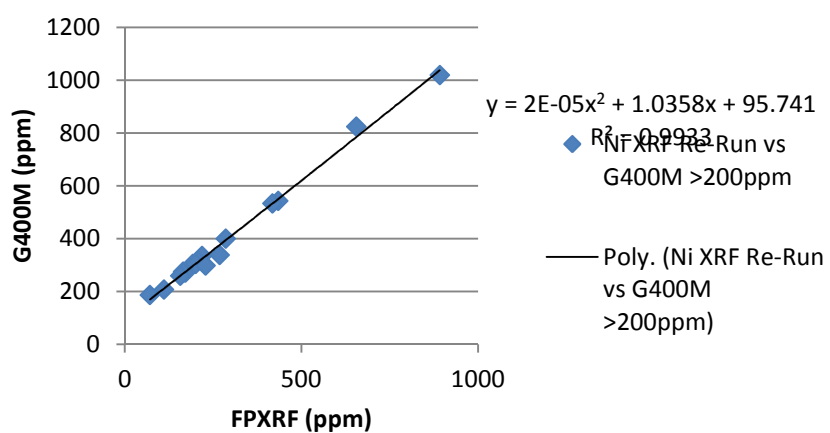
Iron Correction Graph



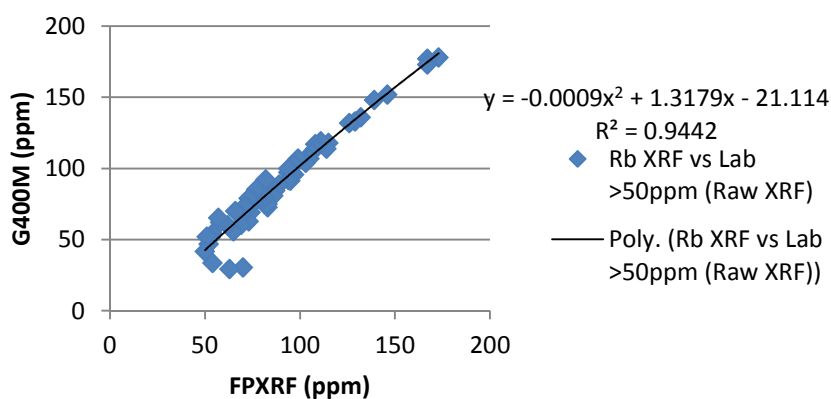
Manganese Correction Graph



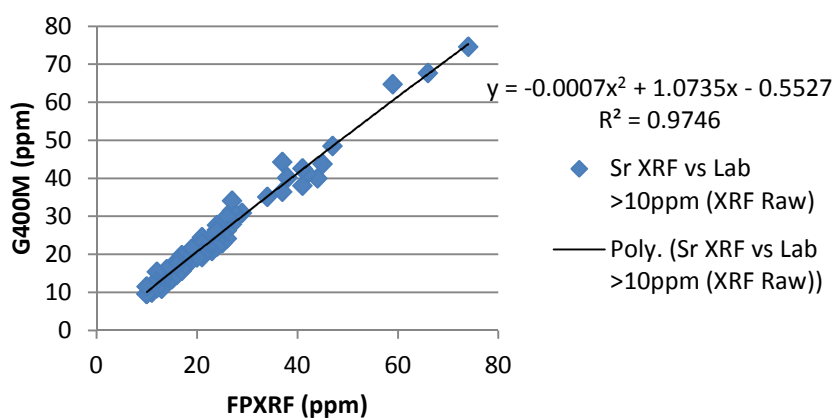
Nickel Correction Graph



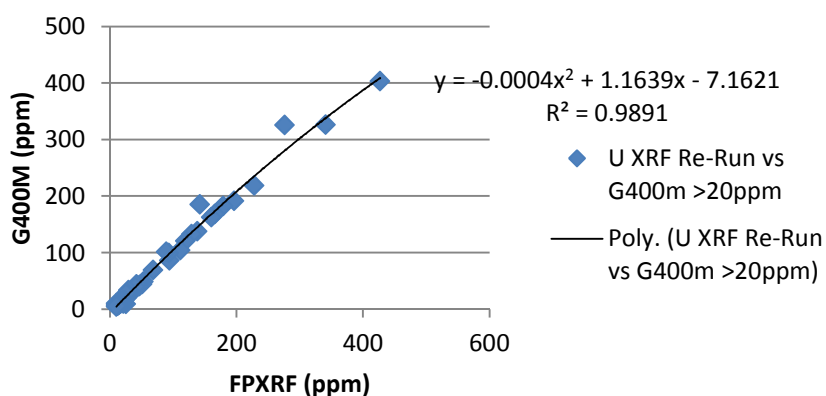
Rubidium Correction Graph



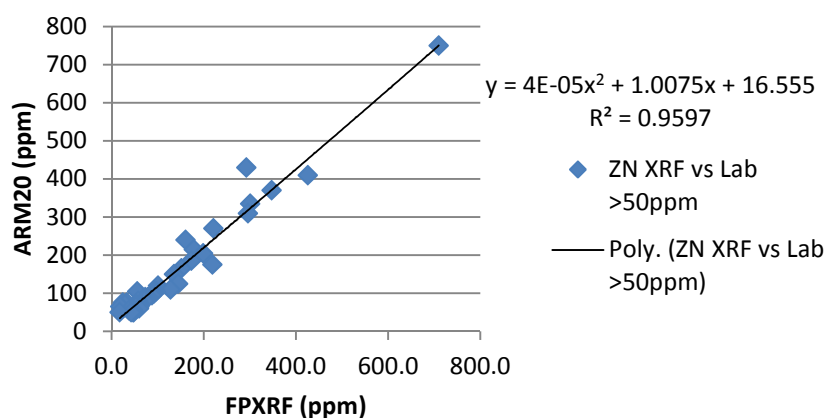
Strontium Correction Graph



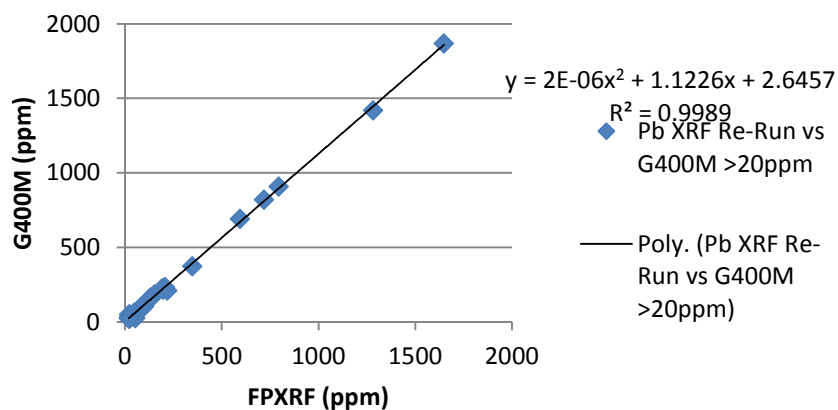
Uranium Correction Graph



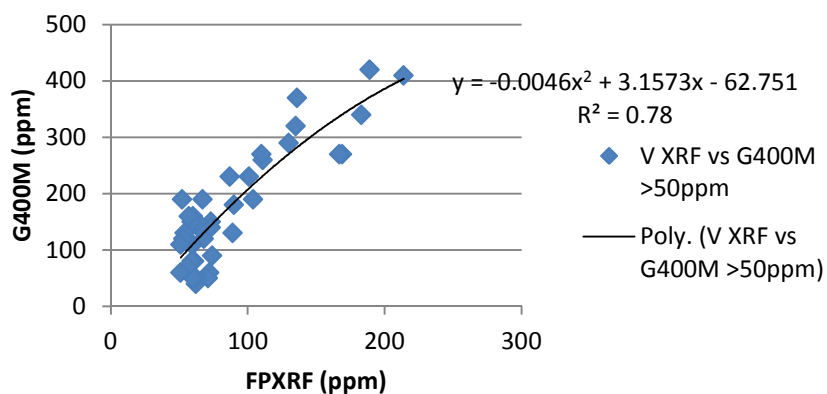
Zinc Correction Graph

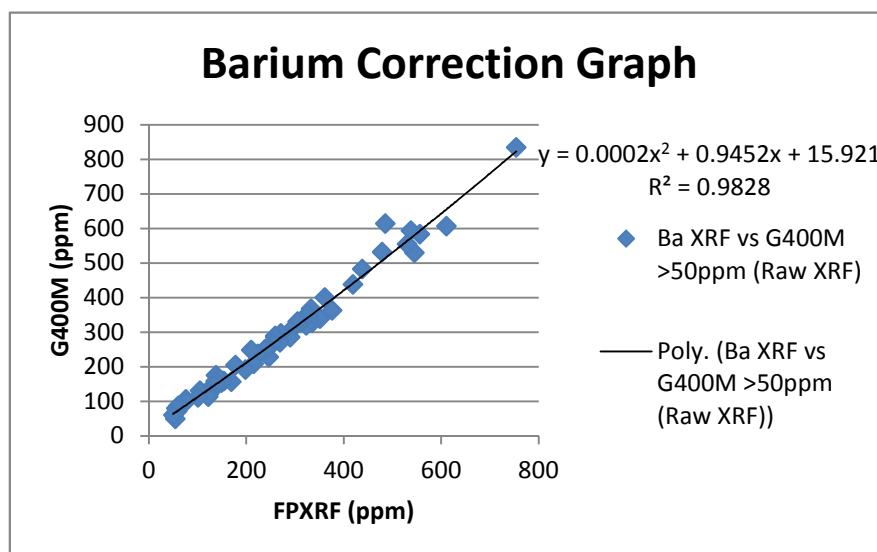


Lead Correction Graph



Vanadium Correction Graph





Appendix 7. Field sheets

Field sheets – Delivered as hard copies to the NT Department of Resources marked

Field sheets for Contract Number D10-0355 - Provision of Detailed Soil and Fluvial Contamination Assessment at the Rum Jungle Mine Site in the Batchelor Region of the Northern Territory

Appendix 8. Chain-of-Custody forms

**Chain of Custody Forms – Delivered as hard copies to the NT Department of
Resources marked**

Chain of Custody Forms for Contract Number D10-0355 - Provision of Detailed Soil and
Fluvial Contamination Assessment at the Rum Jungle Mine Site in the Batchelor Region of
the Northern Territory

Appendix 9. A1 map plans at a scale of 1:5,000

**A1 Map Plans – Delivered as digital copies to the NT Department of Resources
marked**

A1 Map Plans for Contract Number D10-0355 Rum Jungle Mine Site

Appendix 10. Digestion & Analytical Methods

The following Digestion and Analytical methods were used by Amdel to produce the analytical results.

ICP, 4 acid digest

IC4E A 0.1 g subsample of the analytical pulp is fused with lithium metaborate followed by dissolution to give a “total solution”. The solution is presented to an ICPOES for the determination of elements of interest.

Cr (20 ppm) Fe (0.01 %) Mn (0.005 %)

IC4M A 0.1 g subsample of the analytical pulp is fused with lithium metaborate followed by dissolution to give a “total solution”. The solution is presented to an ICPMS for the determination of elements of interest.

Rb (0.5 ppm) Sr (5 ppm) U (0.5 ppm) Zr (2 ppm)

IC3E A subsample of up to 0.2 g of the analytical pulp is digested using an HF/multi acid digest and the solution is presented to an ICPOES for the quantification of the elements of interest. Range is to 1%.

Ag (1 ppm) As (3 ppm) Co (2 ppm) Cu (2 ppm)

Ni (2 ppm) Sb (5 ppm) Zn (2 ppm)

AA6 A 0.75 g sample is digested using a mixture of nitric and hydrochloric acid. The resulting solution is bulked to volume with water and quantified by cold vapour AAS. Range to 20 ppm.

Hg (0.05 ppm)

ARM 20

A subsample of 20g is digested using a mixture of nitric and hydrochloric acid. The resultant solution is bulked to volume with water and quantified using ICPMS.

ICPMS Elements

Ag (0.05 ppm) As (0.5 ppm) Co (0.2 ppm) Cu (0.5 ppm)

Ni (1 ppm) Rb (0.1 ppm) Sb (0.1 ppm) Sr (1 ppm)

U (0.05 ppm) Zn (0.5 ppm) Zr (0.5 ppm)

ICP-OES Elements

Cr (10 ppm) Fe (100 ppm) Mn (10 ppm)

AA6 A 0.75 g sample is digested using a mixture of nitric and hydrochloric acid. The resulting solution is bulked to volume with water and quantified by cold vapour AAS. Range to 20 ppm. Hg (0.05 ppm)