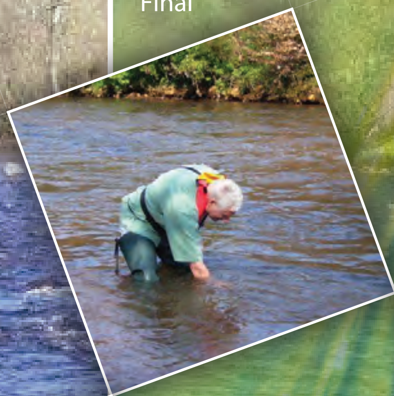
Department of Communications, Energy & Natural Resources

Environmental Monitoring Services at the Former Mining Areas of Silvermines (Co. Tipperary) and Avoca (Co. Wicklow)

Silvermines Monitoring Report - Round 1 (2013)

Final



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Section 1

Introduction

1.1 Objectives and Scope

The Department of Communications, Energy and Natural Resources (the Department) appointed CDM Smith Ireland Ltd (CDM Smith) to undertake a programme of environmental monitoring at the closed mine sites of Silvermines and Avoca for a three year period, commencing 2013.

The scope of the field investigation activities was defined in the Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan, (Document Ref: 95735/40/DG01, dated 26 February 2013) and sampling activities were performed in accordance with the programme and procedures set out therein.

The Monitoring Report for the Silvermines Mining Area presents an evaluation of the results of the field investigations carried out in March-April 2013. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG04, dated 2 May 2013) which contains all field observations and laboratory analytical results collected during the monitoring programme.

1.2 Background of Silvermines Mining Area

The Silvermines mining area is located in the northern foothills of the Silvermine Mountains in Co. Tipperary. The area has been mined intermittently for over one thousand years for a range of commodities including lead, zinc, copper, silver, barite and sulphur. The mining sites include Ballygown (BG), Garryard (GA), Gorteenadiha, Magcobar (MA) and Shallee South (ShS) /East (ShE), and cover an area of approximately 2,300 ha as shown on Map 1 in **Appendix A**. The last working mine, a barite operation at Magcobar, closed in 1993. Just over a decade previously, the final base metal mine shut down, following the cessation of underground operations by Mogul Mines Ltd. (Mogul) at Garryard. The latter operation resulted in the generation of significant volumes of fine to coarse grained sand particles referred to as tailings. Approximately 8 Mt of such tailings were deposited in a specially constructed, 60 ha tailings management facility (TMF) at Gortmore (GM). Rehabilitation works have been completed at various localities including Gortmore TMF, with the site work administered by North Tipperary County Council on behalf of the Department. To date this rehabilitation work has included:

- Capping poorly and non-vegetated areas of the TMF surface, covering approximately 24ha, with a range of materials (Geogrid/geotextile, crushed calcareous rock and blinding layers and a seeded, growth medium);
- Establishing a vigorous grass sward on the capped areas of the TMF to minimise the risk of future dust blow events;
- Various engineering works on the TMF (e.g., improvements to the surface water drainage system, construction of rockfill buttresses to lessen the slopes of the TMF sidewalls, etc.);
- Remedial works to the TMF’s retention ponds and wetlands, so as to improve the quality of waters discharging into adjoining watercourses;

- Fencing and/or capping of old mine shafts and adits at Ballygown, Garryard and Shallee;
- Drainage improvement works at Ballygown, Gorteenadiha and Shallee; and
- Filling an open pit at Ballygown and re-vegetating the pit area.

1.3 Catchment Description

The area is located in the northern foothills of the Silvermine Mountains, Co. Tipperary as shown on Map 1 in **Appendix A**. The Kilmastulla River is the main river which rises in the Silvermine Mountains just south of Silvermines Village (called the Silvermines River) and flows north through the Ballygown mining area. The river then flows west towards the Gortmore TMF which is located to the north of the river. The river is located northwest of the other main areas of previous mining activity including Shallee, Garryard and Magcobar. Streams from Shallee and Garryard drain into the Yellow Bridge River which discharges to the Kilmastulla River at the south-eastern corner of Gortmore TMF.

Ballygown has been extensively worked both on the surface and underground. Most of the many shafts sunk in the area are collapsed or backfilled but a drainage adit that links them continues to discharge mine water into the Silvermines Stream north of the village.

Magcobar mine was the last active mine in the district. Open-pit mining was followed by limited underground mining developed from the base of the pit. Streams draining Silvermines Mountain have been diverted around the open pit using drainage channels which are still operational. SW6-Mag is the sampling point on Foilborrig Stream which has been diverted around the pit.

Garryard is located on both sides of the main road R499. To the south of the road is the old ore stockpile area, whilst north of the road, the site is split by a railway. Knight Shaft was the main mine access and is now covered by a concrete cap. An overflow pipe in the cap discharges mine water, typically after heavy rainfall, which flows north under the railway to the tailings lagoon. The tailings lagoon also receives run-off from the yard. Both the water and the tailings in this lagoon contain high concentrations of mine-related metals such as lead, zinc, arsenic and cadmium. The two settlement ponds south of the railway receive surface runoff from the Garryard plant area, which can also have high metal concentrations. Ponds and the tailings lagoon ultimately drain into the Yellow Bridge River, 1km downstream of the site. Surface run-off from the stockpile area south of the main road enters a drain that runs westwards, parallel to the road, before crossing under the road to enter farmland.

Shallee has been extensively worked both on the surface and underground. A cut-off drain is located upslope of the surface working and drum dump which collects and diverts runoff from Silvermine Mountain; however, the mine does act as a drain for rain water and the open pit and underground workings are partially flooded. Near the southernmost tailings dump, a spring is present in an old streambed that is thought to be fed by water from the underground workings. This then passes under the main R499 road via a culvert and flows along the western boundary of the north tailings impoundment to join the Yellow Bridge River.

Gortmore TMF is some 60ha in area with surface elevations ranging from about 54.0m to 56.5m. The tailings were pumped as a slurry through a pipe from Garryard and deposited in lagoons on the surface of the impoundment. When production at the Garryard plant ceased, the tailings impoundment was closed and the pipeline removed. Various works have been carried out to rehabilitate the impoundment, and most of the surface is now vegetated with grass and moss. Some areas have exposed tailings, with some ponded water. Typical existing ground elevations outside the perimeter of the dam range from about 48 to 50m. Excess water drains via a decant system to ponds which overflow into the Kilmastulla River. A number of constructed wetlands are also present at various locations near the toe of the dam.

1.4 Geology and Hydrogeology

1.4.1 Geology

The geology of the Silvermines district comprises Silurian and Devonian sedimentary rocks (greywackes, pebble conglomerates, sandstones and siltstones) which are overlain by Lower Carboniferous transgressive siliciclastics and carbonates. The local geology of the area is dominated by a complex structure known collectively as the Silvermines Fault. The fault zone trends broadly eastnortheast but includes westnorthwest-striking components. The fault has downthrown the younger Carboniferous strata against the older Silurian and Devonian clastic sequences. Mineralization occurs in fracture zones and as stratabound zones within brecciated and dolomitized Waulsortian reef limestone.

1.4.2 Hydrogeology

The bedrock is overlain by subsoils derived from Devonian Sandstone Till (TDSs). Subsoils are thin (<2 metres) or absent on hilltops and thicker (>2 metres) along valley floors. The Gortmore area is underlain by alluvial sediments along the Kilmastulla River valley. Similarly the groundwater vulnerability ranges from Extreme in the upland areas to Moderate in low-lying areas.

In terms of groundwater yield, the Geological Survey of Ireland (GSI) classifies the bedrock in the Silvermines area as poorly productive: Ll (Locally Important Bedrock Aquifer, Moderately Productive only in Local Zones) and Lm (Locally Important Bedrock Aquifer, Generally Moderately Productive). A locally important (Lg) gravel aquifer overlies the bedrock aquifers in the valley north of the Silvermine Mountain where gravels have accumulated.

Ll is the predominant aquifer type: a relatively poorly connected network of fractures, fissures and joints exists, giving a low fissure permeability which tends to decrease further with depth. A shallow zone of higher permeability is likely to exist within the top few metres of more fractured/weathered rock, and higher permeability may also occur along fault zones. In general, the lack of connection between the limited fissures results in relatively poor aquifer storage and flow paths that may only extend a few hundred metres. Artesian and upward vertical flows are present in the Garryard area and the Gortmore TMF area as indicated by recorded groundwater levels.

Section 2
Methodology

2.1 Field Sampling Methods

2.1.1 Groundwater Sampling

Two of the six groundwater monitoring wells were sampled between 25 and 26 March 2013, as listed in Table 1 and shown on Map 2 in **Appendix A**. The other four wells could not be sampled because they were either damaged or could not be located, as summarised in Table 1 below. Photographs of the boreholes are contained in Appendix D of the Silvermines Data Report.

Table 1 Location of Groundwater Monitoring Points

Borehole Identifier	Easting	Northing	Water Level	Field Parameters & Chemical Analysis	Depth (m bgl)	Description
BH1C/D-GORT-06	180201	172480	Yes	Yes	19.9	The borehole was found buried under the newly laid rocks for slope stability at the edge of the TMF.
BH2C/D-GORT-06	180248	172864	Yes	Yes	20.65	The borehole was found badly damaged with the outer casing crushed over the inner casing. The casing was also full of rusty stagnant water.
TMF1(D)/SRK/01	179826	173165	Yes	Yes	23	Sample obtained and water level measured
TMF2(D)/SRK/01	179445	172307	Yes	Yes	18	Sample obtained and water level measured
TMF3/SRK/01	179196	172237	Yes	Yes	21.2	The borehole could not be located at the coordinates provided or in that vicinity. It was noted in a 2007 Golder report the TMF3 could not be found and was thought to have been destroyed.
TMF4(D)/SRK/01	179874	172180	Yes	Yes	20	The borehole could not be located at the coordinates provided or in that vicinity. It was believed that the borehole could be buried under rocks.
BH1A-GORT-06	180181	172490	Yes	No	8.8	Water level measured
BH2A-GORT-06	180216	172855	Yes	No	10	Water level measured
BH3A-GORT-06	179835	173126	Yes	No	10	Water level measured
BH4A-GORT-06	179570	172826	Yes	No	10	Water level measured
BH5A-GORT-06	179537	172312	Yes	No	10	Water level measured
BH6A-GORT-06	179868	172212	Yes	No	10	Water level measured
BH6B-GORT-06	179867	172225	Yes	No	5	Water level measured

Samples were obtained from the deep well installations outside the perimeter of the TMF: TMF1(D)/SRK/01 is upgradient of the TMF and TMF2(D)/SRK/01 is downgradient (Golder Technical Memo 4 April 2007). TMF1(D)/SRK/01 and TMF2(D)/SRK/01 have a double well installation: the deep installation is sealed in the bedrock and the shallow well is sealed within the overlying soil overburden.

Groundwater samples were collected using the procedure consistent with the Low Flow Groundwater Sampling Procedure (SOP 1-12) detailed in the Monitoring Plan. Groundwater was collected using a portable submersible low-flow pump (Grundfos Redi-Flo). The static water level was measured prior to pumping and was also measured throughout the purging process to monitor drawdown.

Water quality indicator parameters were monitored in the field during low-flow purging using a flow-through cell to minimise oxidation by the atmosphere. Water quality indicator parameters include temperature, pH, ORP, conductivity and dissolved oxygen (DO). Purging continued until the field parameters had stabilised. The results were recorded approximately every five minutes during the purging process on the Groundwater Purging and Sampling Form. Field sheets are contained in Appendix H and physio-chemical field data are summarised in Appendix A of the Data Report.

After purging the water sample and stable parameters have been measured, the flow was reduced for low-flow sample collection. Samples for trace metal analyses were filtered in the field using a 0.45 micron membrane syringe filter before preservation. New bottles supplied by the laboratories were used for sample collection.

The following exceptions to the low flow sampling procedure applied:

- TMF1(D)/SRK/01 borehole was damaged about 1m from the surface. A major obstruction exists and the pump could not be lowered into the well. The borehole was sampled by hand pumping the well using tubing with a foot valve. The sample was collected after three volumes of the well (calculated as $\pi r^2 h$; r is the inner casing radius and h is the height of the water column) had been purged and the field parameters had stabilised.

Water Level

Groundwater levels were measured at the two wells and seven additional wells located within the TMF near its perimeter from the tailings surface, using a portable electronic water level recorder. Groundwater level data are contained in Appendix C of the Data Report and discussed in Section 6.

2.1.2 Surface Water Sampling

Thirty-one surface water locations were sampled between 26 March and 5 April 2013, as listed in Table 2 and shown on Maps 2 to 4 in **Appendix A**. Two of the samples were unable to be obtained because there was no flow at SW2-SM 'Northern Adit' and the stream bed was dry at SW1-GAR.

Surface water sampling was conducted consistent with the Surface Water Sampling Procedure (SOP 1-1) as detailed in the Monitoring Plan. The predetermined surface water sampling locations were located in the field using a GPS. Photographs were taken of the surface water sampling location (Appendix D of the Data Report). Samples were grab samples collected from a well mixed portion of the water stream where possible. The sample location was approached from downstream so that the underlying sediments are not disturbed.

Table 2 Location of Surface Water Monitoring Points

Site Name	Area	Easting	Northing	Flow	Sample Site Notes
SW10_GORT	GM	180196	172397	Bucket and Stopwatch (for wetland discharge only)	Vicinity of discharge from SE wetland. Three samples collected: (1) Wetland discharge prior to outfall; (2) Immediately upstream of the outfall on the Kilmastulla; (3) 20m downstream of the outfall, on the Kilmastulla River.
SW12_GORT	GM	179562	172140	Bucket and Stopwatch (for wetland discharge only)	Vicinity of discharge from SW wetland. Two samples collected: (1) Sample of wetland discharge prior to outfall; (2) 20m downstream of the outfall, on the Kilmastulla River.
SW14_GORT	GM	179336	172164	Not required	Site located on Kilmastulla River, downstream of TMF
SW17_GORT	GM	180538	173038	Not required	Site located on Kilmastulla River, upstream of TMF
SW18_GORT	GM	179772	172666	Not required	Site of discharge from the main pond on the TMF
SW19_GORT	GM	180097	172982	Flume	Discharge at the bottom of the decant
SW1-SM	BG	184083	170732	Flume	Site on Silvermines Stream (upstream of Ballygown mine workings)
SW2-SM	BG	184266	171614	No Flow - sample not obtained	Discharge from 'Northern' adit.
SW2-SM	BG	184280	171582	Bucket and Stopwatch	Discharge from 'Southern' adit.
SW3-SM	BG	184258	171412	Flume	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)
SW4-SM-GA	BG	183990	172460	Flume	Site on Silvermines Stream (downstream of all mine workings)
SW6-MAG	MG	182776	171399	Not required	Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road.
SW1-GAR	GA	182116	171322	Not required – No flow – sample not obtained	Stream sampled south of R499 road (south of old Mogul Yard)
SW2-GAR	GA	181804	171376	Not required	Drainage south of R499 road.
SW3-GAR	GA	181300	171648	Marsh McBirney	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.
SW4-GAR	GA	181335	171404	Flume	NW oriented stream occurring west of Mogul Yard. Sample site is south of R499 road.
SW5-GAR	GA	181950	171418	No flow	Discharge from Knight Shaft
SW7-GAR	GA	181523	171493	Bucket and Stopwatch	Discharge from smaller settlement pond
SW8-GAR	GA	181695	171531	Estimated (low flow not measurable)	Drainage from western part of Mogul Yard sampled in open drain, south of railway
SW9-GAR	GA	181881	171557	Bucket and Stopwatch	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of railway
SW10-GAR	GA	181640	171730	Flume	Discharge from Garryard tailings lagoon
SW12-GAR	GA	181738	171576	Bucket and Stopwatch	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.
SW1-SHAL	ShS	180703	171776	Flume	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.
SW4-SHAL	ShS	180306	171084	Estimated (low flow not measurable)	Water-course occurring west of 'Drum Dump' and Shallee South workings.
SW5-SHAL	ShS	180574	171301	Bucket and Stopwatch	Water course west of fenced off area enclosing King's House and core sheds. Further west, this

Site Name	Area	Easting	Northing	Flow	Sample Site Notes
					same feature runs along the toe of the drum dump.
SW6-SHAL	ShS	180591	171331	Flume	Stream emanating from flooded Field Shaft
SW7-SHAL	ShS	180595	171353	No flow	Stream occurring east of Field Shaft
SW9-SHAL	ShS	180571	171470	Flume	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.
SW10-SHAL	ShS	180609	171499	No flow	Drainage running parallel to R499. Site occurs at northern edge of the southernmost Shallee tailings impoundment.
SW12-SHAL	ShS	180670	171165	Bucket and Stopwatch	Stone lined drainage channel SSW of reservoir

Notes:
Abbreviations: GM- Gortmore; BG- Ballygown; MG- Magcobar; GA- Garryard; ShS- Shallee South

Samples were placed into new laboratory provided bottles with the correct preservatives. The sample bottles that required no filtering were filled directly in the stream. A container was filled at the same time and transported to the shore for filtering using a 0.45 micron membrane syringe filter before preservation for the trace metal analysis.

Water quality indicator parameters were monitored during sampling by collecting them directly from the stream or discharge, when possible, using a multi-parameter meter. The final stabilised results were recorded in the field notebook (Appendix H of the Data Report) and are summarised in Appendix A of the Data Report.

Flow Measurements

Flow was measured at 20 locations using various methods depending upon the quantity of flow to be measured and any safety concerns as detailed in the standard operating procedures in the Monitoring Plan (see Table 2). At 6 locations there was no flow at the time of sampling. Surface water flow results are discussed in Section 5.1 and the data and measurement methodologies are contained in Appendix B of the Data Report. A portable flume was used for small discharges and streams while for very small discrete discharges, a stop watch and calibrated volume container was used. At one location a Marsh McBirney meter was used to measure flow velocities and depths at regular intervals across the streams by wading.

2.1.3 Vegetation Sampling

Twenty vegetation samples were collected between 2 and 3 April 2013, from the recently remediated Areas A and B at Gortmore TMF, as listed in Table 3 and shown on Map 5 in **Appendix A**.

Vegetation sampling was conducted consistent with the procedure detailed in the Monitoring Plan. The predetermined vegetation sampling locations were located in the field using a GPS and a one metre square template was placed on the ground. Within the one meter square area, all obvious weed species were removed. Vegetation samples were collected from the above ground plant material using shears.

Representative samples were collected with a mixture of live and dead vegetation, because there was not enough live vegetation within each metre squared area to collect completely live vegetation samples. Photographs of the one meter square area before sample collection and of the vegetation sample after collection are contained in Appendix D of the Data Report.

Table 3 Location Vegetation Sampling Sites at Gortmore TMF

Site Name	Easting	Northing	Sample Area
SM01	179853	173080	A
SM04	179799	172980	A
SM05	179869	172983	A
SM06	179922	172988	A
SM08	179851	172929	A
SM13	179903	172882	A
SM14	179748	172832	A
SM15	179815	172829	A
SM17	179694	172775	A
SM19	179802	172780	A
SM21	179603	172781	B
SM22	179502	172730	B
SM27	179629	172679	B
SM28	179706	172674	B
SM30	179511	172636	B
SM31	179587	172630	B
SM33	179448	172581	B
SM34	179532	172578	B
SM38	179551	172528	B
SM40	179502	172432	B

2.1.4 Soil Sampling

Annual soil sampling will be carried out in Round 2.

2.1.5 Field QA/QC Samples

In accordance with the QA/QC Protocols set out in the Monitoring Plan, the following samples were collected:

- Groundwater
  - One duplicate groundwater sample was collected; and
  - One decontamination blank was collected by pumping deionised (DI) water through the groundwater pump after decontamination.
- Surface Water:
  - Three duplicate surface water samples; and
  - One decontamination blank was collected by pouring DI water over the surface water sampling equipment after decontamination.
- Two certified standard reference material containing known concentrations of the 18 metals was shipped blind to ALcontrol laboratory (the SRM certificate is contained in Appendix G of the Data Report).
- One water blank was collected of the DI water during the sampling event.

- Vegetation:
  - Two duplicate vegetation r samples were collected; and
  - One decontamination blank was collected by pouring DI water over the vegetation sampling equipment after decontamination.
- Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1515 (a certified standard of apple leaves) was used (certificate is contained in Appendix G of the Data Report).

Sample IDs for the field QA/QC samples are listed in Table 4. The duplicate samples are an independent check on sampling and laboratory precision. The standard reference material is an independent check on laboratory accuracy. The decontamination blanks are a check on the decontamination procedures used in the field. These checks are very important and are independent from the QA/QC samples performed by the laboratories (see discussion in Section 3).

Table 4 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
SMGD01.1	GW Duplicate	Duplicate of TMF2
SMDB01.1	GW Decontamination blank	DI pumped though pump after decon at site TMF2
SMSD01.1	SW Duplicate	Duplicate of SW9-SHAL
SMSD02.1	SW Duplicate	Duplicate of SW10-GAR
SMSD03.1	SW Duplicate	Duplicate of SW4-SM-GA
SMDB02.1	SW Decontamination blank	DI water poured over SW sampling beaker after decon at site SW17-GORT
SMSR01.1	Standard Reference Material	
SMSR02.1	Standard Reference Material	
SM56-V	Vegetation Duplicate	Duplicate of SM14-V
SM57-V	Vegetation Duplicate	Duplicate of SM27-V
SMDB03.1	Vegetation Decontamination blank	DI water poured over shears after final decon
AVWB01.1	Water blank	Deionised water

2.2 Sample Handling

One waterproof label for each sample container collected was completed with an indelible, waterproof, marking pen. The label contained the location, Sample ID code and date and time of sample collection. Samples were stored appropriately so they remained representative of the time of sampling. Sufficient ice was added to cool the samples to 4°C.

A Chain-of-Custody (COC) Form was filled out for each sample type at each sampling location. The field staff double-checked that the information recorded on the sample label was consistent with the information recorded on the COC record. The COC record was placed in a resealable plastic bag and placed inside of all shipping and transport containers. All samples were hand delivered or shipped by courier to the laboratory specified. Samples were packed so that no breakage would occur. Signed COCs are provided in Appendix E of the Data Report.

2.3 Sample Analysis

2.3.1 ALcontrol

Analyses of water samples were performed by ALcontrol. Water (both surface water and groundwater) samples were dispatched from its distribution centre in Dublin and analysed at its facility in North Wales. ALcontrol is accredited by the United Kingdom Accreditation Service (UKAS) in accordance with ISO/IEC 17025:2005 and has also obtained a Certification of Approval by Lloyd's Register Quality Assurance for Environmental Management System Standard ISO 14001:2004.

For groundwater and surface water, analyses were performed for the following parameters: pH, conductivity, dissolved oxygen, Total Dissolved Solids, ammoniacal nitrogen as N, potassium, sodium, chloride, fluoride, calcium (total and dissolved), magnesium (total and dissolved), nitrate as NO_3 and nitrite as NO_2, orthophosphate, sulphate, total alkalinity as $CaCO_3$, free cyanide, total and dissolved metals including Al, Sb, Ag, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Tl, Sn, U, V and Zn. Additionally for surface water, acidity, Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) were analysed.

The Monitoring Plan provides details on the analytical methods, holding times and reporting limits. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. As noted in the Monitoring Plan, ALcontrol is certified for most of the analyses and the few analyses for which certifications are not available are not critical for comparison to regulatory standards.

All the laboratory reports and analytical data are contained in Appendix F of the Data Report and discussed in Section 4 of this report.

2.3.2 CAL Ltd

CAL Ltd, a subsidiary of Natural Resource Management Ltd, undertook the vegetation sample analyses and they are accredited to ISO 17025 by the United Kingdom Accreditation Service. Vegetation samples were analysed for zinc, arsenic, cadmium and lead by ICP-OES (Zn) and ICP-MS (As, Cd, Pb). Samples were dried to 80 degrees to constant weight and ground to <1mm. A representative split sample was digested using 50% nitric acid at elevated temperature and pressure.

All the laboratory reports and analytical data are contained in Appendix F of the Data Report and discussed fully in Section 4 of this report.

Section 3

Data Quality and Usability Evaluation

3.1 Introduction

Laboratory data quality and usability were assessed using data quality indicators (DQIs). Data "usability" means that the data are acceptable to use for their intended purpose and associated evaluations. The DQIs for assessing data are expressed in terms of precision and accuracy. These DQIs provide a mechanism to evaluate and measure laboratory data quality throughout the project. The definitions and methods of measurement of precision and accuracy are discussed below. In addition, use of blank samples as a DQI is also discussed.

3.1.1 Accuracy

Accuracy is defined as the degree of agreement of a measurement with an accepted reference or true value. The accepted reference is typically a standard reference material (SRM) provided by an established institute or company. The "true" value has been determined by performing multiple analyses by various methods and laboratories. Accuracy is a measure of the bias in a system (i.e. the laboratory procedures). Each measurement performed on a sample is subject to random and systematic error. Accuracy is related to the systematic error. Attempts to assess systematic error are always complicated by the inherent random error of the measurement. Accuracy is quantitative and usually expressed as percent recovery (%R) of a sample result compared to the SRM.

%R is calculated as follows:

$$\%R = \frac{A}{T} \times 100$$

where:	%R	=	Percent recovery
	A	=	Measured value of analyte (metal) as reported by the laboratory
	T	=	True value of the analyte in the SRM as reported by the certified institute

Acceptable QC limits are typically between 80 to 120 %R for inorganic methods (i.e. metals in this report). The SRMs used for this project are discussed below.

3.1.2 Precision

Precision is the measurement of the ability to obtain the same value on re-analysis of a sample (i.e., the reproducibility of the data). The closer the results of the measurements are together, the greater is the precision. Precision is not related to accuracy or the true values in the sample. Instead precision is focused upon the random errors inherent in the analysis that result from the measurement process and are compounded by the sample vagaries. Precision is measured by analysing two portions of the sample (sample and duplicate) and then comparing the results. This comparison can be expressed in terms of relative percent difference (RPD). RPD is calculated as the difference between the two measurements divided by the average of the two measurements.

RPD is calculated as follows:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2) \times 0.5} \times 100$$

where: RPD = Relative percent difference
D_1 = First sample value
D_2 = Second sample value (duplicate)

Acceptable RPD values for duplicates generated in the laboratory are usually 65 % to 135 %. Acceptable RPD values for field duplicates are usually 50 % to 150 %. The higher values for field duplicates reflects the difficulty in generating homogeneous duplicates in the field. Both field and laboratory duplicates were generated for this project and are discussed below.

3.1.3 Blanks

Several different types of "blank" samples may be generated to assist in evaluating general data usability. Periodic analysis of laboratory method blanks ensures there is no carryover of contaminants between samples because of residual contamination on the instrument or from contaminants introduced in the laboratory. Laboratory method blanks are typically laboratory pure water, acids or sand that have been processed through all of the procedures, materials, reagents, and labware used for sample preparation and analysis. In addition to the laboratory blanks, decontamination blanks were generated in the field to evaluate the sampling equipment decontamination process. Each of these types of blanks is discussed below.

3.1.4 Field QA/QC Samples

Field QA/QC samples were submitted to the laboratories and analysed to enable the following evaluations:

- Duplicate Samples: Duplicate groundwater and surface water samples were created in the field and submitted blind to the laboratory (see Table 4 for sample IDs). The results are used to evaluate the combined reproducibility of both the laboratory analyses and field sampling.

- Decontamination Blanks: After the sampling equipment was cleaned, DI water was poured over or pumped through the sampling equipment and collected for laboratory analysis (see Table 4 for sample IDs). Analyses of these samples were used to evaluate the adequacy of the sampling equipment cleaning or decontamination procedure.

- Standard Reference Material (SRM):

    - Two certified water SRMs were sent blind to the ALcontrol (Sample IDs SMSR01.1 and SMSR02.1) to evaluate laboratory accuracy. The certified SRM was supplied by Phenova Certified Reference Materials and was Lot #8128·04 (Metals). The Certificate of Analysis is provided in Appendix G of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.

    - Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1515 a certified standard of apple leaves was used (certificate is contained in Appendix G of the Data Report).

- Water Blank: To ensure that the water used for equipment decontamination is analyte free, one water blank sample was collected of the DI water.

3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Four duplicate samples (one groundwater and three surface waters) were generated in the field and sent to ALcontrol for analysis. Table 5 provides the results of the 21 metals for the four duplicate samples and the calculated RPD between each pair of samples.

The majority of RPD values are below 50 %. The RPDs for the following parameters are very good: barium (0.5 to 1.5%), cadmium (0 to 25%), copper (1 to 13%), iron (0 to 14%), lead (0.5 to 16%), nickel (1 to 13%) and zinc (0.5 to 10%). The RPDs range for chromium was slightly higher (9 to 28%) but still considered good. The RPDs that were above 50% included antimony, selenium, tin and vanadium for two sample pairs with the RPD values ranging from 54 to 125%. Mercury for sample pair SW4-SM-GA/SMSD03.1 had an RPD of 143% and arsenic for one sample pair SW10-GAR/SMD02.1 had an RPD of 56%.

Sample pair SW10-GAR/SMD02.1 which is the discharge from Garryard tailings lagoon, had six exceedances in total with the RPD values ranging from 54 to 101%. Low concentrations near the detection limits typically have higher variability. The elevated RPD identified are not considered to significantly impact the integrity of the results or preclude their use for evaluation. The highest reported value of the duplicate pair is selected for interpretive use.

Table 6 provides the results of the four metals for the two duplicate vegetation samples and the calculated RPD between each pair of samples. All the RPD values are below the +/- 50 % RPD values anticipated for field samples. The RPD values range from 4.5 to 41.5 % which is good for field vegetation duplicates. Some of the larger differences are the result of homogeneous duplicates of vegetation material being difficult to generate in the field. In addition, low concentrations near the detection limits typically have higher variability.

Table 5 Water Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Sample Description Dissolved Metal	LOD (µg/l)	TMF2	SMGD01.1	% RPD	SW9-SHAL	SMSD01.1	% RPD	SW10-GAR	SMSD02.1	% RPD	SW4-SM-GA	SMSDO3.1	% RPD
Aluminium	<2.9	<2.9	<2.9	-	15.3	17.1	-11.11	<2.9	<2.9	-	3.22	3.22	0
Antimony	<0.16	<0.16	<0.16	-	0.315	0.367	-15.3	8.29	2.72	**101.2**	1.82	0.418	**125.3**
Arsenic	<0.12	4.43	4.38	1.14	0.59	0.534	9.96	1.03	0.576	**56.5**	0.353	0.319	10.12
Barium	<0.03	572	564	1.41	232	234	-0.86	21	21.2	-0.95	127	128	-0.78
Cadmium	<0.1	<0.1	<0.1	-	1.22	1.14	6.78	18.8	18.6	1.07	0.377	0.293	25.07
Chromium	<0.22	2.17	1.63	28.4	0.51	0.466	9.02	1.43	1.22	15.85	1.15	0.902	24.17
Cobalt	<0.06	0.65	0.699	-7.26	1.42	1.52	-6.80	0.985	0.971	1.43	0.105	0.119	-12.50
Copper	<0.85	1.03	0.901	13.4	10.2	10.1	0.99	4.38	4.23	3.48	1.28	1.24	3.17
Iron	<19	182	177	2.79	38.1	33.1	14.04	<19	<19	-	<19	<19	-
Lead	<0.02	1.51	1.45	4.05	163	164	-0.61	1.56	1.33	15.9	1.08	1.09	-0.92
Manganese	<0.04	1000	992	0.80	61.1	61.2	-0.16	74.1	73	1.50	5.38	5.39	-0.19
Mercury	<0.01	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	0.0598	<0.01	**142.7**
Molybdenum	<0.24	0.372	0.323	14.10	<0.24	<0.24	-	3.14	1.39	**77.3**	0.67	0.515	26.16
Nickel	<0.15	2.16	2.19	-1.38	8.36	8.16	2.42	20.7	21.2	-2.39	2.02	1.77	13.19
Selenium	<0.39	0.462	0.805	**-54.1**	<0.39	<0.39	-	1.69	0.794	**72.1**	<0.39	<0.39	-
Silver	<1.5	<1.5	<1.5	-	<1.5	<1.5	-	<1.5	<1.5	-	<1.5	<1.5	-
Thallium	<0.96	<0.96	<0.96	-	<0.96	<0.96	-	3.25	2.53	24.9	<0.96	<0.96	-
Tin	<0.36	<0.36	<0.36	-	<0.36	<0.36	-	2.71	1.08	**86.02**	0.784	<0.36	**74.1**
Uranium	<1.5	<1.5	<1.5	-	<1.5	<1.5	-	2.24	0.75	39.6	<1.5	<1.5	-
Vanadium	<0.24	0.337	0.353	-4.64	<0.24	<0.24	-	0.605	0.346	**54.5**	0.366	0.249	38.05
Zinc	<0.41	2.1	2.32	-9.95	259	258	0.39	5340	5390	-0.93	303	301	0.66

Notes:
If less than LOD minimum value taken to be half LOD
Bold indicates an exceedance in the Duplicate RPD acceptance criteria

Table 6 Vegetation Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Total Metal	SM14-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM27-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	0.53	0.36	38.2	<0.1	<0.1	-
Cadmium	0.19	0.15	23.53	0.08	0.06	28.57
Lead	6.99	6.67	4.69	0.59	0.52	12.61
Zinc	42.40	27.80	41.6	22.90	26.50	-14.57

3.2.2 Decontamination Blanks

Three decontamination blanks were created by pumping DI water through or pouring water over the sampling equipment after decontamination and sent to ALcontrol for analysis. Table 7 provides the results of the 21 metals for the three decontamination blanks along with the results of the DI water blank also created in the field.

The majority of reported concentrations were below the limits of detection. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. The limits of detection ranged from 0.01 to 2.9 µg/l except for iron with a detection limit of 19 µg/l.

Low level detections were observed for 12 metals. Four of the metals (barium, lead, manganese and zinc) were also detected in the DI water blank but at slightly lower concentrations than the decontamination blanks. Detections of antimony, arsenic, chromium, molybdenum, selenium, iron and tin were also found in the decontamination blanks but not the DI water blank.

In total there were 23 detections of dissolved metals in the decontamination blanks. Only three of these were greater than 10 times the detection limit: iron and manganese in SMDB01.1 and antimony in SMDB02.1. SMDB01.1 was the decontamination blank associated with the sampling pump. In future sampling events, additional water will be used in the decontamination process. The majority of the detections were significantly less than the assessment criteria outlined in Section 4; therefore, these low concentrations in the blanks do not affect interpretation of results. However, the antimony detection was greater than the assessment criteria (5 µg/l), which is discussed further below.

To assess the level of cross-contamination between samples in the field, the concentrations in the decontamination blanks were compared with the concentration in the preceding environmental samples. The concentrations in the blanks were generally greater than 10% of the concentration in the preceding environmental samples. Antimony, molybdenum, selenium and tin were found at greater concentrations in SMDB02.1 than in the preceding environmental sample SW17-Gort.

The results from the laboratory method blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory. The following detections in the method blanks were reported:

- Two detections in Sample Batch 130322-60 (0.412 µg/l tin and 0.052 µg/l lead);
- Two detections in Sample Batch 130328-80 (0.267 µg/l antimony and 0.072 µg/l manganese);

- Nine detections in Sample Batch 130406-24 (4.87 µg/l antimony, 0.38 µg/l arsenic, 0.22 µg/l chromium, 0.689 µg/l selenium, 2.08 µg/l tin, 0.162 µg/l barium, 0.151 µg/l lead, 1.88 µg/l molybdenum and 0.114 µg/l manganese); and
- One detection in Sample Batch 130409-19 (0.513 µg/l antimony).

The detections in the laboratory method blank within Sample Batch 130406-24 could account for the elevated concentrations in the decontamination blanks SMDB02.1 as shown in Table 7, especially because they are in lower concentrations in the proceeding environmental sample SW17-Gort. Overall, we must conclude that the results are acceptable with the exception of the antimony with reported results near to the assessment criteria which should be used only with this precaution.

Table 7 Water Blank and Decontamination Blank Reported Values (µg/l)

Sample Description / Dissolved Metal	LOD (µg/l)	Water Blank AVWB01.1 (µg/l)	Decon blank SMDB01.1 (µg/l)	Decon blank SMDB02.1 (µg/l)	Decon blank SMDB03.1 (µg/l)
	Sample batch:	***130322-60***	***130328-80***	***130406-24***	***130409-19***
Aluminium	<2.9	<2.9	<2.9	<2.9	**11.9**
Antimony	<0.16	<0.16	*<0.16*	***5.21***	*<0.16*
Arsenic	<0.12	<0.12	<0.12	***0.244***	<0.12
Barium	<0.03	**0.045**	**0.076**	***0.07***	**0.141**
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.22	<0.22	**0.376**	***0.277***	<0.22
Cobalt	<0.06	<0.06	<0.06	<0.06	<0.06
Copper	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	**177**	<19	<19
Lead	<0.02	***0.172***	**0.176**	***0.021***	**0.125**
Manganese	<0.04	**0.084**	***0.669***	*<0.04*	**0.149**
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	<0.24	<0.24	<0.24	***1.72***	<0.24
Nickel	<0.15	<0.15	<0.15	<0.15	<0.15
Selenium	<0.39	<0.39	<0.39	***0.448***	<0.39
Silver	<1.5	<1.5	<1.5	<1.5	<1.5
Thallium	<0.96	<0.96	<0.96	<0.96	<0.96
Tin	<0.36	<0.36	<0.36	***1.96***	<0.36
Uranium	<1.5	<1.5	<1.5	<1.5	<1.5
Vanadium	<0.24	<0.24	<0.24	<0.24	<0.24
Zinc	<0.41	**0.568**	<0.41	**0.587**	**2.05**

Notes:
Bold indicates a detection
Bold and italics indications a detection of a parameter also detected in the laboratory instrumentation blank.

To assess the level of cross-contamination between vegetation samples in the field, the concentrations in decontamination blank SMDB03.1 were examined. The low level detections were either due to detections in the DI water or in the case of aluminium and zinc, they are likely due the fact that metallic shears were utilised as sampling equipment. In future sampling, alternative sampling shears will be used and/or additional water will be used in the decontamination process.

3.2.3 Standard Reference Materials

SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.1 and SMSR02.1) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 8 summarises the SRM results and provides the calculated %R values for the 18 requested metals.

Reported values for aluminium, antimony, arsenic, barium, chromium, cobalt, copper, iron, lead, manganese, selenium, thallium, vanadium and zinc are in excellent agreement with the certified value (%R ranged from 85.7 to 108.2%). The reported values for silver are within 20% of the certified value and are acceptable.

One of the reported values for cadmium, molybdenum and nickel in ID SMSR01.1 and one for silver in ID SMSR02.1 were low at 81.6 %, 77.7 %, 86.8 % and 85 % respectively, which fall out of the acceptable range. However the second reported value is within the acceptable range and therefore the reported values are considered usable.

Table 8 SRM Reported Values (µg/l) and Calculated % R

Sample Description Dissolved Metal	Certified Value (µg/l)	Acceptance Limits (%)	SMSR01.1 (µg/l)	% R	SMSR02.1 (µg/l)	% R
Aluminium	2640	82.6 -116	2440	92.4	2510	95.1
Antimony	605	70.2 -120	632	104.5	568	93.9
Arsenic	672	84.1 -117	585	87.1	648	96.4
Barium	1710	86.5 -113	1710	100.0	1710	100.0
Cadmium	423	85.1 -113	345	**81.6**	392	92.7
Chromium	765	87.2 -113	709	92.7	737	96.3
Cobalt	346	87.6 -112	329	95.1	339	98.0
Copper	637	90.0 -110	580	91.1	602	94.5
Iron	1560	88.5 -113	1380	88.5	1390	89.1
Lead	245	85.3 -114	210	85.7	233	95.1
Manganese	805	89.8 -111	739	91.8	767	95.3
Molybdenum	337	84.3 -115	262	**77.7**	298	88.4
Nickel	644	89.9 -112	559	**86.8**	588	91.3
Selenium	1820	79.7 -116	1970	108.2	1720	94.5
Silver	399	86.0 -115	348	87.2	339	**85.0**
Thallium	466	79.8 -121	417	89.5	439	94.2
Vanadium	1480	87.8 -112	1360	91.9	1400	94.6
Zinc	1980	86.4 -115	1940	98.0	1870	94.4

Notes:
Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

ALcontrol undertakes a range of activities associated with both quality control and assessment to assure the quality of test results. Specifically ALcontrol conduct the following analyses on water samples

- Analytical Quality Control Samples (AQC) including, Certified Reference Material (CRM), Internal Reference Material (IRM) and Matrix spiked material. For batch sizes of 20 samples or less, a minimum of one AQC and for batches of greater than 20 samples, one AQC every additional twenty samples or part thereof. They are introduced into the sample batch on a random basis where possible. They are prepared at the same time as the rest of the batch and by the same person who prepares the batch;

- Process Blanks: A process blank was included with each batch of samples. The blanks are matrix matched where possible and was taken through the entire analytical system;

- Instrument Blanks: An instrument blank was run to check for any contamination within the instrument;

- Independent Check Standard: An independent check standard was included with every instrumental run of samples. This standard is prepared from a separately sourced standard to the calibration standards and is used as a check on the validity of the calibration standards. The acceptance criteria for this standard was method specific; and

- Replicate samples (samples tested more than once using the same method) were included at the same frequency as the AQCs.

All of the ALcontrol laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding times were occasionally exceeded for dissolved oxygen and total dissolved solids. For five samples the holding times were exceeded in the laboratory for free cyanide, which is 7 days with preservative. The holding times were exceeded by 2 to 7 days. Note that all the reported values for free cyanide were below the detection limit of 0.05 mg/l. We will work with the laboratory to prevent the free cyanide holding times being exceeded in the future. These exceedances of the holding times are typically considered acceptable from a technical perspective given the preservation and conservative nature of holding times.

ALcontrol provided the associated analytical quality control samples (AQC) data. The percentage recovery results for the AQC samples that were run with the regular environmental samples were checked against the individual lower control and upper control limits. All AQC samples run with the environmental samples were within these upper and lower control limits. The results of method blanks were also assessed as described in Section 3.2.2 above.

3.3.2 CAL Ltd.

CAL provided the results for the following samples:

- SRMs: CAL analysed SRM NIST 1515 after every 10 samples for a total of two analyses. The results are provided in the laboratory report in Appendix F of the Data Report (reported as CRM NIST 1515). SRM NIST 1515 is a certified standard of apple leaves provided by the USA National Institute of Standards & Technology. The certificate of analysis is provided in Appendix G of the Data Report. In addition, CAL routinely analysed an in-house reference material (a dried ground grass sample, GST002). The reference material was analysed three times for arsenic, cadmium, lead and zinc;

- Duplicates: CAL did not analyse duplicates of the field samples. However, the two analyses of SRM NIST 1515 can be used to evaluate precision; and

- Blanks: CAL performed three method blanks during the analyses of arsenic, cadmium, lead and zinc. The method blanks were clean aqueous solutions.

SRM Vegetation

Table 9 provides the results of the two analyses of SRM NIST 1515 and the % R values.

Table 9 SRM NIST 1515 Reported Values and Calculated % R

Total Metal	Certified Value (mg/kg)	Certified value Acceptance Range (mg/kg)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R
Arsenic	0.038	0.031-0.45	0.15	395	0.18	474
Cadmium	0.013	0.011-0.015	0.01	76.9	0.01	76.9
Lead	0.47	0.446-0.494	0.34	72.3	0.34	72.
Zinc	12.5	12.2-12.8	12.4	99.2	12.4	99.2

The Zn results are acceptable with the % R values of 99.2 %. The reported Cd values may be slightly low (% R is 76.9); however, all values are very near the detection limit. The Pb values may be slightly low (% R is 72 %). The Cd and Zn values are acceptable to use, noting the values may be slightly low.

As shown, the values reported by the laboratory for the arsenic concentrations are much higher than the certified value. The laboratory report by CAL (provided in Appendix F of the Data Report) discussed these results and states:

- SRM NIST 1515 was re-analysed together with three other CRMs of comparable matrix which bracket the value for 1515. For the other CRMs, there is a small consistent negative bias: opposite of 1515, which led CAL Ltd to the conclusion that the value given by NIST 1515 for arsenic is highly suspect. However, there is still confidence in the reported arsenic results because the other CRMs gave reasonable agreement with their certified values;

- The methods (this applies to lead as well) used to establish the certified value (ICP-MS) are different from those used at the certification laboratory. Frequently differences between results are obtained from alternate methodologies; and

- Method blanks did not indicate arsenic carryover/contamination.

As previously discussed, CAL also analysed an in-house reference material (GST002). The reported values are compared to historical mean and standard deviation values using a control chart. If the reported values for GST002 are outside +/- 2 standard deviations of the historical mean, corrective action is taken and all samples reanalysed. If two consecutive GST002 results are between 2 and 3 standard deviations on the same side of the mean, the samples are also reanalysed. All results for the in-house reference material were acceptable.

Duplicates

As previously discussed, the laboratory did not perform duplicate analyses of the field samples. However, the analyses of the SRM NIST 1515 (Table 9) can be considered duplicate samples. As shown in Table 9, the precision was very good. The two values of As ranged from 0.15 to 0.18 mg/kg, all Pb values were 0.34 mg/kg, all Cd were 0.01 mg/kg and all Zn were 12.4 mg/kg.

Blanks

As previously discussed, CAL performed method blanks (3 for arsenic, cadmium, lead and zinc). All Zn results were below reporting limits (non-detects); As values ranged from 0.001 to 0.002 mg/l; Cd values ranged from below reporting limits to 0.002 mg/l; and Pb values ranged from below reporting limits to 0.002 mg/l. CAL reported that all these values were acceptable stating that the results “did not indicate carryover or contamination”.

3.4 Summary of Data Checks

3.4.1 Field physio-chemical Versus Laboratory Data

Table 10 summarises the field and laboratory results for pH, conductivity and Dissolved Oxygen (DO) and provides the calculated %RPD values. Note that DO and pH measurements in the laboratory were taken from the unpreserved sample and therefore the results do not affect the results of samples from preserved bottles (e.g., metals).

DO measurements for the groundwater were generally lower in the field than the readings in the laboratory and field results are considered more representative of actual dissolved oxygen conditions. In some instances the pH reading in the field were lower than the laboratory, all had a RPD of less than 24 % which is very good. The field pH is more representative of actual conditions and is used for interpretive purposes. Overall the RPDs between the field and laboratory data are considered satisfactory.

Table 10 Field physio-chemical data and Laboratory Reported Values and Calculated % RPD

Sample Description	pH Lab	pH Field	% RPD	Cond. Lab	Sp. Cond. Field	% RPD	DO Lab	DO Field	% RPD
	pH Units			(mS/cm)			(mg/l O_2)		
TMF1	8.05	7.32	9.50	0.332	0.428	-25.3	7.65	2.12	**113**
TMF2	8.18	7.40	10.0	0.452	0.495	-9.08	4.59	0.30	**176**
SW12-Gort-Disc	8.19	7.64	6.95	1.23	1.362	-10.2	8.24	8.31	-0.85
SW12-Gort-River	8.13	8.53	-4.80	0.525	0.565	-7.34	9.29	12.81	-31.9
SW14-Gort	8.15	8.53	-4.56	0.475	0.502	-5.53	9.68	13.14	-30.32
SW18-Gort	8	8.83	-9.86	0.856	0.948	-10.2	9.66	12.44	-25.2
SW10-Gort-Disc	7.66	7.91	-3.21	1.14	1.266	-10.5	9.38	9.61	-2.42
SW10-Gort-DS	8.03	8.40	-4.50	0.517	0.565	-8.87	9.7	11.99	-21.1
SW10-Gort-US	8.12	8.41	-3.51	0.498	0.550	-9.92	9.72	11.62	-17.8
SW19-Gort	7.86	8.07	-2.64	0.962	1.064	-10.1	9.9	10.69	-7.67
SW10-SHAL	8.38	6.59	23.9	1.08	1.283	-17.2	5.8	1.64	**112**
SW12-SHAL	5.77	5.05	13.3	0.0464	0.051	-9.45	10.4	14.12	-30.3
SW1-SHAL	7.7	7.50	2.63	0.174	0.188	-7.73	9.76	7.50	26.2
SW4-SHAL	7.75	7.41	4.49	0.212	0.238	-11.6	9.39	11.50	-20.2
SW5-SHAL	7.14	6.74	5.76	0.45	0.504	-11.3	10.2	13.09	-24.8
SW6-SHAL	7.72	6.29	20.4	0.136	0.148	-8.45	8.46	9.53	-11.9
SW7-SHAL	7.75	7.07	9.18	0.38	0.421	-10.2	9.36	11.26	-18.4
SW9-SHAL	7.82	7.17	8.67	0.159	0.173	-8.43	9.86	11.88	-18.6
SW10-GAR	8.05	7.95	1.25	0.921	1.051	-13.2	9.35	13.63	-37.3
SW12-GAR	7.83	7.76	0.90	1.5	1.698	-12.2	9.15	12.03	-27.2
SW3-GAR	8.13	8.08	0.62	0.871	0.982	-12.0	9.69	12.11	-22.2
SW7-GAR	8.05	7.90	1.88	0.681	0.759	-10.8	9.57	13.35	-33.0
SW8-GAR	7.7	7.28	5.61	1.74	1.987	-13.5	8.43	8.53	-1.18
SW9-GAR	7.87	7.83	0.51	1.42	1.580	-10.7	9.19	12.35	-29.3
SW1-SM	7.97	7.81	2.03	0.152	0.162	-6.37	9.26	13.13	-34.6
SW2-GAR	7.67	6.94	9.99	0.998	1.127	-12.1	8.06	5.08	45.4
SW2-SM	8.03	7.15	11.6	0.461	0.516	-11.3	8.44	7.09	17.4
SW3-SM	8.08	7.68	5.08	0.201	0.217	-7.66	9.83	12.87	-26.8
SW4-GAR	8.05	6.67	18.8	0.221	0.241	-8.66	9.2	12.90	-33.5
SW4-SM-GA	8.23	7.97	3.21	0.319	0.346	-8.12	11	12.19	-10.3
SW5-GAR	7.54	6.59	13.5	2.83	3.260	-14.1	8.39	6.50	25.4
SW6-MAG	7.66	7.65	0.13	0.523	0.570	-8.60	9.44	13.49	-35.3
SW17-GORT	8.34	7.08	16.3	0.417	0.457	-9.15	11.3	11.95	-5.59

Notes:
Bold indicates an exceedance in acceptance limits

3.4.2 Internal Consistency Analysis

The analyses were checked for internal consistency using both charge balance and mass balance relationships.

The charge balance was calculated as follows:

(Σ(Cations x charge) - Σ(Anions x charge))/ (Σ(Cations x charge) + Σ(Anions x charge)) x 100%

Where, "cations" refers to the molar concentration of positively charged ions (millimoles/L) and "anions" to the molar concentration of negatively charged ions.

The mass balance was calculated using the following relationship:

(TDS-Calc – TDS-Meas)/TDS-Meas x 100%

TDS-Calc was calculated by summing the concentrations of all species in mg/l. Adjustments were made in cases where the species that would be formed upon evaporation (laboratory analytical procedure to yield TDS-Meas) was in a different form than that provided by the laboratory. For instance, the bicarbonate concentration was multiplied by a factor of 0.49 to account for loss of carbon dioxide gas during evaporation.

By evaluating both the mass balance and charge balance, conclusions can be drawn about the accuracy and completeness of the analysis. The possible mass balance and charge balance combinations and the corresponding interpretations are shown in Table 11.

The general acceptance criteria for internal consistency is ±10 % for both the charge balance and the mass balance. The charge balance was consistently within acceptable limits, with most values below 2 % which is excellent. One exception is SW8-GAR which had a 9.6 % difference but is still within the acceptable limit. The mass balance, in many cases (bolded values) did not meet these criteria. However most values were less than 20 %; which overall is very good considering the complex nature of some of the samples with high metal concentrations. The fact that the high values are all negative suggests that either one or more parameters were under-reported by the analytical laboratory and/or one or more parameters present within the samples were not analysed (e.g. silica).

Table 11 Charge Balance and Mass Balance Results

Site Description	TDS (Calc) (mg/l)	TDS (Meas) (mg/l)	Cations minus anions	Charge Balance % Diff	Mass Balance% Diff	Conclusion
TMF1	242	275	-0.08	-0.85	**-12.0**	Missing cations
TMF2	269	267	-0.06	-0.54	0.67	Too many anions
SW10-GAR	743	837	0.50	2.00	**-11.2**	Missing anions
SW10-Gort-Disc	938	1040	0.46	1.52	-9.85	Missing anions
SW10-Gort-DS	326	405	0.06	0.50	**-19.6**	Missing anions
SW10-Gort-US	320	308	-0.14	-1.16	3.91	Too many anions
SW10-SHAL	872	877	0.95	3.06	-0.56	Missing anions
SW12-GAR	1343	1540	1.81	4.11	**-12.8**	Missing anions
SW12-Gort-Disc	1008	1080	1.34	3.91	-6.70	Missing anions
SW12-Gort-River	340	310	0.01	0.05	9.53	Too many cations
SW12-SHAL	22	20.5	0.02	2.54	5.61	Too many cations
SW14-Gort	309	311	0.08	0.69	-0.70	Missing anions
SW17-GORT	265	276	-0.24	-2.43	-4.11	Missing cations
SW18-Gort	671	747	0.63	2.92	**-10.2**	Missing anions
SW19-Gort	799	808	-0.20	-0.82	-1.07	Missing cations
SW1-SHAL	101	135	-0.03	-0.73	**-25.1**	Missing cations
SW1-SM	87	114	-0.08	-2.30	**-23.5**	Missing cations
SW2-GAR	842	936	0.06	0.23	**-10.0**	Missing anions
SW2-SM	300	313	-0.09	-0.77	-4.23	Missing cations
SW3-GAR	697	825	0.09	0.37	**-15.5**	Missing anions
SW3-SM	120	141	-0.12	-2.69	**-15.0**	Missing cations
SW4-GAR	134	163	-0.01	-0.29	**-17.7**	Missing cations
SW4-SHAL	126	141	0.02	0.32	**-11.0**	Missing anions
SW4-SM-GA	198	229	0.00	-0.06	**-13.4**	Missing cations
SW5-GAR	3032	3720	0.27	0.28	**-18.5**	Missing anions
SW5-SHAL	332	368	0.17	1.57	-9.65	Missing anions
SW6-MAG	382	415	-0.17	-1.38	-7.94	Missing cations
SW6-SHAL	78	78.4	0.00	-0.10	-0.33	Missing cations
SW7-GAR	514	599	-0.16	-0.93	**-14.3**	Missing cations
SW7-SHAL	257	314	0.10	1.10	**-18.0**	Missing anions
SW8-GAR	1715	1890	5.37	9.64	-9.25	Missing anions
SW9-GAR	1221	1420	0.84	2.11	**-14.0**	Missing anions
SW9-SHAL	95	120	-0.07	-2.03	**-20.4**	Missing cations

Notes:
Bold indicates an exceedance of the acceptance criteria

The specific conductivity (SC) of the solutions can be used to further evaluate the internal consistency. The specific conductivity total dissolved solids (SC/TDS) ratio of natural waters varies, but typically ranges from ranges from 1 to 1.8. By comparing both the calculated TDS (TDS- Calc) and the measured TDS (TDS-Meas) to SC, an evaluation can be made of the reliability of these analyses. The majority of the ratios in Table 12 are within the range for natural waters and therefore the analyses are considered reliable. The one exception on the high range (SW12-SHAL with ratios of 2.1 and 2.3) had the lowest measured conductivity and TDS. At these low levels, the relationships are less accurate. The one exception on the low range (SW5-GAR with ratios of 0.9 and 0.8) had the highest measured conductivity and TDS. The low values may be due to ion pairing resulting in a low conductivity measurement. Figure 1 shows the relationship between specific conductivity and TDS and that there is a strong positive correlation between SC and both the calculated (R^2=0.98) and measured (R^2=0.97) TDS.

Table 12 Comparison of Specific Conductivity to Total Dissolved Solids (SC/TDS) Ratio

Sample Description	Sample Type	Conductivity (uS/cm)	TDS (Calc) (mg/l)	TDS (Meas) (mg/l)	Ratio SC/ C-TDS	SC/ M-TDS
SW10-GAR	SW	921	743	837	1.2	1.1
SW10-Gort-Disc	SW	1140	938	1040	1.2	1.1
SW10-Gort-DS	SW	517	326	405	1.6	1.3
SW10-Gort-US	SW	498	320	308	1.6	1.6
SW10-SHAL	SW	1080	872	877	1.2	1.2
SW12-GAR	SW	1500	1340	1540	1.1	1.0
SW12-Gort-Disc	SW	1230	1000	1080	1.2	1.1
SW12-Gort-River	SW	525	340	310	1.5	1.7
SW12-SHAL	SW	46	21.7	20.5	2.1	2.3
SW14-Gort	SW	475	309	311	1.5	1.5
SW17-GORT	SW	417	265	276	1.6	1.5
SW18-Gort	SW	856	671	747	1.3	1.1
SW19-Gort	SW	962	799	808	1.2	1.2
SW1-SHAL	SW	174	101	135	1.7	1.3
SW1-SM	SW	152	87.2	114	1.7	1.3
SW2-GAR	SW	998	842	936	1.2	1.1
SW2-SM	SW	461	300	313	1.5	1.5
SW3-GAR	SW	871	697	825	1.2	1.1
SW3-SM	SW	201	120	141	1.7	1.4
SW4-GAR	SW	221	134	163	1.6	1.4
SW4-SHAL	SW	212	126	141	1.7	1.5
SW4-SM-GA	SW	319	198	229	1.6	1.4
SW5-GAR	SW	2830	3030	3720	0.9	0.8
SW5-SHAL	SW	450	333	368	1.4	1.2
SW6-MAG	SW	523	382	415	1.4	1.3
SW6-SHAL	SW	136	78.1	78.4	1.7	1.7
SW7-GAR	SW	681	514	599	1.3	1.1
SW7-SHAL	SW	380	257	314	1.5	1.2
SW8-GAR	SW	1740	1720	1890	1.0	0.9
SW9-GAR	SW	1420	1220	1420	1.2	1.0
SW9-SHAL	SW	159	95.5	120	1.7	1.3
TMF1	GW	332	242	275	1.4	1.2
TMF2	GW	452	269	267	1.7	1.7

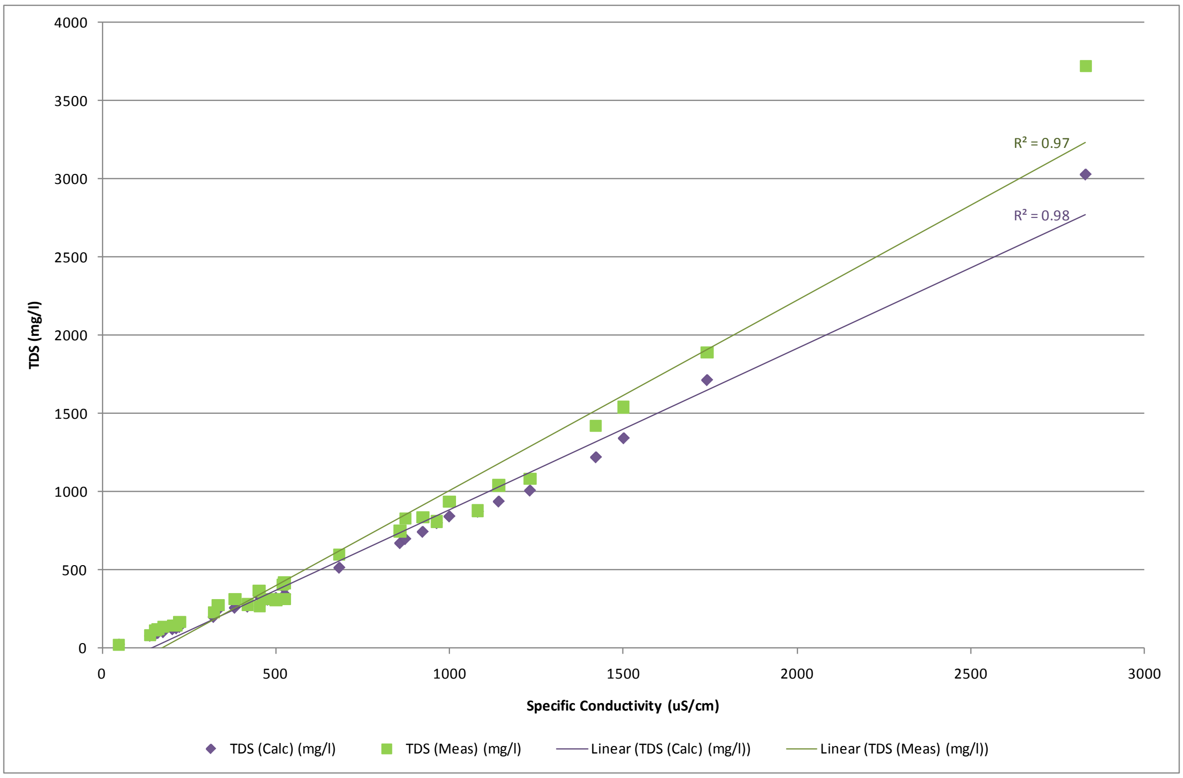

Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

3.4.3 Comparison of Total and Dissolved Metals

Total metals are the concentration of metals determined in an unfiltered sample (combination of metals contained in the solid sediments, colloidal particles and in the dissolved phase), while dissolved metals are those which pass through a 0.45µm membrane filter. Dissolved metals are more biologically available than total metals.

Normally the dissolved metal concentrations would be less than the total metals because they are a portion of the total concentration. This was checked for the key metals cadmium, lead and zinc, by calculating the RPD between the total and dissolved metals to evaluate if the concentrations were indistinguishable. Refer to Appendix B for the full tabulation of results.

The total metals were greater than or equal to the dissolved metals with the exception of some cadmium and copper results that were close to the limit of detection. The total concentrations were significantly higher than the dissolved concentrations for lead and total and dissolved concentrations were very similar for zinc. A relationship between high suspended solids and the highest differences in total versus dissolved metals is not apparent for lead. However the highest differences between total and dissolved for barium did correspond to higher suspended solids ranging from 3.5 to 23.5 mg/l.

Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater, surface water and vegetation and a comparison of the analytical results against selected assessment criteria. An analysis of loading and time trends is provided in Section 5 and groundwater levels are discussed in Section 6.

All the laboratory reports and analytical data are contained in Appendix F of the Data Report.

4.1 Statistical Summary of Analytical Results

4.1.1 Groundwater Sample Results

Table 13 provides a summary of the reported results of the two groundwater samples. Included in the table are the minimum, maximum and mean dissolved metal concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

Table 13 Summary of Dissolved Metal Concentrations in Groundwater

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Aluminium	<2.9	2	2	1.45	1.45	1.45
Antimony	<0.16	2	1	0.08	3.15	1.62
Arsenic	<0.12	2	2	2.94	4.43	3.69
Barium	<0.03	2	2	151	572	362
Cadmium	<0.1	2	0	0.05	0.05	-
Chromium	<0.22	2	2	0.82	2.17	1.50
Cobalt	<0.06	2	2	0.699	0.813	0.756
Copper	<0.85	2	2	0.913	1.03	0.972
Iron	<19	2	1	9.5	182	95.8
Lead	<0.02	2	2	0.333	1.51	0.922
Manganese	<0.04	2	2	65.2	1000	533
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	2	0.372	0.52	0.446
Nickel	<0.15	2	2	2.19	2.36	2.28
Selenium	<0.39	2	1	0.195	0.805	0.5
Silver	<1.5	2	0	0.75	0.75	-
Thallium	<0.96	2	0	0.48	0.48	-
Tin	<0.36	2	0	0.18	0.18	-
Uranium	<1.5	2	0	0.75	0.75	-
Vanadium	<0.24	2	2	0.305	0.353	0.329
Zinc	<0.41	2	2	1.59	2.32	1.96

Notes:
If less than LOD minimum value taken to be half LOD.

Dissolved barium (572 µg/l), iron (182 µg/l).and manganese (1000 µg/l) were found in the highest concentrations in TMF2(D)/SRK/01, which were significantly higher than the concentrations in TMF1(D)/SRK/01. Arsenic was detected in both wells with the highest concentration at TMF2(D)/SRK/01 of 4.43 µg/l. Detections of antimony, chromium, lead, nickel and zinc were reported which were slightly more elevated in TMF2(D)/SRK/01 than in TMF(1)/SRK/01.

4.1.2 Surface Water Sample Results

Surface water samples were collected for two major categories: the first includes mine adit discharges and discharges from wetland as well as some drainage ditches and the second includes the rivers and streams. Table 14 provides a summary of the reported results of the 16 discharge/ drainage samples and Table 15 provides a summary of the reported results of the 15 river and stream samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metal concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

Discharges and Drainage

Table 14 Summary of Dissolved Metal Concentrations in Discharges and Drainage

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	16	16	1.45	40.8	6.37	10.1
Antimony	<0.16	16	11	0.08	8.29	1.33	2.00
Arsenic	<0.12	16	16	0.181	3.79	0.71	0.90
Barium	<0.03	16	16	8.07	277	79.0	89.6
Cadmium	<0.1	16	15	0.05	40.8	10.3	12.5
Chromium	<0.22	16	16	0.304	1.96	1.16	0.48
Cobalt	<0.06	16	16	0.124	24	3.31	7.07
Copper	<0.85	16	16	0.425	14.1	5.37	3.89
Iron	<19	16	5	9.5	624	72.3	160
Lead	<0.02	16	16	0.069	236	28.8	62.1
Manganese	<0.04	16	16	1.55	16400	1630	4350
Mercury	<0.01	16	1	0.005	0.011	0.01	0
Molybdenum	<0.24	16	7	0.12	3.14	0.66	0.90
Nickel	<0.15	16	16	1.38	637	60.26	155
Selenium	<0.39	16	8	0.195	6.44	0.86	1.54
Silver	<1.5	16	0	0.75	0.75	-	-
Thallium	<0.96	16	7	0.48	6.59	1.87	1.96
Tin	<0.36	16	4	0.18	2.71	0.43	0.64
Uranium	<1.5	16	2	0.75	2.55	0.96	0.56
Vanadium	<0.24	16	9	0.12	0.759	0.31	0.21
Zinc	<0.41	16	16	20.4	96600	10100	23800

Notes:
If less than LOD minimum value taken to be half LOD.

SW5-GAR (discharge from Knights Shaft) had the highest concentrations of zinc (96,600 µg/l), nickel (637 µg/l) and manganese (16,400 µg/l). SW8-GAR (drainage from the western part of the Mogul Yard) also had high zinc (21,600 µg/l) and nickel (76.1 µg/l). The dissolved metals concentrations were lowest in SW18-Gort discharge from the main pond on Gortmore TMF), SW19-Gort (decant from the TMF) and SW12-Shal (stoned lined drainage channel at Shallee). The discharges from Gortmore TMF wetlands (SW10-Gort-Disc and SW12-Gort-Disc) were also relatively low in dissolved metals when compared with other discharges and drainage ditches at Silvermines.

Rivers and Streams

Table 15 Summary of Dissolved Metal Concentrations in Rivers and Streams

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	15	15	3.22	73.7	12.5	17.6
Antimony	<0.16	15	11	0.08	2.62	0.70	0.72
Arsenic	<0.12	15	15	0.127	0.975	0.41	0.21
Barium	<0.03	15	15	37.6	524	172	123
Cadmium	<0.1	15	11	0.05	31.3	3.41	8.26
Chromium	<0.22	15	15	0.425	1.55	0.89	0.35
Cobalt	<0.06	15	14	0.03	4.37	0.95	1.22
Copper	<0.85	15	15	0.425	10.4	3.87	3.84
Iron	<19	15	10	9.5	254	62.1	67.4
Lead	<0.02	15	15	0.089	164	23.1	48.6
Manganese	<0.04	15	15	2.76	991	167	256
Mercury	<0.01	15	2	0.005	0.0721	0.01	0.02
Molybdenum	<0.24	15	6	0.12	0.799	0.29	0.24
Nickel	<0.15	15	14	0.075	90.8	10.7	22.6
Selenium	<0.39	15	12	0.195	0.563	0.26	0.13
Silver	<1.5	15	0	0.75	0.75	-	-
Thallium	<0.96	15	1	0.48	1.26	0.53	0.20
Tin	<0.36	15	2	0.18	0.784	0.24	0.17
Uranium	<1.5	15	0	0.75	0.75	-	-
Vanadium	<0.24	15	7	0.12	0.382	0.22	0.11
Zinc	<0.41	15	15	1.25	14100	1360	3640

Notes:
If less than LOD minimum value taken to be half LOD.

SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc (1.25 and 4.81 µg/l, respectively) than the rest of the rivers and streams sampled in the Silvermines area. However SW17-Gort has background concentrations of manganese (153 µg/l) and aluminium (15.5 µg/l).

SW5-Shal the stream downstream of the "drum dump" has the highest concentrations of aluminium (73.7 µg/l), cadmium (31.3 µg/l), manganese (991 µg/l), nickel (90.8 µg/l) and zinc (14100 µg/l).

4.1.3 Vegetation Sample Results

Table 16 provides a summary of the results of the 20 vegetation samples from the recently remediated Areas A and B at Gortmore TMF. Included in this table are the mean, median, minimum, maximum, and standard deviation (SDEV). The values were calculated by substituting 0.05 for arsenic values <0.1 mg/kg and only using the original result of the field duplicate samples.

CDM Smith

Table 16 Summary of Vegetation Concentrations (mg/kg) at Gortmore TMF

	Arsenic	Cadmium	Lead	Zinc
Number	20	20	20	20
Minimum	<0.1	0.04	0.44	19.20
Maximum	0.78	0.27	7.17	89.30
Mean	0.28	0.10	2.71	33.6
SDEV	0.23	0.06	2.30	16.7

The highest arsenic concentration (0.78 mg/kg) was found in a sample SM04-V. The highest cadmium concentration (0.27 mg/kg) and highest zinc concentration (89.3 mg/kg) were found in vegetation sample SM01-V. Both SM04-V and SM01-V are located to the north-eastern edge of the site. The highest lead concentration (7.17 mg/kg) was found in a sample SM40-V located to the southern edge of the site. Fifteen detections of arsenic were greater than the reporting limit of 0.1 mg/kg.

4.2 Assessment Criteria

4.2.1 Groundwater and Surface Water Assessment Criteria

To assess the analytical results of the groundwater and surface water samples, assessment criteria have been selected to screen reported values against for both ecological and human health. To assess ecological criteria, the environmental quality standards (EQS) from the European Communities Environmental Objectives (Surface Water) Regulations, 2009 (S.I. 272 of 2009) and amendments were utilised, as shown in Table 17. These include standards for physico-chemical conditions supporting the biological elements general conditions and standards for specific pollutants. Compliance with the standards in the surface water regulations is either based on an annual average (AA), a maximum allowable concentration (MAC) or a 95 percentile standard. The MAC or 95 percentile (95%ile) was selected where possible as the assessment criteria because it is the most appropriate for assessment of one value; however, the AA was used in the absence of the MAC or 95%ile. To supplement the Irish legislation, screening criteria were selected from Oak Ridge National Laboratory (Suter and Tsao, 1996) for certain metals including aluminium, barium, cobalt, manganese and uranium (Table 17).

For hardness-dependent metals copper, zinc and cadmium, the hardness is taken into account when selecting the appropriate EQS value. The average hardness in the rivers and streams in the Silvermines mining area was determined to be 165 mg/l $CaCO_3$ and therefore the EQSs for hardness greater than 100 mg/l were selected as shown in Table 17. Also note that the EU Freshwater Fish Directive (78/659/EEC) which specifies standards for salmonid and cyprinid waters are not utilised because they will be revoked under the Water Framework Directive (2000/60/EC) on 22 December 2013 and they have been largely replaced by standards in the Surface Water Regulations.

To assess the potential human health risks, the Drinking Water Regulations, 2007 (S.I. No. 106 of 2007) and amendments were utilised and are listed in Table 18. These values are the maximum permissible values for a drinking water source.

The two main receptors to groundwater at Gortmore TMF are surface water bodies and the groundwater resource as a drinking water supply. Therefore to assess the potential impact of the groundwater quality on relevant groundwater receptors, the same standards and guidelines as mentioned for surface water were utilised for screening purposes (Table 17 and Table 18).

Table 17 Surface Water and Groundwater Assessment Criteria for Biological Elements

Parameter	Unit	AA	MAC (or 95%ile)	Source	Description
Ammonia as N	mg/l	0.065	**0.14**	S.I. No. 272 of 2009	Good status
Ortho-phosphate as P	mg/l	0.035	**0.075**	S.I. No. 272 of 2009	Good status
pH	pH units		**> 4.5** and < 9.0	S.I. No. 272 of 2009	Within range
Free Cyanide	mg/l	**0.01**	-	S.I. No. 272 of 2009	
Fluoride	mg/l	**0.5**	-	S.I. No. 272 of 2009	
Arsenic	µg/l	**25**	-	S.I. No. 272 of 2009	
Cadmium	µg/l	≤0.08 (Class 1) 0.08 (Class 2) 0.09 (Class 3) 0.15 (Class 4) 0.25 (Class 5)	≤0.45 (Class 1) 0.45 (Class 2) 0.6 (Class 3) **0.9** (Class 4) 1.5 (Class 5)	S.I. No. 327 of 2012	Hardness measured in mg/l CaCO3 (Class 1: <40 mg CaCO3/l, Class 2: 40 to <50 mg CaCO3/l, Class 3: 50 to <100 mg CaCO3/l, Class 4: 100 to <200 mg CaCO3/l and Class5: ≥200 mg CaCO3/l)
Chromium	µg/l	**3.4**		S.I. No. 272 of 2009	
Copper	µg/l	5 or **30**	-	S.I. No. 272 of 2009	5 µg/l applies where the water hardness measured in mg/l CaCO3 is ≤ 100; the value 30 applies where the water hardness > 100 mg/l CaCO3.
Lead	µg/l	**7.2**	-	S.I. No. 327 of 2012	
Mercury	µg/l	0.05	**0.07**	S.I. No. 327 of 2012	
Nickel	µg/l	**20**	-	S.I. No. 327 of 2012	
Zinc	µg/l	8 or 50 or **100**	-	S.I. No. 272 of 2009	8 µg/l for water hardness with annual average values ≤ 10 mg/l CaCO3, 50 µg/l for water hardness > 10 mg/l CaCO3 and ≤ 100 mg/l CaCO3 and 100 µg/l elsewhere
Supplementary standards:					
Aluminium	µg/l	-	**1900**	Oak Ridge National Laboratory	Invertebrates only - Lowest Chronic Value for Daphnids
Barium	µg/l	-	**4**	Oak Ridge National Laboratory	Invertebrates and Salmon fish
Cobalt	µg/l	-	**5.1**	Oak Ridge National Laboratory	Invertebrates only - Lowest Chronic Value for Daphnids
Manganese	µg/l	-	**1,100**	Oak Ridge National Laboratory	Invertebrates only - Lowest Chronic Value for Daphnids
Uranium	µg/l	-	**2.6**	Oak Ridge National Laboratory	Invertebrates only - Lowest Chronic Value for Daphnids

Table 18 Surface Water and Groundwater Assessment Criteria for Drinking Water

Parameter	Unit	Parametric value
pH	pH units	>6.5 to <9.5
Chloride	mg/l	250
Conductivity	mS/cm	2.5
Free Cyanide	mg/l	0.05
Ammonium	mg/l	0.3
Fluoride	mg/l	1.5
Nitrate as NO3	mg/l	50
Nitrite as NO2	mg/l	0.5
Sulphate	mg/l	250
Sodium	mg/l	200
Aluminium	µg/l	200
Antimony	µg/l	5
Arsenic	µg/l	10
Cadmium	µg/l	5
Chromium	µg/l	50
Copper	µg/l	2,000
Iron	µg/l	200
Lead	µg/l	10
Manganese	µg/l	50
Mercury	µg/l	1
Nickel	µg/l	20
Selenium	µg/l	10

4.2.2 Vegetation Assessment Criteria

The European Communities (Undesirable Substances in Feedingstuffs) Regulations 2003 (S.I. 317 of 2003) are in place to control the metal content in animal feed and give effect to the Directive 2002/32/EC on Undesirable Substances in Animal Feed. The EU Directive was last updated on 29 September 2006. Table 19 summarises the maximum content in feedingstuff for arsenic, cadmium and lead applicable to the vegetation samples collected. No values are available for zinc.

Table 19 Assessment Criteria for Vegetation (mg/kg)

Undesirable Substance	Directive 2002/32/EC		Oak Ridge National Laboratory	
	Product Intended for Animal Feed	Maximum Content in Animal Feed (mg/kg)	Plants	Wildlife No Effect / Low Effect Level (mg/kg)
Arsenic	Feed materials	2	Concentrations for adverse effects in whitetail deer (dietary exposure)	0.621 / 6.211
Cadmium	Feed materials of Vegetable Origin	1		8.787 / 87.871
Lead	Green Fodder	30		72.88 / 728.78
Zinc	n/a	None		1457.6 / 2915.1

For arsenic in animal feed, the value given in the above table is the lowest provided. For Cd, feeding stuffs for calves, lambs and kids should have a maximum concentration of 0.5 mg/kg. Exceptions are provided for other products such as meal made from grass, minerals, etc. For Pb, green fodder is defined as “products intended for animal feed such as hay, silage, fresh grass, etc.”

The maximum content is actually the “Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12 %”. For Cd and Pb, the Directive states that the extraction be “performed with nitric acid (5 % w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency.” The CAL drying and digestion methods for the vegetation samples probably yield slightly higher values than those reported to a moisture content of 12 % and using 5 % nitric acid. Therefore any comparisons to the measured values to the standards in Table 19 will be conservative and provide adequate protection.

Additional comparisons of the measured vegetation concentrations to published criteria and screening levels were also performed. The criterion for plants shown on Table 19 are for digestion by wildlife (whitetail deer) sourced from the Oak Ridge National Laboratory (Sample *et al.*, 1996).

4.3 Comparison to Assessment Criteria

A comparison of the groundwater and surface water analytical results was made against the relevant assessment criteria for ecological and human health as described in Section 4.2. Table B-2 in **Appendix B** highlights the exceedances of the assessment criteria. Where there was an exceedance of the ecological assessment criteria, the result is highlighted in purple; for an exceedance of the human health criteria the result is highlight in blue. In some cases the reported values exceeded both the ecological and human health criteria and these results are highlighted in pink.

A comparison of the vegetation results was made against the relevant assessment criteria as described in Section 4.2. Table B-3 in **Appendix B** highlights the exceedances of the assessment criteria for vegetation; where there is an exceedance in the maximum concentration in Feeding Stuff, the result is highlighted in pink and exceedances of the no effect and low effect levels for digestion in wildlife is highlighted in blue and purple, respectively.

Groundwater, surface water and vegetation results and exceedances of the relevant assessment criteria are discussed in this section.

4.3.1 Groundwater Assessment

The pH was found to be within the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria with an average of pH 7.36. The electrical conductivity ranged from 0.332 to 0.452 mS/cm which was well within the criteria for human health of 2.5 mS/cm.

Sulphate was within normal ranges with only one detection of 13.8 mg/l at TMF1(D)/SRK/01, which was well below the criteria for human health of 250 mg/l. Ammonia and fluoride were less than the limit of detection.

For dissolved metal concentrations, the only exceedances of the assessment criteria in groundwater were barium and manganese, with higher concentrations in the downgradient monitoring well. Barium exceeded the ecological health criteria of 4 µg/l in both monitoring wells; TMF1(D)/DRK/01 had a result of 151 µg/l and TMF2(D)/DRK/01 had a result of 572 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1(D)/DRK/01 had a result of 65.2 µg/l and TMF2(D)/DRK/01 had a result of 1,000 µg/l.

4.3.2 Surface Water Assessment

The pH in surface waters in the Silvermines mining area was found to be near neutral, ranging from 5.05 to 8.83, with an average of 7.48. The only exceedance in the assessment criteria for pH was at SW12-Shal which is the stone lined drainage with a pH of 5.05 which was below the acceptable range for human health of 6.5 to 9.5 pH. Low acidity results were detected at eight locations which ranged from 5.48 to 23.7 mg/l: two samples were the surface water drainage from the Gortmore TMF (SW18-Gort and SW19-Gort), one location at Shallee (SW5-Shal, the stream downstream of the “drum dump”) and the other five locations were all drainage sites within the Garryard area, with the highest acidity at SW8-GAR (23.7 mg/l, the drainage from the western part of the Mogul Yard). The conductivity ranged from 0.046 to 2.83 mS/cm with an average of 0.713. The only exceedance in the human health criteria (2.5 mS/cm) was at SW5-Shal which had the highest conductivity (2.83 mS/cm).

Nutrients in surface water were generally acceptable with a few exceptions where the ecological assessment criteria were exceeded for ammonia and ortho-phosphate. The ammonia ecological assessment criteria (0.14 mg/l) was exceeded at the upstream location on the Kilmastulla River (SW17-Gort – 0.213 mg/l), the adit discharge in the Silvermines area (SW2-Sm – 0.209 mg/l) and the downstream location on the Silvermines River (SW4-Sm-Ga – 0.256 mg/l) which is also downstream of a small wastewater treatment plant. The locations with drainage running along the main road at SW10-Shal (0.626 mg/l) and SW2-Gar (1.47 mg/l) had the highest ammonia which also exceeded the criteria for human health (0.3 mg/l). SW4-Sm-Ga (0.08 µg/l) was the only location that the criteria for ecological health (0.075 mg/l) for ortho-phosphate was exceeded.

Fluoride results were elevated ranging from 0.6 to 1.99 mg/l in the majority of drainage and discharge sites in the Garryard area and at SW5-Shal. The ecological assessment criteria (0.5 mg/l) was exceeded in two of the samples; SW9-Gar (0.636 mg/l) and SW12-Gar (1.1 mg/l). Both the ecological and human health (1.5 mg/l) criteria were exceeded in four locations: SW2-Gar (1.99 mg/l), SW8-Gar (1.97 mg/l), SW5-Gar (1.7 mg/l) and SW5-Shal (1.85 mg/l).

Sulphate exceeded the criteria for human health (250 mg/l) at all of the discharge and drainage locations in the Garryard area and at SW3-Gar (the stream containing the discharge flows from both the Mogul Yard and the tailings lagoon). The sulphate results that exceeded the criteria ranged from 282 to 1860 mg/l. Sulphate also exceeded the assessment criteria for human health at all of the discharge and drainage sites at Gortmore TMF with results ranging from 395 to 572 mg/l. The locations on the Kilmastulla River that were sampled were below the criteria with the highest result found at SW12-Gort-River (51.8 mg/l) downstream of the wetland discharge SW12-Gort-Disc.

Dissolved Metals Assessment

Concentrations of dissolved barium, cadmium, lead, manganese, nickel and zinc were elevated and exceeded the assessment criteria in many locations, see the Table B-2 in **Appendix B** for the full listing. The ecological assessment criteria for barium of 4 µg/l was exceeded at all locations with high results even at upstream locations SW1-SM (40.6 µg/l) and SW17-Gort (243 µg/l), and is not discussed further. Dissolved arsenic was detected at all locations but was significantly below both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria, with the highest concentration of 3.79 µg/l at SW10-Shal.

In the Ballygown area (Map 4 of **Appendix A**) which the Silvermines stream runs through, barium exceeded of the assessment criteria as mentioned above. Downstream of mining area at SW3-SM, mercury (0.0721 µg/l) and zinc (107 µg/l) were just above the ecological assessment criteria of 0.07 and 100 µg/l, respectively. This was the only occurrence of mercury exceeding the ecological assessment criteria out of all of the samples from the Silvermines area. The southern adit SW2-SM discharges to the Silvermines stream and had cadmium (4.72 µg/l) and zinc (1970 µg/l) above the ecological assessment criteria of 0.9 µg/l for cadmium and 100 µg/l for zinc. Further downstream at SW4-SM-GA, cadmium (0.377 µg/l) and mercury (0.0598 µg/l) were detected but below the assessment criteria. Zinc was also at a concentration of 303 µg/l, which was an increase from its upstream location and still above the assessment criteria. SW6-Mag downstream of the Magcobar area also had cadmium (1.82 µg/l) and zinc (929 µg/l) above the ecological assessment criteria.

At Gortmore TMF (Map 2 of **Appendix A**), only zinc, barium and manganese exceeded the assessment criteria and levels of cadmium, lead and nickel were relatively low. Zinc exceeded the ecological assessment criteria of 100 µg/l in all discharges and drainages at Gortmore with results ranging from 128 to 656 µg/l. The concentration of zinc increased on the Kilmastulla River from 4.81 µg/l at the upstream location SW17-Gort to 63.5 µg/l but remained below the assessment criteria. Zinc concentrations increased to just above the assessment criteria on the Kilmastulla River at SW12-Gort-River (113 µg/l) and SW14-Gort (108 µg/l). These locations are downstream of the wetland discharge (SW12-Gort-Disc – 332 µg/l) and the Yellow Bridge Tributary which drains Garrymore and Shallee. The loading from these areas are discussed in Section 5. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all locations, with results ranging from 64.4 to 165 µg/l. The exceptions were at SW18-Gort (17.2 µg/l, the discharge from the main pond on Gortmore TMF) and SW19-Gort (1.6 µg/l, the decant from the TMF). Manganese was also high at the upstream location SW17-Gort (153µg/l).

At Shallee (Map 3 of **Appendix A**), lead exceeded the both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations, with concentrations ranging from 12.1 to 236 µg/l. The highest concentration was from the Field Shaft discharge (SW6-Shal). Cadmium exceeded the ecological assessment (0.9 µg/l) criteria at all locations except SW12-Shal and sSW4-Shal. At three locations the human health (5 µg/l) criteria was exceeded also; SW10-Shal (6.45 µg/l), SW7-Shal (8.64 µg/l) and SW5-Shal (31.3 µg/l). Nickel was also above the both the ecological and human health assessment criteria of 20 µg/l at these three locations with values ranging from 23.2 to 90.8 µg/l. With the exception of SW12-Shal (stone lined drainage channel) and SW4-Shal (upstream location), zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 179 to 14,100 µg/l. The highest concentrations of cadmium, lead, nickel and zinc in the Shallee area was at SW5-Shal (the stream downstream of the “drum dump”).

In the Garryard area (Map 3 of **Appendix A**), some of the highest concentrations of dissolved metals were observed. SW5-GAR (discharge from Knights Shaft) had the highest concentrations of zinc (96,600 µg/l), nickel (637 µg/l) and manganese (16,400 µg/l). Each location exceeded the zinc ecological assessment criteria of 100 µg/l including the discharges from the tailings lagoon SW10-GAR (5,390 µg/l) and SW3-GAR (3,590 µg/l, the stream containing the discharges from the tailings lagoons). All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium, with the exception of two locations to the west of Garryard (SW4-GAR – 1.77 µg/l and SW7-GAR – 0.906 µg/l) which only exceeded the ecological criteria. Lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at three locations with these results ranging from 12.4 to 18.5 µg/l. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at these six locations with values ranging from 21.2 to 637 µg/l.

4.3.3 Vegetation Assessment

Based on the summary in Table 16 (maximum values) and the CAL laboratory report in Appendix F of the Data Report, no measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium or lead exceeded the Maximum Content standards in Table 19.

The measured concentrations in the vegetation were all below both the no effect and low effect levels provided in Table 16, except for arsenic at three locations: SM01-V (0.64 mg/kg), SM04-V (0.78 mg/kg) and SM06-V (0.74 mg/kg) which were slightly above the no effect level of 0.62 mg/kg but below the low effect level of 6.21 mg/kg for digestion in wildlife (whitetail deer).

Section 5

Flows, Loads and Trend Analysis

5.1 Surface Water Flows

No river flow gauging stations are present within the Silvermines mining area. The nearest gauge on the Kilmastulla River is Coole (EPA station 25044) which is 10 km downstream. The flow record from January 2010 to April 2013 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >6 m^3/s following major rainfall events to less than 1 m^3/s during low-flow, with a median flow of about 1.3 m^3/s. The flows in the Kilmastulla River in the Silvermines mining area are expected to be considerably lower as many small tributaries drain from the surrounding mountains between the mining area and the Coole gauging station. The EPA tool for ungauged catchments was utilised to estimate the percentile flows of the Kilmastulla River at the location just downstream of the Gortmore TMF: the high flow (5%-ile) was 4.4 m^3/s, the median flow (50%-ile) was 0.8 m^3/s and low flow (95%-ile) was 0.16 m^3/s.

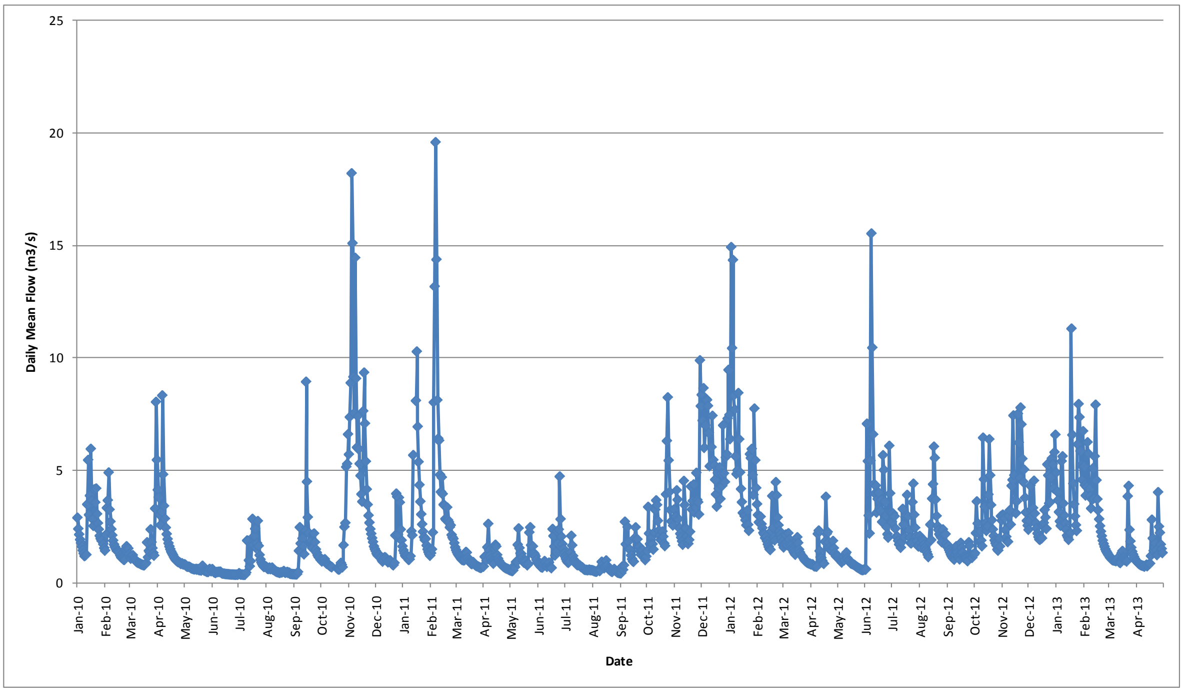

Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from Jan 10 to April 13

Flow was measured directly in the field using different methodologies depending upon the quantity of flow to be measured and any safety concerns, as described in Section 2.1.2. Table 20 presents a summary of the results from the flow measured in March and April 2013 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 20 Surface Water Flow Value Measured in March/ April 2013

Site Name	Flow l/s	Date
SW10_GORT Discharge	5.13	27/03/2013
SW12_GORT Discharge	7.14	26/03/2013
SW19_GORT	0.60	27/03/2013
SW1-SM	9.53	04/04/2013
SW2-SM South Discharge	2.35	04/04/2013
SW2-SM North Discharge	No Flow	04/04/2013
SW3-SM	14.02	04/04/2013
SW4-SM-GA	21.45	04/04/2013
SW1-GAR	No Flow	04/04/2013
SW2-GAR	No Flow	04/04/2013
SW3-GAR	5.93	03/04/2013
SW4-GAR	0.310	04/04/2013
SW5-GAR	No Flow	04/04/2013
SW7-GAR	0.37	03/04/2013
SW8-GAR	0.008	03/04/2013
SW9-GAR	0.218	03/04/2013
SW10-GAR	5.46	03/04/2013
SW12-GAR	0.339	03/04/2013
SW1-SHAL	4.09	02/04/2013
SW4-SHAL	0.004	02/04/2013
SW5-SHAL	0.039	02/04/2013
SW6-SHAL	5.51	02/04/2013
SW7-SHAL	No Flow	02/04/2013
SW9-SHAL	5.89	02/04/2013
SW10-SHAL	No Flow	02/04/2013
SW12-SHAL	0.605	02/04/2013

5.2 Loading Analysis

5.2.1 Loading Analysis Methodology

Mass loads (g/day) were calculated for the locations with measured flows using the measured flow and concentration data, as follows:

Load (g/day) =[C (µg/L) * F (L/day)] / 1,000,000 µg/g

Where, C = the concentration of the parameter in the water
F = the flow rate of the input

5.2.2 Loading Results and Discussion

The calculated mass loads in Table 21 aid with the interpretation of the loading of sulphate and dissolved cadmium, lead, manganese, nickel and zinc to rivers. The metal with the highest mass loading was zinc 0.015 to 2540 g/day. The largest mass load of zinc was the discharge from the tailings lagoon SW10-GAR (2540 g/day). Further downstream at SW3-GAR which is located in a stream containing the SW10-GAR discharge and the western part of the Mogul yard, the loading appears to decrease to 1840 g/day of zinc. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

Table 21 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day

Site Description	Date Sampled	Flow	pH	Sulphate		Cadmium		Lead		Manganese		Nickel		Zinc	
		l/s	Units	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day
SW1-SM	04/04/2013	9.53	7.81	4900	4030	0.05	0.041	0.091	0.075	4.75	3.911	5.25	4.32	1.25	1.03
SW3-SM	04/04/2013	14.02	7.68	7100	8600	0.248	0.300	1.1	1.33	2.76	3.343	1.05	1.27	107	130
SW2-SM	04/04/2013	2.35	7.15	30500	6190	4.72	0.958	1.03	0.209	1.55	0.315	7.69	1.56	1970	400
SW4-SM-GA	04/04/2013	21.45	7.97	15700	29100	0.377	0.699	1.09	2.02	5.39	9.99	2.02	3.74	303	562
SW3-GAR	03/04/2013	5.93	8.08	356000	182000	11.8	6.046	0.928	0.475	201	103	16.4	8.40	3590	1840
SW4-GAR	04/04/2013	0.31	6.67	36400	975	1.77	0.047	16.8	0.450	469	12.6	6.27	0.168	389	10.4
SW7-GAR	03/04/2013	0.37	7.90	282000	9010	0.906	0.029	0.651	0.021	87.4	2.79	6.92	0.221	801	25.6
SW8-GAR	03/04/2013	0.008	7.28	985000	680	23.7	0.02	0.697	0.000	353	0.244	76.1	0.053	21600	14.9
SW9-GAR	03/04/2013	0.218	7.83	739000	13,900	14.1	0.000	1.21	0.000	60.3	1	32.4	0.61	7440	140
SW10-GAR	03/04/2013	5.46	7.95	384000	181000	18.8	8.87	1.56	0.736	74.1	35.0	21.2	10.0	5390	2540
SW12-GAR	03/04/2013	0.339	7.76	785000	23000	13.7	0.401	1.05	0.031	1250	36.6	58.4	1.711	9520	279
SW10-Gort-Disc	27/03/2013	5.13	7.91	572000	254000	0.142	0.063	0.209	0.093	64.4	28.5	8.82	3.91	656	291
SW12-Gort-Disc	26/03/2013	7.14	7.64	531000	328000	0.102	0.063	0.069	0.043	165	102	9.46	5.836	332	205
SW19-Gort	27/03/2013	0.6	8.07	498000	25800	0.409	0.021	0.351	0.018	1.6	0.083	5.3	0.275	309	16.0
SW1-SHAL	02/04/2013	4.09	7.50	20800	7350	1.23	0.435	113	39.9	143	50.5	8.4	2.968	262	92.6
SW4-SHAL	02/04/2013	0.004	7.41	100	0.03	0.674	0.000	12.1	0.004	154	0.053	4.16	0.001	43	0.015
SW5-SHAL	02/04/2013	0.039	6.74	188000	633	31.3	0.105	31.8	0.107	991	3.34	90.8	0.306	14100	47.5
SW6-SHAL	02/04/2013	5.51	6.29	12000	5710	0.905	0.431	236	112	60.7	28.9	8.05	3.83	179	85.2
SW9-SHAL	02/04/2013	5.89	7.17	19300	9,800	1.22	0.621	164	83.5	61.2	31.1	8.36	4.25	259	132
SW12-SHAL	02/04/2013	0.605	5.05	100	5.23	0.05	0.003	14.7	0.768	69	3.61	1.38	0.072	20.4	1.066

Notes:
Sites with no flow on the day of sampling are omitted from the table.

The zinc load upstream of Ballygown (SW1-SM) was calculated to be 1.03 g/day, which increases to 130 g/day downstream of the mine workings (SW3-SM). The southern adit (SW2-SM) also contributes 400 g/day of zinc to the stream. This balances well with the calculated mass load at SW4-SM-GA of 562 g/day (130 + 400 = 530 g/day). The Silvermines stream contributes this load to the Kilmastulla River.

The highest load of lead was from the Field Shaft (SW6-Shal) with a calculated value of 112 g/day. The dissolved lead load slightly decreases further downstream to 83.5 g/day at SW9-Shal, which could be an indication that it infiltrates into the ground. At SW1-Shal (a water course that runs parallel to the road and discharges to the Yellow Bridge River) a load of 40 g/day was observed.

The loads of zinc and nickel from the two wetland discharges at Gortmore TMF were very similar; SW10-Gort-Disc had 291 g/day of zinc and 3.91 g/day nickel and SW12-Gort-Disc had 205 g/day of zinc and 5.84 g/day nickel. Discharges from the Garryard area therefore provide the greatest mass loads of zinc to the Kilmastulla River in the Gortmore area where the Yellow Bridge River discharges.

5.3 Trend Analysis

No suitable historic data were found to conduct a meaningful trend analysis. Concentration time trend evaluations will be carried out as additional data are collected throughout the monitoring programme using an appropriate statistical package. This will be carried out for key parameters of concern at select locations such as the discharges from the wetland and tailings lagoon and downstream on the Kilmastulla River.

Section 6

Groundwater Levels

Groundwater levels were measured at the two wells outside the Gortmore TMF and seven additional wells located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder. Table 22 displays the measured depth to groundwater and calculated groundwater elevations. All groundwater level data are contained in Appendix C of the Data Report.

The groundwater elevations outside the TMF decreased from 48.65 m Ordnance Datum (OD) at the upgradient location TMF1(D)/SRK/01 to 46.24 mOD at the downgradient location TMF2(D)/SRK/0. These elevations are consistent with the groundwater flow in the bedrock being south-westerly towards the Kilmastulla River. The groundwater gradient was calculated to be 0.003, however the level of the river is unknown. BH2C/D-GORT-06 (also located outside the TMF) was found badly damaged but artesian water conditions were encountered.

Within the tailings area, measured water levels were in the range of 2.5 to 4.5m below the top of the tailings pond. The exceptions are in BH3A-GORT-06 and BH6A-GORT-06 where deeper water levels were recorded. The groundwater elevations within the TMF varied between 48.49 to 53.87 mOD.

Table 22 Measures Groundwater Levels March 2013

Borehole Identifier	Location description	Date	Time	Depth to Groundwater (m bTOC)	Groundwater Elevation (m OD)
TMF1(D)/SRK/01	Outside the perimeter of the TMF	25/03/2013	15:30	0.94	48.65
TMF2(D)/SRK/01		26/03/2013	12:00	2.22	46.24
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	25/03/2013	12:00	3.82	52.59
BH2A-GORT-06		25/03/2013	13:00	3.43	52.86
BH3A-GORT-06		25/03/2013	15:15	8.44	48.49
BH4A-GORT-06		25/03/2013	15:00	4.7	51.98
BH5A-GORT-06		25/03/2013	13:45	3.77	52.87
BH6A-GORT-06		25/03/2013	14:00	5.76	51.01
BH6B-GORT-06		25/03/2013	13:30	2.8	53.87

Notes:
m is metres
OD is Ordnance Datum
bTOC is below top of casing

Section 7

Summary and Recommendations

7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in March 2013 and water levels were measured in seven additional monitoring wells. Thirty one surface water locations were sampled and analysed in March/April 2013 with flows measured at 20 of the locations. Twenty vegetation samples were collected and analysed in April 2013. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QC/QC samples and laboratory reports were also reviewed. Overall the data quality is acceptable and the data can be used to compare to the assessment criteria.

Statistical summaries of the analytical results for groundwater, surface water and vegetation were prepared and results were compared to assessment criteria. Analyses of metal loadings and groundwater levels were also provided.

The overall conclusions are as follows:

- Dissolved metal concentrations in the two groundwater monitoring wells that were sampled only had exceedances of the assessment criteria for barium and manganese, with higher concentrations in the downgradient monitoring well (572 and 1000 µg/l, respectively). Barium exceeded the ecological health criteria and manganese exceeded the human health criteria in both monitoring wells. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- SW5-GAR (discharge from Knights Shaft) had the highest concentrations of zinc (96,600 µg/l), nickel (637 µg/l) and manganese (16,400 µg/l). SW8-GAR (drainage from the western part of the Mogul Yard) also had high zinc (21,600 µg/l) and nickel (76.1 µg/l). The discharges from Gortmore TMF wetlands (SW10-Gort-Disc and SW12-Gort-Disc) were relatively low in dissolved metals when compared with other discharges and drainage ditches at Silvermines.

- SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc (1.25 and 4.81 µg/l, respectively) than the rest of the rivers and streams sampled in the Silvermines area. At the downstream location on the Kilmastulla River (SW14-Gort) manganese exceeded the assessment criteria for human health and zinc and barium exceeded the assessment criteria for ecological health.

- The metal with the highest mass loading was zinc at the discharge from the tailings lagoon SW10-GAR with 2540 g/day. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River. The highest mass load of lead was from the Field Shaft (SW6-Shal), however, the decreased further downstream which could be an indication that it infiltrates into the ground.

- The measured concentrations in the vegetation were all below both the no effect and low effect levels, except for arsenic at three locations: SM01-V (0.64 mg/kg), SM04-V (0.78 mg/kg) and SM06-V (0.74 mg/kg) which were slightly above the no effect level (0.62 mg/kg) but below the low effect level (6.21 mg/kg) for digestion in wildlife (whitetail deer).

7.2 Recommendations for the Monitoring Programme

Based on the data analysis and above conclusions the following recommendations are made:

- Dissolved Oxygen is currently being analysed in the field and by the laboratory. However, the field measurements are more representative of actual DO of the groundwater and surface water than the results in the laboratory.

- Groundwater monitoring wells TMF1(D)/SRK/01 and TMF2(D)/SRK/01 should be continued to be monitored as per the sampling procedures utilised in this round. These monitoring wells represent groundwater upgradient and downgradient of the Gortmore TMF, respectively. Monitoring wells BH1C/D-GORT-06, TMF3/SRK/01 and TMF4(D)/SRK/01 were either found buried, or believed to be destroyed and should therefore be omitted from the monitoring programme. An evaluation on whether or not any of these wells need to be replaced will be carried out after the next round of sampling.

- Monitoring well BH2C/D-GORT-06 was found badly damaged with the outer casing crushed over the inner casing. It is possible that the crushed upper part of the casing could be cut off. This option should be investigated with a drilling contractor or equivalent. The borehole also requires an appropriate cap to prevent water ingress into the borehole.

Section 8
References

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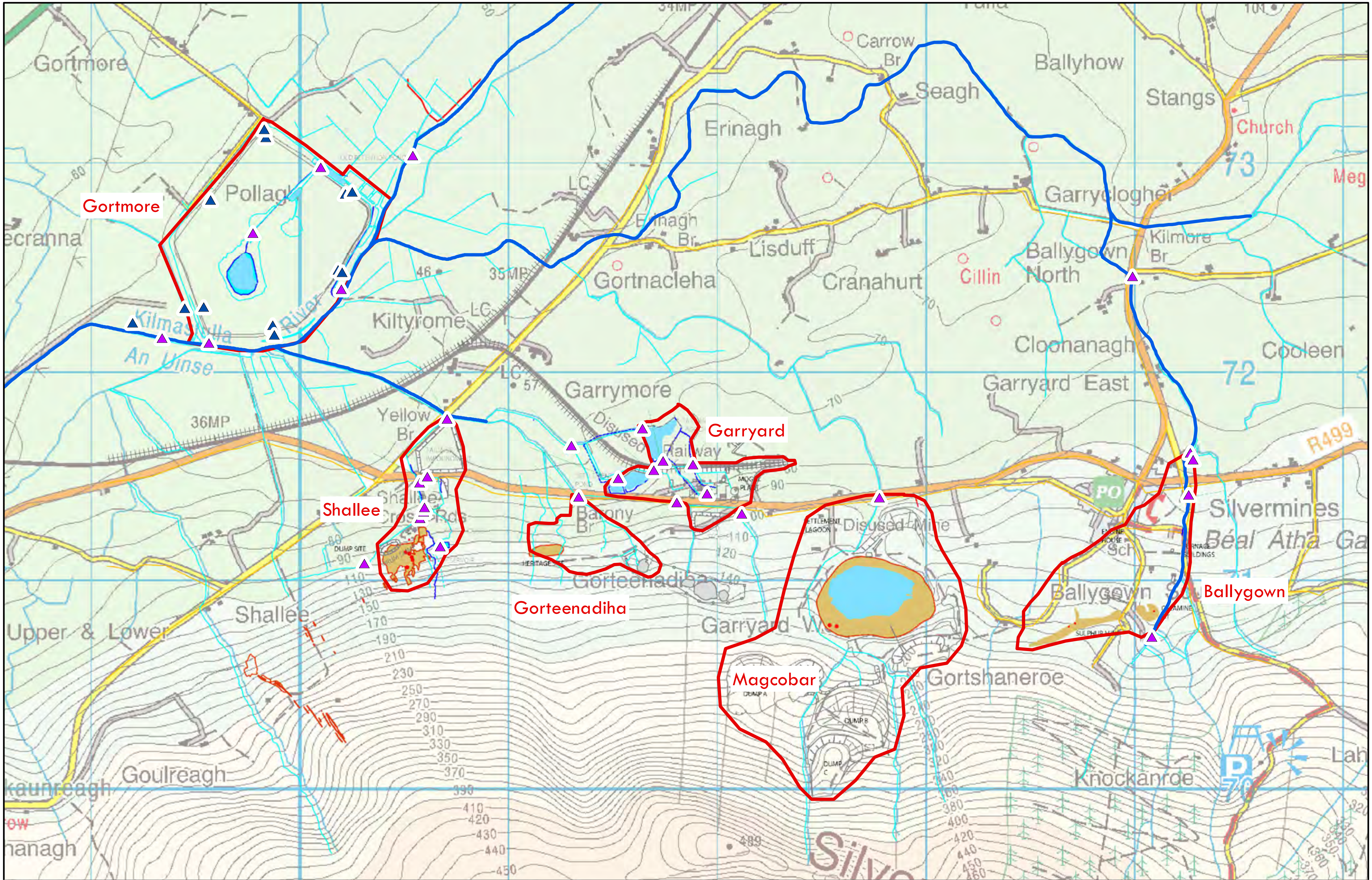
Appendix A

Figures



Map 1 - Silvermines - Overview

Drawn by: LG Date: 06/06/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\03_MonRpt\MXD\01_SilverMon1.mxd

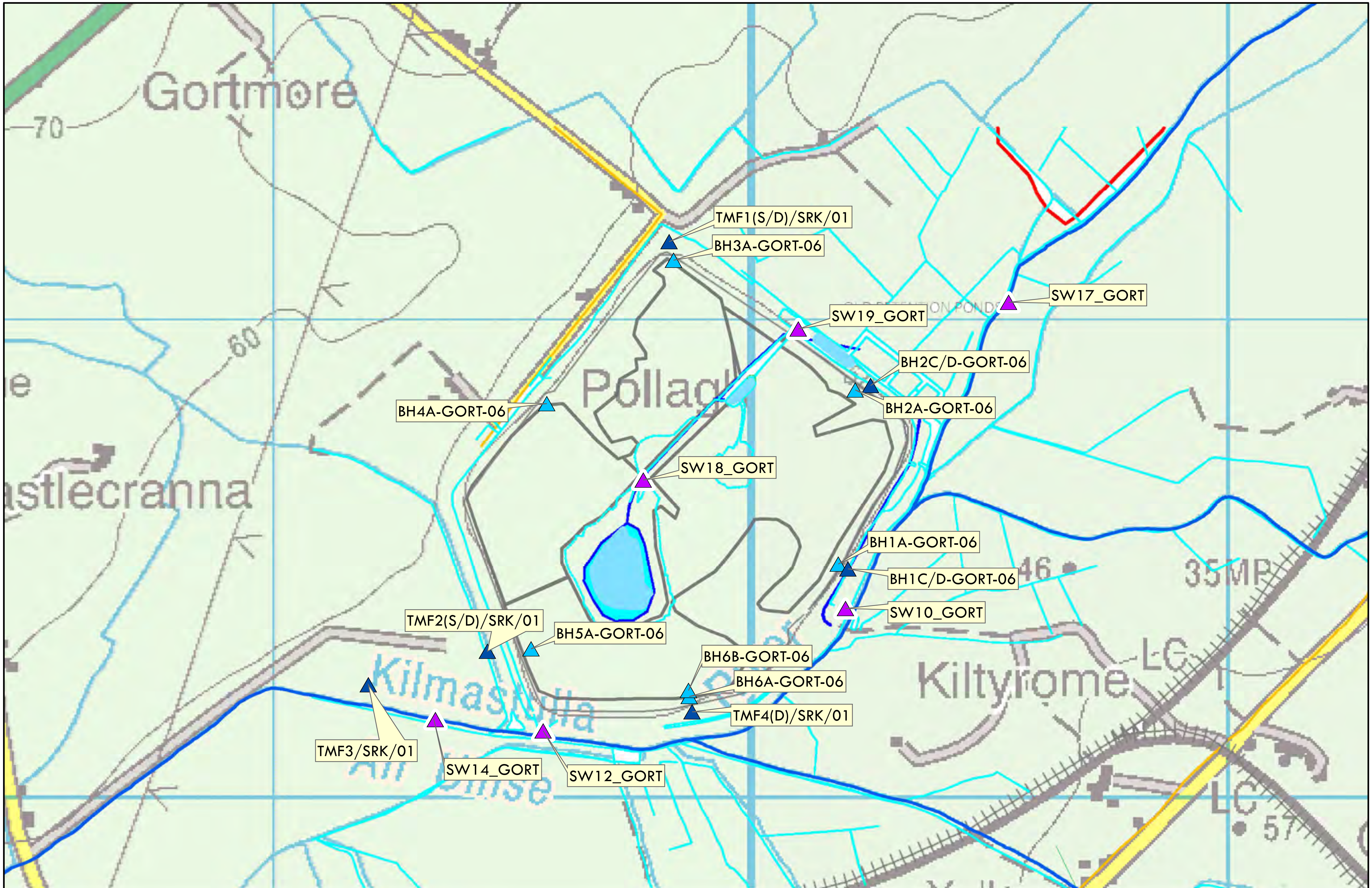
CDM Smith

Source: © Ordnance Survey Ireland.

Legend

- Site Boundaries
- Surfacewater Locations
- Groundwater Locations
- Rivers

0 125 250 500 750 1,000 Meters



Map 2 - Silvermines - Gortmore TMF

Drawn by: LG Date: 06/06/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\03_MonRpt\MXD\02_SilverMonGM.mxd

CDM Smith

Source: © Ordnance Survey Ireland.

Legend

- Surfacewater Locations
- Groundwater Locations
- Groundwater Locations - Levels Only
- Rivers
- TMF Areas

N W E S

0 125 250 Meters

Map 3 - Silvermines - Shallee South and Garryard

Drawn by: LG Date: 06/06/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\03_MonRpt\MXD\03_SilverMonShS_GA.mxd

CDM Smith

Source: © Ordnance Survey Ireland.

Legend

- Surfacewater Locations
- Rivers

0 125 250 Meters

Map 4 - Silvermines - Magcobar and Ballygown

Drawn by: LG Date: 06/06/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\03_Monrpt\MXD\04_SilverMonMa_BG.mxd

CDM Smith

Source: © Ordnance Survey Ireland.

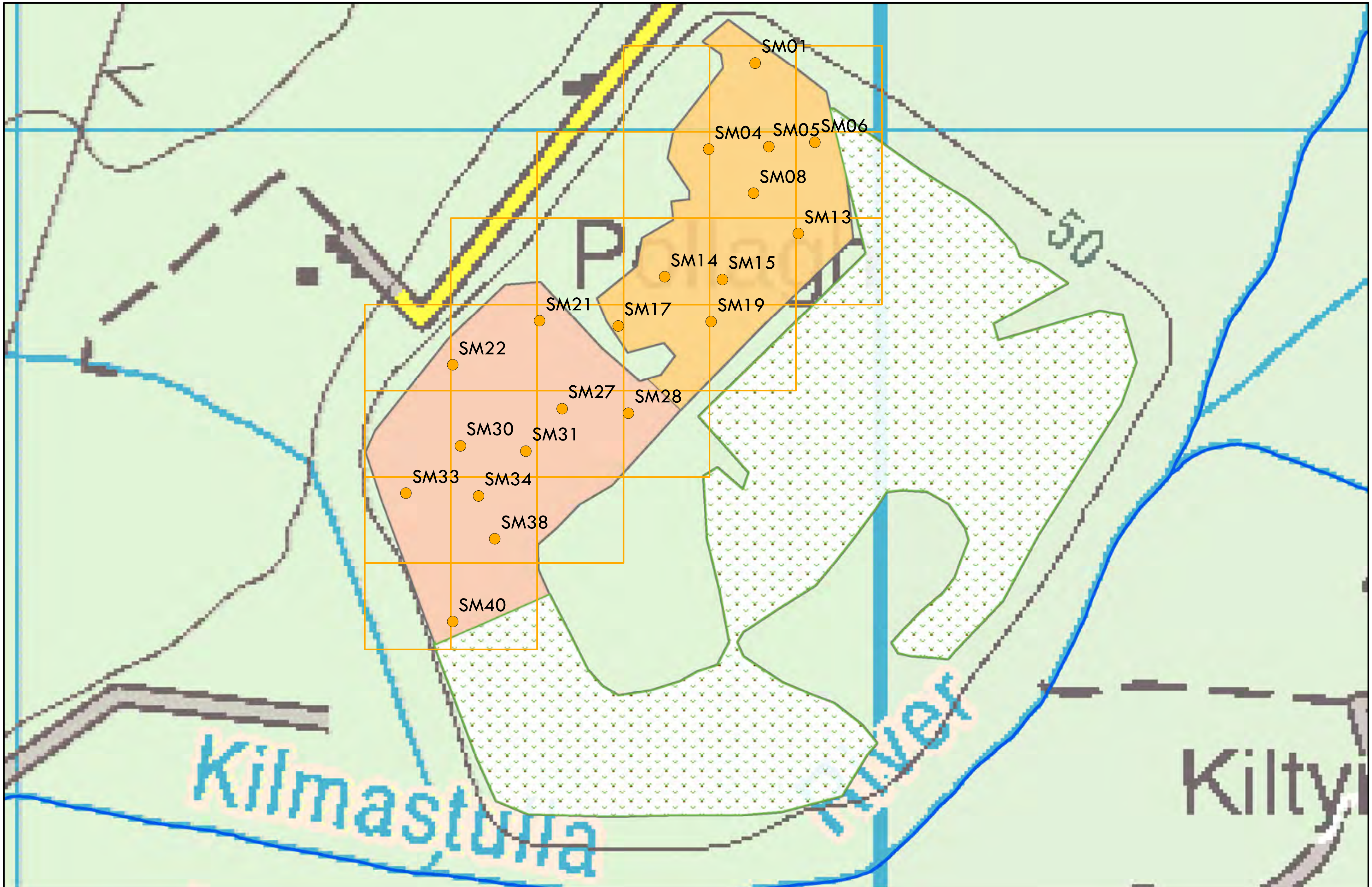
Legend

Surfacewater Locations

Rivers

N E S W

0 125 250 Meters



Map 5 - Silvermines - Gortmore - Soil and Vegetation

Drawn by: LG Date: 06/06/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\03_MonRpt\MXD\05_SilverMonVeg.mxd

CDM Smith

Source: © Ordnance Survey Ireland.

Legend

- Sampling Locations - Area A and B - Soil and Vegetation Samples
- 1 ha grid
- TMF Areas
- Rivers
- Sampling Area A
- Sampling Area B
- Sampling Area GS1 to GS3

N W E S

0 125 250 Meters

Appendix B

Analytical Data Tables and Assessment Criteria

CDM Smith

Table B-1 Comparison of Total Versus Dissolved Metals Concentrations in groundwater adits and surface water

Sample Description	Sample Type	Date Sampled	Suspended solids, Total	Barium (tot.unfilt)	Barium (diss.filt)	%RPD	Cadmium (tot.unfilt)	Cadmium (diss.filt)	%RPD	Lead (tot.unfilt)	Lead (diss.filt)	%RPD	Zinc (tot.unfilt)	Zinc (diss.filt)	%RPD
			mg/l	µg/l	µg/l		µg/l	µg/l		µg/l	µg/l		µg/l	µg/l	
SW10-GAR	SW	03/04/2013	3.5	25.6	21.2	-18.80	20.5	18.8	-8.65	5.24	1.56	-108.24	6480	5390	-18.37
SW10-Gort-Disc	SW	27/03/2013	<2	13.8	10.4	-28.10	0.05	0.142	95.83	0.25	0.209	-17.86	750	656	-13.37
SW10-Gort-DS	SW	27/03/2013	3	166	145	-13.50	0.05	0.05	0.00	2.73	0.726	-115.97	63.7	63.5	-0.31
SW10-Gort-US	SW	27/03/2013	2	180	148	-19.51	0.05	0.05	0.00	3.15	0.413	-153.63	50.6	46.1	-9.31
SW10-SHAL	SW	02/04/2013	<2	179	144	-21.67	0.05	6.45	196.92	133	76.9	-53.45	1510	1480	-2.01
SW12-GAR	SW	03/04/2013	3.5	23.4	14.7	-45.67	15.8	13.7	-14.24	23.6	1.05	-182.96	11400	9520	-17.97
SW12-GORT-DISC	SW	26/03/2013	2	163	158	-3.12	0.05	0.102	68.42	0.25	0.069	-113.48	388	332	-15.56
SW12-Gort-River	SW	26/03/2013	2.5	169	161	-4.85	0.05	0.207	122.18	7.58	1.75	-124.97	115	113	-1.75
SW12-SHAL	SW	02/04/2013	3	310	277	-11.24	0.526	0.05	-165.28	61.8	14.7	-123.14	28.1	20.4	-31.75
SW14-Gort	SW	26/03/2013	5	181	157	-14.20	0.05	0.271	137.69	6.63	1.71	-117.99	115	108	-6.28
SW17-GORT	SW	05/04/2013	6	276	243	-12.72	0.05	0.05	0.00	0.958	0.089	-166.00	5.67	4.81	-16.41
SW18-Gort	SW	26/03/2013	<2	16.3	11.2	-37.09	0.05	0.279	139.21	2.1	1.01	-70.10	122	128	4.80
SW19-Gort	SW	27/03/2013	<2	18.2	13.3	-31.11	0.05	0.409	156.43	0.25	0.351	33.61	357	309	-14.41
SW1-SHAL	SW	02/04/2013	<2	247	236	-4.55	1.38	1.23	-11.49	195	113	-53.25	288	262	-9.45
SW1-SM	SW	04/04/2013	<2	49.8	40.6	-20.35	0.05	0.05	0.00	0.25	0.091	-93.26	3.27	1.25	-89.38
SW2-GAR	SW	04/04/2013	6.5	29.4	10.9	-91.81	0.05	40.8	199.51	141	18.5	-153.61	12500	11600	-7.47
SW2-SM	SW	04/04/2013	<2	173	141	-20.38	5.53	4.72	-15.80	2.03	1.03	-65.36	2220	1970	-11.93
SW3-GAR	SW	03/04/2013	3	51.3	37.6	-30.82	15.1	11.8	-24.54	13.3	0.928	-173.91	4160	3590	-14.71
SW3-SM	SW	04/04/2013	<2	75.1	65.7	-13.35	0.05	0.248	132.89	1.62	1.1	-38.24	121	107	-12.28
SW4-GAR	SW	04/04/2013	<2	279	245	-12.98	0.05	1.77	189.01	75.3	16.8	-127.04	436	389	-11.39
SW4-SHAL	SW	02/04/2013	9.5	600	524	-13.52	0.877	0.674	-26.18	106	12.1	-159.02	55.9	43	-26.09
SW4-SM-GA	SW	04/04/2013	2	163	128	-24.05	0.05	0.377	153.16	3.84	1.09	-111.56	375	303	-21.24
SW5-GAR	SW	04/04/2013	28	127	8.07	-176.10	0.05	30.3	199.34	155	12.4	-170.37	90000	96600	7.07
SW5-SHAL	SW	02/04/2013	23.5	354	174	-68.18	34.5	31.3	-9.73	546	31.8	-177.99	18700	14100	-28.05
SW6-MAG	SW	04/04/2013	<2	51.8	37.9	-30.99	2.23	1.82	-20.25	5.14	0.545	-161.65	1110	929	-17.75
SW6-SHAL	SW	02/04/2013	<2	260	236	-9.68	1.14	0.905	-22.98	343	236	-36.96	204	179	-13.05
SW7-GAR	SW	03/04/2013	<2	73.9	60	-20.76	2.06	0.906	-77.82	1.94	0.651	-99.50	1020	801	-24.05
SW7-SHAL	SW	02/04/2013	2	186	130	-35.44	9.61	8.64	-10.63	234	93.8	-85.54	3230	3100	-4.11
SW8-GAR	SW	03/04/2013	3.5	26.9	15	-56.80	25.9	23.7	-8.87	22.2	0.697	-187.82	25700	21600	-17.34
SW9-GAR	SW	03/04/2013	<2	16.2	13.2	-20.41	15.3	14.1	-8.16	12.1	1.21	-163.64	9250	7440	-21.69
SW9-SHAL	SW	02/04/2013	<2	254	234	-8.20	1.52	1.22	-21.90	254	164	-43.06	291	259	-11.64
TMF1	GW	25/03/2013	-	235	151	-43.52	0.05	0.05	0.00	0.764	0.333	-78.58	1.5	1.59	5.83
TMF2	GW	26/03/2013	-	636	572	-10.60	0.05	0.05	0.00	7.49	1.51	-132.89	1.5	2.32	42.93

Notes:

xx RPD greater than 50% i.e. dissolved metal result is greater that total

xx RPD less than 50% i.e. total metal result is greater that dissolved

Values less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD

- Not analysed

RPD - Relative percent difference

GW - Groundwater

SW - Surface Water

Table B-2 Comparison of Groundwater and Surface Water Results to Assessment Criteria

Sample Description	Area	Type	Date Sampled	Acidity as HCL	Alkalinity, Total as CaCO3	Hardness as CaCO3	Ammoniacal Nitrogen as N	Chloride	COD, unfiltered	Conductivity @ 20 deg.C	Cyanide, Free	Dissolved solids, Total	Fluoride	Nitrate as NO3	Nitrite as NO2	Oxygen, dissolved	pH	Phosphate (ortho) as P	Sulphate	Sodium (diss.filt)	Suspended solids, Total
			Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	pH Units	mg/l	mg/l	mg/l	mg/l
Ecological Criteria				-	-	-	0.14	-	-	-	0.01	-	0.5	-	-	-	4.5 to 9	0.075	-	-	-
Human Health Criteria				-	-	-	0.3	250	-	2.5	0.05	-	1.5	50	0.5	-	6.5 to 9.5	-	250	200	-
SW2-SM	BG	Discharge	04/04/2013	*2*	235	286.7	0.209	12.9	*3.5*	0.461	*0.025*	313	*0.25*	7.27	*0.025*	8.44	7.15	*0.01*	30.5	7.28	*0.1*
SW1-SM	BG	River/ Stream	04/04/2013	*2*	65	79.3	*0.1*	9.8	*3.5*	0.152	*0.025*	114	*0.25*	2.73	*0.025*	9.26	7.81	*0.01*	4.9	6.28	*0.1*
SW3-SM	BG	River/ Stream	04/04/2013	*2*	95	115.9	*0.1*	10.2	*3.5*	0.201	*0.025*	141	*0.25*	2.75	*0.025*	9.83	7.68	*0.01*	7.1	6.39	*0.1*
SW4-SM-GA	BG	River/ Stream	04/04/2013	*2*	150	183	0.256	12.4	*3.5*	0.319	*0.025*	229	*0.25*	7.46	0.062	11	7.97	0.0839	15.7	9.02	2
SW10-GAR	GA	Discharge	03/04/2013	5.48	190	231.8	*0.1*	13.2	*3.5*	0.921	*0.025*	837	*0.25*	1.48	*0.025*	9.35	7.95	*0.01*	384	7.74	3.5
SW7-GAR	GA	Discharge	03/04/2013	*2*	120	146.4	*0.1*	12.4	7.18	0.681	*0.025*	599	*0.25*	*0.15*	*0.025*	9.57	7.76	*0.01*	282	6.38	*0.1*
SW5-GAR	GA	Discharge	04/04/2013	11	445	542.9	*0.1*	13	29.7	2.83	*0.025*	3720	1.7	3.09	*0.025*	8.39	6.59	*0.01*	1860	7.54	28
SW12-GAR	GA	Drainage	03/04/2013	7.3	220	268.4	*0.1*	12.6	7.08	1.5	*0.025*	1540	1.11	2.47	*0.025*	9.15	7.76	*0.01*	785	11.1	3.5
SW8-GAR	GA	Drainage	03/04/2013	23.7	210	256.2	*0.1*	14.4	8.92	1.74	*0.025*	1890	1.97	3.93	*0.025*	8.43	7.28	*0.01*	985	7.09	3.5
SW9-GAR	GA	Drainage	03/04/2013	5.48	185	225.7	*0.1*	11.6	*3.5*	1.42	*0.025*	1420	0.636	3.12	*0.025*	9.19	7.83	*0.01*	739	6.93	*0.1*
SW2-GAR	GA	Drainage	04/04/2013	*2*	160	195.2	1.47	11.7	*3.5*	0.998	*0.025*	936	1.99	6.47	*0.025*	8.06	6.94	*0.01*	483	6.98	6.5
SW3-GAR	GA	River/ Stream	03/04/2013	*2*	190	231.8	*0.1*	14	7.87	0.871	*0.025*	825	*0.25*	0.72	*0.025*	9.69	7.68	*0.01*	356	7.21	3
SW4-GAR	GA	River/ Stream	04/04/2013	*2*	65	79.3	*0.1*	11.8	7.81	0.221	*0.025*	163	*0.25*	1.68	*0.025*	9.2	6.67	*0.01*	36.4	6.62	*0.1*
SW12-GORT-DISC	GM	Discharge	26/03/2013	*2*	244	297.68	*0.1*	17.4	15.2	1.23	*0.025*	1080	*0.25*	5.79	*0.025*	8.24	7.64	*0.01*	531	9.96	2
SW10-Gort-Disc	GM	Discharge	27/03/2013	*2*	125	152.5	*0.1*	14.4	8.21	1.14	*0.025*	1040	*0.25*	*0.15*	*0.025*	9.38	7.91	*0.01*	572	6.5	*0.1*
SW18-Gort	GM	Drainage	26/03/2013	5.48	89.9	109.678	*0.1*	13.9	11.3	0.856	*0.025*	747	*0.25*	*0.15*	*0.025*	9.66	8.83	*0.01*	395	6.28	*0.1*
SW19-Gort	GM	Drainage	27/03/2013	5.48	90	109.8	*0.1*	13.8	*3.5*	0.962	*0.025*	808	*0.25*	0.386	*0.025*	9.9	8.07	*0.01*	498	6.04	*0.1*
SW12-Gort-River	GM	River/ Stream	26/03/2013	*2*	240	292.8	*0.1*	15.1	13.9	0.525	*0.025*	310	*0.25*	7.48	*0.025*	9.29	8.53	*0.01*	51.8	8.87	2.5
SW14-Gort	GM	River/ Stream	26/03/2013	*2*	221	269.62	*0.1*	14.8	12.9	0.475	*0.025*	311	*0.25*	7.43	*0.025*	9.68	8.53	*0.01*	42	8.87	5
SW10-Gort-DS	GM	River/ Stream	27/03/2013	*2*	235	286.7	*0.1*	15.1	9.98	0.517	*0.025*	405	*0.25*	8.08	*0.025*	9.7	8.4	*0.01*	43.3	8.49	3
SW10-Gort-US	GM	River/ Stream	27/03/2013	*2*	250	305	*0.1*	15.2	10	0.498	*0.025*	308	*0.25*	8.26	*0.025*	9.72	8.41	*0.01*	30.9	8.39	2
SW17-GORT	GM	River/ Stream	05/04/2013	*2*	210	256.2	0.213	16.6	12.4	0.417	*0.025*	276	*0.25*	13.8	*0.025*	11.3	7.08	*0.01*	12.8	10.6	6
SW6-MAG	MG	River/ Stream	04/04/2013	*2*	55	67.1	*0.1*	9.6	*3.5*	0.523	*0.025*	415	*0.25*	1.71	*0.025*	9.44	7.65	*0.01*	233	4.86	*0.1*
SW6-SHAL	ShS	Discharge	02/04/2013	*2*	43.5	53.07	*0.1*	10.6	*3.5*	0.136	*0.025*	78.4	*0.25*	1.91	*0.025*	8.46	6.29	*0.01*	12	6.03	*0.1*
SW10-SHAL	ShS	Drainage	02/04/2013	*2*	370	451.4	0.626	15.5	12.7	1.08	*0.025*	877	*0.25*	0.399	*0.025*	5.8	6.59	*0.01*	348	8.48	*0.1*
SW12-SHAL	ShS	Drainage	02/04/2013	*2*	2	2.44	*0.1*	10.5	8.04	0.0464	*0.025*	20.5	*0.25*	0.508	*0.025*	10.4	5.05	*0.01*	*0.1*	5.39	3
SW7-SHAL	ShS	Drainage	02/04/2013	*2*	100	122	*0.1*	11	*3.5*	0.38	*0.025*	314	*0.25*	3.46	*0.025*	9.36	7.07	*0.01*	97.5	6.15	2
SW1-SHAL	ShS	River/ Stream	02/04/2013	*2*	55	67.1	*0.1*	11	*3.5*	0.174	*0.025*	135	*0.25*	1.55	*0.025*	9.76	7.5	*0.01*	20.8	6.08	*0.1*
SW4-SHAL	ShS	River/ Stream	02/04/2013	*2*	105	128.1	*0.1*	12.1	9.34	0.212	*0.025*	141	*0.25*	0.411	*0.025*	9.39	7.41	*0.01*	*0.1*	6.59	9.5
SW5-SHAL	ShS	River/ Stream	02/04/2013	9.13	46	56.12	*0.1*	11	7.91	0.45	*0.025*	368	1.85	2.02	*0.025*	10.2	6.74	*0.01*	188	6.15	23.5
SW9-SHAL	ShS	River/ Stream	02/04/2013	*2*	52	63.44	*0.1*	11	*3.5*	0.159	*0.025*	120	*0.25*	1.61	*0.025*	9.86	7.17	*0.01*	19.3	6.1	*0.1*
TMF1	GM	GW	25/03/2013	-	211	257.42	*0.1*	13.1	-	0.332	*0.025*	275	*0.25*	*0.15*	*0.025*	7.65	7.32	*0.01*	13.8	9.66	-
TMF2	GM	GW	26/03/2013	-	244	297.68	*0.1*	17	-	0.452	*0.025*	267	*0.25*	*0.15*	*0.025*	4.59	7.4	*0.01*	*0.1*	10.1	-

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

xx Less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD

- Not analysed or no assessment criteria

* Use result with caution. Potential cross contamination.

Table B-2 Comparison of Groundwater and Surfa
Results to Assessment Criteria

Sample Description	Area	Type	Aluminium (diss.filt) µg/l	Antimony (diss.filt) µg/l	Arsenic (diss.filt) µg/l	Barium (diss.filt) µg/l	Cadmium (diss.filt) µg/l	Chromium (diss.filt) µg/l	Cobalt (diss.filt) µg/l	Copper (diss.filt) µg/l	Iron (diss.filt) µg/l	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Mercury (diss.filt) µg/l	Molybdenum (diss.filt) µg/l	Nickel (diss.filt) µg/l	Selenium (diss.filt) µg/l	Silver (diss.filt) µg/l	Thallium (diss.filt) µg/l	Tin (diss.filt) µg/l	Uranium (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) µg/l
Ecological Criteria			**1,900**	**-**	**25**	**4**	**0.9**	**3.4**	**5.1**	**30**	**-**	**7.2**	**1100**	**0.07**	**-**	**20**	**-**	**-**	**-**	**-**	**2.6**	**-**	**100**
Human Health Criteria			**200**	**5**	**10**	**-**	**5**	**50**	**-**	**2000**	**200**	**10**	**50**	**1**	**-**	**20**	**10**	**-**	**-**	**-**	**-**	**-**	**-**
SW2-SM	BG	Discharge	3.87	0.493	0.273	141	4.72	1.63	0.124	*0.43*	*9.5*	1.03	1.55	0.011	0.489	7.69	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.51	1970
SW1-SM	BG	River/ Stream	3.39	0.649	0.127	40.6	*0.05*	0.664	*0.03*	*0.43*	*9.5*	0.091	4.75	*0.005*	0.373	*0.075*	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	1.25
SW3-SM	BG	River/ Stream	4.33	1.06	0.177	65.7	0.248	0.861	0.081	*0.43*	*9.5*	1.1	2.76	0.0721	0.38	1.05	*0.195*	*0.75*	*0.48*	0.467	*0.75*	0.281	107
SW4-SM-GA	BG	River/ Stream	3.22	1.82	0.353	128	0.377	1.15	0.119	1.28	*9.5*	1.09	5.39	0.0598	0.67	2.02	*0.195*	*0.75*	*0.48*	0.784	*0.75*	0.366	303
SW10-GAR	GA	Discharge	1.45	8.29*	1.03	21.2	18.8	1.43	0.985	4.38	*9.5*	1.56	74.1	*0.005*	3.14	21.2	1.69	*0.75*	3.25	2.71	2.24	0.605	5390
SW7-GAR	GA	Discharge	5.18	*0.08*	0.22	60	0.906	0.714	0.241	2.28	*9.5*	0.651	87.4	*0.005*	*0.12*	6.92	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	801
SW5-GAR	GA	Discharge	1.45	1.06	1.53	8.07	30.3	1.96	24	13.3	624	12.4	16400	*0.005*	1.97	637	6.44	*0.75*	2.87	0.898	2.55	0.759	96600
SW12-GAR	GA	Drainage	1.45	1.81	0.486	14.7	13.7	1.46	2.8	6.89	*9.5*	1.05	1250	*0.005*	1.52	58.4	0.766	*0.75*	1.53	0.617	*0.75*	0.541	9520
SW8-GAR	GA	Drainage	8.98	*0.08*	0.38	15	23.7	1.37	1.98	6.87	*9.5*	0.697	353	*0.005*	*0.12*	76.1	0.644	*0.75*	5.43	*0.18*	*0.75*	0.339	21600
SW9-GAR	GA	Drainage	1.45	1.41	0.647	13.2	14.1	1.4	0.703	8.57	9.5	1.21	60.3	*0.005*	1.48	32.4	0.776	*0.75*	*0.48*	0.48	*0.75*	0.3	7440
SW2-GAR	GA	Drainage	8.9	0.516	0.181	10.9	40.8	1.11	0.291	6.11	*9.5*	18.5	3.09	*0.005*	0.282	36.8	0.448	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	11600
SW3-GAR	GA	River/ Stream	7.64	*0.08*	0.465	37.6	11.8	0.662	0.957	2.67	21.9	0.928	201	*0.005*	*0.12*	16.4	0.548	*0.75*	1.26	*0.18*	*0.75*	0.329	3590
SW4-GAR	GA	River/ Stream	5.03	0.856	0.356	245	1.77	0.696	2.79	10.4	254	16.8	469	*0.005*	0.616	6.27	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	389
SW12-GORT-DISC	GM	Discharge	1.45	*0.08*	0.489	158	0.102	1.77	0.501	3.07	73.7	0.069	165	*0.005*	*0.12*	9.46	0.704	*0.75*	*0.48*	*0.18*	*0.75*	0.346	332
SW10-Gort-Disc	GM	Discharge	1.45	*0.08*	0.22	10.4	0.142	1.25	0.293	3.55	*9.5*	0.209	64.4	*0.005*	*0.12*	8.82	*0.195*	*0.75*	2.86	*0.18*	*0.75*	0.379	656
SW18-Gort	GM	Drainage	1.45	1.19	0.349	11.2	0.279	0.386	0.244	4.04	*9.5*	1.01	17.2	*0.005*	*0.12*	4.31	*0.195*	*0.75*	3.12	*0.18*	*0.75*	*0.12*	128
SW19-Gort	GM	Drainage	1.45	1.93	0.526	13.3	0.409	1.04	0.235	3.78	*9.5*	0.351	1.6	*0.005*	0.617	5.3	0.707	*0.75*	6.59	*0.18*	*0.75*	*0.12*	309
SW12-Gort-River	GM	River/ Stream	7.71	2.62	0.503	161	0.207	0.877	0.294	1.37	70.7	1.75	74.6	*0.005*	*0.12*	3.08	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	113
SW14-Gort	GM	River/ Stream	6.33	0.973	0.428	157	0.271	0.723	0.271	1.66	64.6	1.71	68.6	*0.005*	*0.12*	2.64	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.273	108
SW10-Gort-DS	GM	River/ Stream	7.05	*0.08*	0.467	145	*0.05*	1.41	0.259	1.13	68.6	0.726	71.9	*0.005*	*0.12*	2.37	0.407	*0.75*	*0.48*	*0.18*	*0.75*	0.359	63.5
SW10-Gort-US	GM	River/ Stream	3.91	0.272	0.498	148	*0.05*	1.55	0.253	1.06	63.5	0.413	72.6	*0.005*	*0.12*	2.21	0.563	*0.75*	*0.48*	*0.18*	*0.75*	0.382	46.1
SW17-GORT	GM	River/ Stream	15.5	0.365	0.461	243	*0.05*	1.48	0.32	1.34	61.1	0.089	153	*0.005*	0.391	1.82	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.296	4.81
SW6-MAG	MG	River/ Stream	7.4	0.486	0.204	37.9	1.82	0.802	0.468	6.87	76.9	0.545	38.1	*0.005*	0.799	10.8	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	929
SW6-SHAL	ShS	Discharge	16.5	0.377	0.739	236	0.905	0.722	1.62	14.1	49.8	236	60.7	*0.005*	*0.12*	8.05	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	179
SW10-SHAL	ShS	Drainage	4.57	2.15	3.79	144	6.45	1.27	18.2	4.19	261	76.9	7410	*0.005*	*0.12*	27.2	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.307	1480
SW12-SHAL	ShS	Drainage	40.8	*0.08*	0.247	277	*0.05*	0.304	0.236	1.08	44	14.7	69	*0.005*	*0.12*	1.38	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	20.4
SW7-SHAL	ShS	Drainage	1.45	1.7	0.203	130	8.64	0.743	0.445	3.27	*9.5*	93.8	16.3	0.005	*0.12*	23.2	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	3100
SW1-SHAL	ShS	River/ Stream	18.2	0.652	0.975	236	1.23	0.425	1.75	7.18	164	113	143	*0.005*	*0.12*	8.4	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	262
SW4-SHAL	ShS	River/ Stream	6.26	*0.08*	0.286	524	0.674	0.826	0.81	2.19	*9.5*	12.1	154	*0.005*	*0.12*	4.16	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	43
SW5-SHAL	ShS	River/ Stream	73.7	*0.08*	0.2	174	31.3	0.717	4.37	9.88	*9.5*	31.8	991	*0.005*	*0.12*	90.8	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	14100
SW9-SHAL	ShS	River/ Stream	17.1	0.367	0.59	234	1.22	0.51	1.52	10.2	38.1	164	61.2	*0.005*	*0.12*	8.36	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	259
TMF1	GM	GW	1.45	3.15	2.94	151	*0.05*	0.82	0.813	0.913	*9.5*	0.333	65.2	*0.005*	0.52	2.36	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.305	1.59
TMF2	GM	GW	1.45	*0.08*	4.43	572	*0.05*	2.17	0.699	1.03	182	1.51	1000	*0.005*	0.372	2.19	0.805	*0.75*	*0.48*	*0.18*	*0.75*	0.353	2.32

xx Exceeds Ecological Assessment Criteria
xx Exceeds Human Health Assessment Criteria
xx Exceeds both Ecological and Human Health Criteria
xx Less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD
 - Not analysed or no assessment criteria
* Use result with caution. Potential cross contamination.

Table B-3 Comparison of Vegetation Results to Assessment Criteria

	Total Arsenic	Total Cadmium	Total Lead	Total Zinc
	mg/kg	mg/kg	mg/kg	mg/kg
Max Concentration in Feeding stuff	**2**	**1**	**30**	**-**
No effect for digestion in wildlife	**0.621**	**8.787**	**72.88**	**1457.6**
Low effect for digestion in wildlife	6.211	87.871	728.78	2915.1
SM01-V	0.64	0.27	6.39	89.30
SM04-V	0.78	0.17	5.95	60.80
SM05-V	0.30	0.10	2.03	26.10
SM06-V	0.74	0.17	4.50	49.40
SM08-V	0.21	0.09	1.45	25.30
SM13-V	0.37	0.10	2.40	26.10
SM14-V	0.53	0.19	6.99	42.40
SM15-V	0.25	0.08	2.31	29.60
SM17-V	0.34	0.09	4.16	30.20
SM19-V	0.27	0.11	1.97	26.90
SM21-V	0.12	0.10	0.81	25.30
SM22-V	*0.05*	0.06	0.68	26.50
SM27-V	*0.05*	0.08	0.59	22.90
SM28-V	0.11	0.09	1.00	19.20
SM30-V	*0.05*	0.06	1.03	27.90
SM31-V	*0.05*	0.06	0.44	21.70
SM33-V	0.11	0.04	1.05	22.80
SM34-V	*0.05*	0.07	0.75	25.60
SM38-V	0.18	0.08	2.52	42.20
SM40-V	0.41	0.07	7.17	32.30

xx Exceeds the Maximum Concentration in Feeding Stuff
xx Exceeds No effect level for digestion in wildlife
xx Exceeds Low effect level for digestion in wildlife
xx Less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD